Tertiary Larger Foraminifera from Guam

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By W. STORRS COLE

GEOLOGY OF GUAM, MARIANA ISLANDS

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Description, distribution, and occurrence of species ranging from the Eocene to the Pleistocene, and correlation with faunas of Saipan, Bikini, Eniwetok, Fiji, and the Malayan Archipelago

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By W. Storrs Cole

ABSTRACT

The distribution and occurrence of larger Foraminifera ranging in age from Eocene, Tertiary *b*, to Pleistocene on Guam are given in this report. Species that have not been discussed in previous studies of this general area are illustrated and described in detail, but most of the well-known species are only listed.

Twenty-one species were found in the Alutom Formation. These species, with the exception of *Camerina fichteli* which occurred at two localities, are known to be diagnostic of the Eocene, Tertiary *b*. *Camerina fichteli* is considered to be diagnostic of the Oligocene, Tertiary *c* and *d*, in the Malayan Archipelago. Certain localities on Guam, at which the limestone beds containing larger Foraminifera were known to be in their original position, and at which *Camerina fichteli* was not found, are assigned to Tertiary *b*. Other localities, at which *Camerina fichteli* was found in association with assumed reworked Tertiary *b* species, are assigned to Tertiary *c*. Certain other localities in the Alutom Formation could be either Eocene or Oligocene.

The Maemong Limestone Member of the Umatac Formation, with a fauna of 18 species, is assigned to the Miocene, Tertiary *e*, and is divided into two paleontologic zones. This limestone correlates with the Tagpochau Limestone of Saipan. The Bolanos Pyroclastic Member, which overlies the Maemong Limestone Member, is either late Tertiary *e* or early Tertiary *f* (Miocene) in age, or both. The fauna obtained from boulders and matrix material in this conglomerate is the same as that from the Maemong Limestone Member.

Fifteen species, of which all but one had been recorded previously from the Futuna Limestone of Lau, Fiji, were found in the Bonya Limestone of Tertiary *f* (Miocene) age.

The lower part of the Alifan Limestone, in which *Rotalia atjehensis* and *Miogypsinoides cupulaeformis* were found, may correlate with the upper part of the Bonya Limestone or be slightly younger. The part of the Alifan Limestone that contains a *Cycloclypeus–Operculina* fauna may be still younger, and may be equivalent to the Barrigada Limestone of Tertiary *g* (Miocene) age.

The Barrigada Limestone, which contained only three diagnostic species of larger Foraminifera, is assigned to Tertiary *g* (Miocene), because these species were found in drill holes on Bikini and Eniwetok Atolls in strata that were assumed to represent this stage.

The fore-reef facies was the only part of the Mariana Limestone that contained recognizable larger Foraminifera. This facies, with abundant *Calcarina spengleri*, is Pleistocene or Recent in age.

INTRODUCTION

The larger Foraminifera of Guam are similar to those found on Saipan (Cole and Bridge, 1953; Cole, 1957a), in the drill holes on Bikini Atoll (Cole, 1954) and Eniwetok Atoll (Cole, 1957b), on Lau, Fiji (Cole, 1945), and at numerous localities in the Malayan Archipelago. The similarities of these faunas to those previously described are so great that all the species found in the sediments on Guam could be referred to species described from these other areas. Moreover, the association of species within a given fauna and the stratigraphic ranges of the genera and species are identical with those of adjacent areas and the Malayan Archipelago.

The letter classification first proposed by Van der Vlerk and Umbgrove (1927), and subsequently modified by Van der Vlerk (1955) for the subdivision of strata in the Malayan Archipelago, is used for Guam as it was in previous reports on adjacent areas. Faunas which characterize Tertiary *b* (Eocene), Tertiary *c* (lower Oligocene), Tertiary *e* (Miocene), Tertiary *f* (Miocene), Tertiary *g* (Miocene), and Pleistocene were found on Guam.

The stratigraphic section of Guam is more complete than that of Saipan, in that species of larger Foraminifera that characterize Tertiary *c*, Tertiary *f*, and Tertiary *g* were found on Guam, but they were not present in any of the material collected on Saipan. The most striking similarity between faunas was apparent in collections from widely separated areas—between the Tertiary *f* fauna of the Bonya Limestone of Guam and the Tertiary *f* fauna of the Futuna Limestone (Ladd and Hoffmeister, 1945, p. 36) of Lau, Fiji.

Whenever it was possible, specimens that could be separated from the matrix were studied first. These specimens were identified not only by their external appearance, but also by oriented thin sections. The samples that could not be reduced to free the specimens

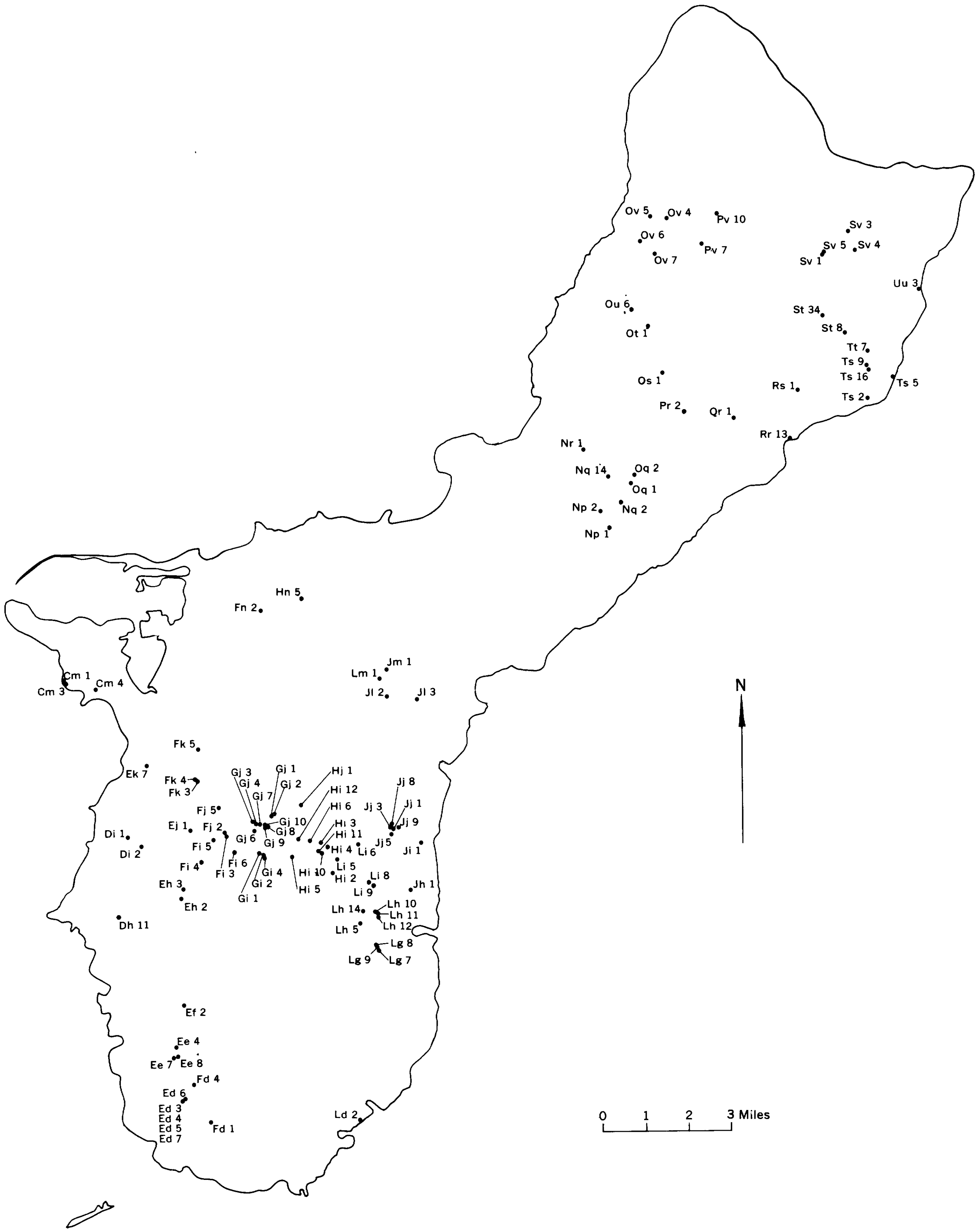

FIGURE 1. Localities of collections of larger Foraminifera, Guam.

were studied by means of random thin sections. Normally, a minimum of three thin sections was prepared from each sample. At many localities more than one sample was taken; therefore, numerous thin sections were available from these localities. The locations of the localities from which the samples were collected are shown on figure 1. The thin sections and specimens are deposited in the U.S. National Museum.

PREVIOUS STUDIES OF LARGER FORAMINIFERA FROM GUAM

In 1938, Captain Spencer L. Higgins of the U.S. Navy Medical Corps sent the writer specimens of larger Foraminifera from fourteen localities on Guam. Six species from this collection were identified, and two specimens of *Lepidocyclina* were illustrated without being identified specifically (Cole, 1939). All the localities at which recognizable species occurred were assigned to the lower Miocene, Tertiary *e*.

The localities D 7, D 10, D 11, D 12, C 23, and C 27 were correctly assigned to Tertiary *e* and represent the Maemong Limestone member. Locality D 12 definitely belongs in the *Miogypsinoides dehaartii* zone, and D 10 and D 11 probably belong in this zone. Locality D 7 definitely, and C 27 probably, should be assigned to the *Heterostegina borneensis* zone.

Localities C 23 and C 64, from which specimens identified as *Rotalia schroeteriana* (=*R. atjehensis*) were obtained, represent the Bonya Limestone of Tertiary *f* age rather than Tertiary *e*. However, Cole (1939) observed correctly that these localities were stratigraphically younger than the others because of the presence of reworked specimens of *Lepidocyclina* (*Nephrolepidina*) *parva* (=*L.* (*N.*) *sumatrensis*) in the limestone from locality C 23.

The sample from locality D 7 was reexamined during this study, and two specimens of *Heterostegina borneensis*, which had been overlooked in the original study, were found.

Recently, Cloud and Cole (1953) listed and briefly discussed the occurrence on Guam of certain larger Foraminifera from one locality that they believed to be Eocene in age.

DISTRIBUTION AND CORRELATION OF THE FAUNAS

EOCENE, TERTIARY b, ALUTOM FORMATION

Diagnostic Tertiary *b* (Eocene) genera and species of larger Foraminifera occurred in abundance at certain localities within the Alutom Formation. The distribution of these species is shown on table 1, including their

TABLE 1.—*Distribution of species in the Alutom Formation*

[Matrix-free specimens: x. Specimens in thin sections: a, abundant; c, common; r, rare]

Species	Age and occurrence, locality, sample number																													
	Eocene in original position											Eocene or Oligocene with reworked Eocene								Oligocene with reworked Eocene									Saipan	Eniwetok
	Hj 1									Ek 7		Di 1	Fn 2	Hi 6	Hn 5		Im 1	Jl 2	Jm 1	Ej 1	Fk 3	Fk 4						Fk 5		
	1	2	3	4	5	6	8	10	11	2	3	1	1	1	1	3	1	1	1	1	1	1	3	4	7	8	9	1		
Asterocyclina matanzensis Cole	-	-	-	-	-	-	-	-	-	r	r	x	-	-	-	-	x	x	-	-	x	-	-	-	-	-	-	-	x	x
penuria Cole	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	x	x	x	-	-	-	-	-	-	x	x	x
praecipua Cole	-	-	-	-	r	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-	x	-	-	-	-	-	-	-	-	x
Biplanispira fulgeria (Whipple)	-	-	r	-	r	-	-	-	c	c	-	-	-	-	-	-	-	-	x	x	x	-	r	-	-	-	-	-	x	x
mirabilis Umbgrove)	-	-	-	-	r	-	-	-	r	c	-	x	-	-	-	-	x	-	x	x	x	-	-	-	-	-	-	x	x	x
Camerina djokdjokarta (Martin)	-	-	-	-	-	-	-	-	-	-	-	x	x	x	-	-	-	-	-	-	-	c	c	-	-	-	-	-	x	x
fichteli (Michelotti)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-
pengaronensis (Verbeek)	-	-	-	-	-	-	-	-	-	r	-	-	-	-	-	-	-	x	x	x	x	-	-	-	-	-	-	x	x	x
Discocyclina omphala (Fritsch)	-	-	-	-	r	-	-	-	-	c	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-
Eorupertia plecte (Chapman)	-	-	-	-	r	r	-	-	r	-	-	-	-	-	-	-	x	-	-	-	-	c	r	c	c	r	r	x	x	-
Fabiania saipanensis Cole	c	c	r	c	c	a	a	r	-	-	-	-	-	-	-	-	-	x	-	-	x	-	a	r	a	a	a	-	x	x
Gypsina vesicularis (Parker and Jones)	-	-	-	-	r	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x
Halkyardia bikiniensis Cole	-	-	-	-	-	-	-	-	-	-	-	-	-	x	r	r	-	-	-	-	-	-	-	-	-	-	-	-	x	-
Heterostegina aequatoria Cole	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x
saipanensis Cole	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-	-	x	x
Operculina eniwetokensis Cole	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x
saipanensis Cole	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	x	x
subformai (Provale)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-	-	-	x
Pellatispira orbitoidea (Provale)	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	x	x	x	-	x	-	-	-	-	-	-	-	x	x
provaleae Yabe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	x	-	x	-	-	-	-	-	-	-	x	x
Spiroclypeus vermicularis Tan	-	-	r	-	-	-	-	-	-	r	-	x	-	-	-	-	-	-	-	-	x	-	-	-	r	-	-	-	x	x

occurrence on Saipan (Cole, 1957a, p. 322) and in the Eniwetok drill holes (Cole, 1957b, p. 749).

At two localities (Ej 1 and Fk 3), numerous specimens of *Camerina fichteli*, a species which elsewhere in the Indo-Pacific region previously had been reported only in Tertiary *c* and Tertiary *d* (Oligocene) deposits, were found in association with typical and diagnostic Tertiary *b* (Eocene) genera and species.

Cole (Cloud and Cole, 1953, p. 323) previously had identified several of the species from Cloud's locality MGC5 (which is the same locality as Fk 3), and had concluded that the fossils demonstrated a Tertiary *b* (Eocene) age for this locality. Cole had recognized the presence of *Camerina fichteli* in this fauna, but had thought that the abundant and well-known Eocene species which were present at this locality could not have been reworked. Therefore, he suggested that on Guam, at least, the range of *C. fichteli* would have to be extended downward into the Eocene (Tertiary *b*).

There is still a distinct possibility that this suggestion is the correct one. However, at the two localities (Hj 1 and Ek 7) within the Alutom Formation where the limestones are known to be in their original position, no specimens of *Camerina fichteli* were found. Moreover, *C. fichteli* was found in the matrix material from locality Fk 3, but specimens of this species were not found in the thin sections made from reworked-limestone fragments of definite Tertiary *b* age collected at locality Fk 4, which is a few feet from locality Fk 3 and at the same stratigraphic level.

Inasmuch as *Camerina fichteli* only occurred with known Tertiary *b* genera and species at localities where the specimens could be readily separated from the matrix material, there is the distinct possibility that these localities represent Tertiary *c* (Oligocene) accumulations into which reworked Tertiary *b* (Eocene) genera and species were carried.

Although it is impossible with the data at hand to present convincing evidence as to which possibility is correct, the writer favors the postulate that the upper part of the Alutom Formation is Tertiary *c* in age with reworked Eocene species. Elsewhere in the Indo-Pacific area, *Camerina fichteli* is found consistently in strata assigned to Tertiary *c* + *d* and has not been reported previously with Eocene species.

Reworked specimens occur abundantly in certain of the younger formation on Guam; for example, in the Bonya Limestone. Rutten (1948, p. 170) has reported that on Borneo, numerous Tertiary *b* species were found associated with a typical Tertiary *e* (Miocene) fauna,[1] and many other examples could be cited.

Fossiliferous samples were collected at 13 localities in the Alutom Formation (table 1). At two localities (Hj 1 and Ek 7), the limestones are known to be in their original positions. These localities are placed definitely in Tertiary *b*. Seven localities (Di 1 through Jm 1, table 1) could be either Tertiary *b* or Tertiary *c* At these localities, only Tertiary *b* species were found, possibly because the samples were small and *Camerina fichteli* might not have been collected. In the geologic mapping of the Guam area, localities Di 1, Hn 5, Im 1, Jl 2, Jm 1, and Fk 5 were thought to be stratigraphically equivalent to Fk 3; and Hi 6 was thought to be stratigraphically higher than Fk 3. Therefore, on the basis of field evidence, all of these localities are thought to be of Tertiary *c* (Oligocene) age.

OLIGOCENE, TERTIARY c, ALUTOM FORMATION

The occurrence of *Camerina fichteli* at two localities within the Alutom Formation has been discussed above. These localities (Ej 1 and Fk 3, table 1) are assigned to the Tertiary *c* (Oligocene) on the assumption that the Tertiary *b* species that accompany *C. fichteli* are reworked.

Localities Fk 4 and Fk 5 are assigned to Tertiary *c* on their known stratigraphic position in the field. Locality Fk 4 is within a few feet of Fk 3, and Fk 5 is close to both. The fauna from locality Fk 4 is known only from thin sections made from limestone boulders, and, as would be expected, contains only Tertiary *b* species. Matrix material from this locality would contain, without doubt, specimens of *Camerina fichteli*. The fauna from locality Fk 5 is known only from six specimens that were collected on the outcrop and is not representative of the potential fauna from this locality.

MIOCENE, TERTIARY c, UMATAC FORMATION

Maemong Limestone Member.—The distribution of the species from 37 samples from 19 localities in the Maemong Limestone Member is shown on table 2. Although *Heterostegina borneensis* was found only at three localities, five other localities are assigned to this zone, as they had species commonly associated with *H. borneensis*. Eleven localities are referred to the *Miogypsinoides dehaartii* zone, either because of the presence of this species, or because of the presence of species which normally are associated with *M. dehaartii*.

Cole (1957a, p. 324) divided the Tertiary *e* stage of Saipan into two paleontological zones, a lower zone characterized by *Heterostegina borneensis*, and an upper zone based on the presence of *Miogypsinoides dehaartii*, or, in its absence, on species that were found associated with it elsewhere.

Recently, the question has been raised as to whether these zones are completely distinct chronologically, inasmuch as they appear to represent two distinct facies (Schlanger, written communication). Schlanger interprets most of the sediments referred to the *Mio-*

[1] The specimen identified by Rutten (1948, fig. 3) as *Lockhartia* sp. is not that genus, but an oblique section of *Pettatispira*.

TABLE 2.—*Distribution of species in the Maemong Limestone Member of the Umatac Formation*

[Matrix-free specimens: X. Specimens in thin sections: a, abundant; c, common; r rare; p, probably this species]

Species	Species zone, locality, sample number																																				
	Heterostegina borneensis								*Miogypsinoides dehaartii*																												
	Ed 3	Ed 4	Ed 5	Ee 4	Ee 8	Ef 2	Dh 11	Hi 10	Ed 6	Ed 7	Ee 7	Fd 4	Gj 3				Hi 3							Hi 4					Hi 5			Hi 11		Hi 12			Ii 5
	1	1	1	1[1]	1	1	1	1	1	2	1	1	1	2	3	4	1	2	4	5	6	7	8	1	2	3	4	5	1	2	3	1	2	1	2	3	1
Borelis pygmaeus Hanzawa	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	r	--	--	--	--	--	--	--	--	--	--	--	r	--	--	--	--	--	--	--	--
Cycloclypeus (Cycloclypeus) eidae Tan	--	--	--	--	--	--	--	--	--	--	p	r	--	r	r	r	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Eorupertia semiornata (Howchin)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	r	--	--	--	--	--	--	--	--	--	r	--	--
Gypsina marianensis Hanzawa	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	r	--	--	--	--	--	--	--	r	r	--	r	--
Heterostegina borneensis Van der Vlerk	r	r	--	--	r	--	--	p	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lepidocyclina (Eulepidina) ephippioides Jones and Chapman	r	r	r	a	c	a	--	--	r	r	--	r	c	r	--	r	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
(Nephrolepidina) sumatrensis (Brady)	c	r	a	c	r	c	a	--	r	r	--	r	r	--	r	--	--	--	--	--	--	--	--	--	--	--	--	--	--	r	r	--	--	--	r	--	--
verbeeki Newton and Holland	--	--	--	--	--	--	--	--	--	--	--	--	r	r	--	c	r	r	r	r	--	--	r	r	r	r	r	r	--	--	--	r	r	c	c	c	--
Miogypsina (Miogypsina) thecideaeformis (Rutten)	--	--	--	--	--	--	--	--	r	--	--	c	--	--	r	--	a	a	c	c	r	--	c	a	a	a	a	a	r	r	r	c	r	c	c	c	--
Miogypsinoides bantamensis Tan	--	--	--	r	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
dehaartii (Van der Vlerk)	--	--	--	--	--	--	--	--	r	r	--	a	c	c	r	r	r	r	r	r	r	r	c	--	r	r	r	a	--	--	--	a	a	c	c	c	a
Sorites martini (Verbeek)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	r	--	--	--	--	--	r	--	--	--	--	r	--	r	r	--	--	--
Spiroclypeus higginsi Cole	--	--	--	--	--	--	--	--	r	c	--	r	--	c	r	r	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
orbitoideus H. Douvillé	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
yabei Van der Vlerk	--	--	--	c	--	c	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Streblus saipanensis Cole	--	--	r	r	--	c	c	p	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

[1] Contains also reworked Eocene species: *Camerina pengaronensis* and *Halkyardia bikiniensis*.

TABLE 2a.—*Distribution of species in the Bolanos Pyroclastic Member of the Umatac Formation*

[Matrix-free specimens: X. Specimens in thin sections: a, abundant; c, common; r, rare; p, probably this species]

Species	Species zone, locality, sample number																																																		
	Heterostegina borneensis									*Miogypsinoides dehaartii*																																									
	Ii 6									Eh 2				Fd 1	Fi 4	Fi 6						Fj 2					Gi 1		Gj 4				Id 2	Ii 6																		Ii 9
	11	32	33	34	35	36	37	38	39	1	2	4	5	1	1	1	2	3	5	6	7	1	2	3	4	5	2	3	1	2	3	4	1	2	3	4	7	8	9	13	14	15	16	17	18	25	26	27	28	29	31	2
Borelis pygmaeus Hanzawa	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	r	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cycloclypeus (Cycloclypeus) eidae Tan	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	c	c	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	r	--	r	--	r	--	r	--	--	r	r	--	--	--	--	--	--	--	--
Eorupertia semiornata (Howchin)	--	r	--	r	--	--	--	--	--	r	--	r	r	r	--	r	--	--	--	--	--	r	--	r	r	--	--	r	r	--	--	--	--	--	--	--	--	--	r	--	r	--	--	--	--	--	--	--	r	--	r	r
Gypsina marianensis Hanzawa	--	--	--	--	--	--	--	--	--	--	--	--	--	r	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	r	--	--	--	--	--	--	--	--	--	--	--	--	c	--	--	--	--	--	--	--
Heterostegina borneensis Van der Vlerk	r	c	c	a	c	c	c	c	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lepidocyclina (Eulepidina) ephippioides Jones and Chapman	--	a	a	c	a	a	a	c	X	--	--	--	--	--	--	r	r	--	--	--	--	--	--	r	--	--	--	--	--	--	--	--	r	--	--	--	--	--	--	--	--	--	--	r	--	--	--	--	--	--	--	--
(Nephrolepidina) cubiculirhomboides Cole	--	--	--	--	--	--	--	--	--	--	--	r	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
sumatrensis (Brady)	c	--	--	--	--	--	--	--	X	--	--	--	--	--	X	c	r	r	--	r	r	--	--	--	--	--	r	--	r	r	--	r	r	c	c	c	a	c	--	a	c	--	--	--	--	r	r	r	r	--	--	a
verbeeki Newton and Holland	--	--	--	--	--	--	--	--	--	--	--	--	--	r	--	r	r	--	r	--	--	r	c	--	r	r	--	--	--	--	r	--	--	--	--	--	--	--	--	--	--	--	c	c	--	--	--	--	--	c	--	--
Marginopora vertebralis Quoy and Gaimard	--	--	--	--	--	--	--	--	--	r	--	r	r	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	r	--	--	--	--	--	--	--	--	--	--	--	--	r	--	--	--	--	--	--	--	--	--	--
Miogypsina (Miogypsina) thecideaeformis (Rutten)	--	--	--	--	--	--	--	--	--	a	a	--	c	--	X	--	--	--	c	r	--	--	--	--	r	r	r	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	r	--	r	r	c	a	c	c	c	--
Miogypsinoides bantamensis Tan	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
dehaartii (Van der Vlerk)	--	--	--	--	--	--	--	--	--	a	a	a	a	a	X	c	r	a	a	a	--	c	a	--	a	a	c	--	c	a	a	r	--	--	--	--	--	--	--	--	--	r	a	a	r	r	--	r	--	--	--	--
grandipustula Cole	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	r	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sorites martini (Verbeek)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	r	--	--	--	--	--	--	--	--	c	--	--	--	--	--	--	--	--	--	--	--	--	c	--	--	--	--	--	r	--
Spiroclypeus higginsi Cole	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	r	--	--	--	--	--	--	--	c	--	--	r	a	--	--	--	--	--	c	c	c	c	r	r	r	--	--	--	--	--	r	--	--	--	--	--	--
orbitoideus H. Douvillé	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	r	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
yabei Van der Vlerk	--	--	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Streblus saipanensis Cole	--	c	c	c	c	c	c	c	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

gypsinoides dehaartii zone as forming on or near the reef wall in shallow water, and most of the sediments referred to the *Heterostegina borneensis* zone as having been deposited as fore-reef talus in deeper water. Thus, he suggests that the two paleontologic zones could be in part stratigraphically equivalent, rather than one being younger than the other.

Leupold and Van der Vlerk (1931, table 2) gave the stratigraphic ranges of *Heterostegina borneensis* as Tertiary e_{1-4}, of *Miogypsinoides dehaartii* as e_{4-5}, and of *Miogypsina* (*Miogypsina*) as e_5 through f_3. Later, Van der Vlerk gave these same stratigraphic ranges for *H. borneensis* and *M.* (*Miogypsina*) on figure 1 of a report published in 1948, but in the text (p. 61) he stated that *M.* (*Miogypsina*) occurred with *H. borneensis* in the lower part of Tertiary *e*. Recently, Van der Vlerk (1955, table 1) published another chart on which he showed *H. borneensis* as restricted to lower Tertiary *e*, and *M.* (*Miogypsina*) as first appearing in upper Tertiary *e*. Rutten (*in* Bemmelen, 1949, table 13), following Van der Vlerk's 1948 range chart, gave overlapping ranges for *H. borneensis* and *M.* (*Miogypsina*), whereas Mohler (1949, fig. 3) did not show any *M.* (*Miogypsina*) below Tertiary e_5.

In the Bikini drill holes and on Saipan, *Heterostegina borneensis* and *Miogypsinoides dehaartii* did not occur together. At many localities on Saipan, *M. dehaartii* was accompanied by *Miogypsina* (*Miogypsina*). In the Bikini drill holes, the *M. dehaartii* zone occurred stratigraphically higher than the *Heterostegina* zone (Cole, 1954, p. 572). On Saipan it was impossible to check absolutely the stratigraphic relationship between the two zones, but in situations where a partial check could be made, the *H. borneensis* zone appeared to be stratigraphically lower than the *M. dehaartii* zone.

However, in the study of the samples from the Eniwetok drill holes, a few specimens identified as *Heterostegina borneensis* (Cole, 1957a, p. 747) were found at a depth of 1,210 to 1,220 feet in association with *Miogypsinoides dehaartii*. The zone of abundant *H. borneensis* did not appear in these drill holes until a depth of 1,688 to 1,925 feet was reached.

A core taken in the Eniwetok drill hole F–1, between 1,230 and 1,248 feet (core 3), contained *Miogypsinoides dehaartii* and rare specimens of *Miogypsina* (*Miogypsina*) *thecideaeformis*, but did not show any specimens of *Heterostegina borneensis*. Thus, in the Saipan, Guam, and Eniwetok drill holes, *Miogypsina* (*Miogypsina*) and *Miogypsinoides* occur together, but *H. borneensis* was found in association with *Miogypsinoides dehaartii* in only one sample of cuttings in the Eniwetok drill holes.

Moreover, abundant *Heterostegina borneensis* have not been found with *Miogypsinoides dehaartii* and *Miogypsina* (*Miogypsina*). In every situation where the stratigraphic relationship of the zones could be observed, the zone of abundant *H. borneensis* appeared to be stratigraphically lower than the zone of abundant *Miogypsinoides* and *Miogypsina* (*Miogypsina*).

However, the one occurrence of *Heterostegina borneensis* with *Miogypsinoides dehaartii* in Eniwetok drill hole F–1 shows that the top part of the *H. borneensis* zone in the central Pacific overlaps the basal part of the *M. dehaartii* zone.

In the Caribbean region, miogypsinids and *Heterostegina* are found commonly in association in rocks of Oligocene and Miocene age, and in this region, at least, they appear to respond to the same ecological controls. Insofar as ecological conditions can be interpreted, there is no valid reason why miogypsinids and *Heterostegina* should not occur together in the central Pacific as they do in the Caribbean area and elsewhere.

Data available from the Malayan Archipelago and from areas adjacent to Guam indicate that *Heterostegina borneensis* is seemingly limited to the lower Tertiary *e* stage, with the exception of one drill hole on Eniwetok Atoll, where a few specimens assigned to this species were found in the basal part of upper Tertiary *e*. *Miogypsinoides dehaartii*, and probably *Miogypsina* (*Miogypsina*), seemingly is confined to upper Tertiary *e* and stratigraphically younger stages.

Therefore, it would seem from the evidence given that spatial separation of these two paleontologic zones on Guam may be due to a combination of ecologic and chronologic factors.

Bolanos Pyroclastic Member.—The distribution of the species found in 52 samples collected from 10 localities within this member is shown on table 2. All the larger Foraminifera except those from localities Ii 6–39 and Fi 4–1 came from limestone boulders collected from this conglomerate, and therefore represent reworked material from the underlying Maemong Limestone Member. The matrix-free specimens from localities Ii 6–39 and Fi 4–1 either may be reworked specimens, or they may have been living in the area when the Bolanos Pyroclastic Member was deposited.

Nine samples from one locality (Ii 6) contain the *Heterostegina borneensis* fauna, but 18 other samples from this same locality contain the *Miogypsinoides dehaartii* fauna. The faunas from the other 9 localities are those of the *Miogypsinoides dehaartii* zone.

Inasmuch as all the larger Foraminifera found in the Bolanos Member are known to occur in Tertiary *e* or older beds, it is impossible to make an exact age assignment, as the field relationship as well as the fossils demonstrate that most of the boulders containing larger Foraminifera were derived from the underlying Maemong Limestone Member. As mentioned above, the few matrix-free specimens also could have been reworked.

One sample from locality Ii 8 represented an Eocene cobble containing abundant specimens of *Biplanispira mirabilis* and rare specimens of *Eorupertia plecte* and *Fabiania saipanensis.* Inasmuch as this was the only Eocene material submitted from the Bolanos Pyroclastic Member, it is not plotted on table 2.

Although Tertiary *f* species were not found, the Bolanos Member could have accumulated during Tertiary *f* time in a situation that was unfavorable for the development of Tertiary *f* species. Therefore, the Bolanos Member must have been deposited after the accumulation of upper Tertiary *e* sediments containing *Miogypsinoides dehaartii,* and before the accumulation of the Bonya Limestone of the Tertiary *f* stage, as the Bolanos Member represents either late Tertiary *e* or early Tertiary *f* time, or both.

MIOCENE, TERTIARY c

BONYA LIMESTONE

Fifty-four samples from 19 localities in the Bonya Limestone were examined (table 3). The fauna of larger Foraminifera in this formation proves that it is equivalent stratigraphically to the upper part of the Futuna Limestone (Ladd and Hoffmeister, 1945, p. 36) of Lau, Fiji. Cole (1945, p. 272) assigned the Futuna Limestone to Tertiary *f* (Miocene). The species of larger Foraminifera found in the Bonya and Futuna Limestones have been reported from many Tertiary *f* localities in Borneo, Java, and elsewhere in the Indo-Pacific area. One of the first described faunas of this age was the one from the vicinity of Rembang, Java, published by Douvillé (1916, p. 19).

Cole (1945, table 18) listed 30 species and subspecies of larger Foraminifera from the Futuna Limestone of Lau, Fiji. This number of species and subspecies is

TABLE 3.—*Distribution of species in the Bonya Limestone*

[Matrix-free specimens: x. Specimens from thin sections: a, abundant; c, common; r, rare. Thin sections contain reworked Tertiary *e* species shown by footnotes]

Species	Locality and sample number																										
	Fi 3				Fi 5		Gi 2					Gi 4			Gj 1			Gj 6		Gj 7		Gj 9			Hi 2		
	1	2	[1]3	4	[2]1	[3]2	1	2	3	4	6	[4]1	[5]2	[6]3	1	2	3	[7]1	[8]2	1	2	1	2	4	1	2	3
Cycloclypeus (*Cycloclypeus*) *indopacificus* Tan	p		r												r	r			r	c		x	x	x			
(*Cycloclypeus*) *posteidae* Tan		r			r	r		r										r				x	x	x			
(*Katacycloclypeus*) *annulatus* Martin							r								r	r	r				r	x	x	x			
martini Van der Vlerk																					r						
Flosculinella bontangensis (Rutten)																		r									
Lepidocyclina (*Nephrolepidina*) *japonica* Yabe	r														r		r				r						
martini Schlumberger					r	r														r	r						
rutteni Van der Vlerk																											
sumatrensis (Brady)	r	r	r	r	c	c													r	r	r				r	p	r
Marginopora vertebralis Quoy and Gaimard																											
Miogypsinoides cupulaeformis (Zuffardi-Comerci)											r					r	r			r		x	x	x			r
Operculina ammonoides (Gronovius)		r			r	r	c	r	r						r	r	r	r		c	c	x	x	x	c	r	
bartschi Cushman	r									r												x	x	x	r	r	
venosa (Fichtel and Moll)												r	r	r				r				x	x	x	r		r
Rotalia atjehensis Van der Vlerk	a	c	c	c	a	a	a	c	a	c	a	c	c	c	c	a	a	a	c	a	a	x	x	x	a	a	a

Species	Locality and sample number																								
	Ih 5							Ih 10		Ih 14		Jj 1			Jj 3			Jj 5		Jj 8	Jj 9			Rr 13	Ts 2		
	2	3	4	5	6	7	8	1	2	1	2	1	2	3	1	2	3	2	3	1	1	2	3	1	1	1a	1b
Cycloclypeus (*Cycloclypeus*) *indopacificus* Tan		p	p							r							r	r	r					a	a	a	c
(*Cycloclypeus*) *posteidae* Tan												c		r									x				
(*Katacycloclypeus*) *annulatus* Martin	r				r	r	r												r							r	
martini Van der Vlerk																							x			r	r
Flosculinella bontangensis (Rutten)																r											
Lepidocyclina (*Nephrolepidina*) *japonica* Yabe							r					r											x				
martini Schlumberger			r			r																	x	r			
rutteni Van der Vlerk																									r	r	r
sumatrensis (Brady)	p																		r				x				
Marginopora vertebralis Quoy and Gaimard												r								r							
Miogypsinoides cupulaeformis (Zuffardi-Comerci)					r																		x				
Operculina ammonoides (Gronovius)		r	r							r	r	r		r	r	c	r	r					x	r			r
bartschi Cushman									r	r	r	r											x				
venosa (Fichtel and Moll)						r	r							r					r			r				r	
Rotalia atjehensis Van der Vlerk	c	c	c	r	a	c	c	a	a	a	a	a		r	a	c	c	c	c		r	r	x				

[1] *Gypsina marianensis.*
[2] Pebble with Tertiary *e Lepidocyclina.*
[3] *Gypsina marianensis, Miogypsina thecideaeformis.*
[4] *Spiroclypeus higginsi.*
[5] *Spiroclypeus higginsi, Miogypsinoides dehaartii, Lepidocyclina ephippioides.*
[6] *Spiroclypeus higginsi, Lepidocyclina ephippioides.*
[7] *Miogypsina thecideaeformis, Miogypsinoides dehaartii.*
[8] *Streblus saipanensis.*

misleading, because, at the time the identifications were made, Cole attempted to recognize the various subspecies of *Cycloclypeus* proposed by Tan (1932) in his monograph on this genus. Moreover, certain species were not identified correctly; for example, *C.* (*Cycloclypeus*) *eidae*. Certain specimens from the Futuna Limestone previously assigned to this species are known now to be *C.* (*C.*) *posteidae*, and others represent *C.* (*C.*) *indopacificus*.

The list of species and subspecies from the Futuna Limestone, therefore, can be reduced from 30 to 27 by the elimination of the subspecies of *Cycloclypeus* and the species of this genus that were not identified correctly. Additional reduction in the number of species in the Futuna Limestone might be possible if the species of the other genera present were restudied critically.

Fifteen species were identified in the samples from the Bonya Limestone. Thirteen of these species are common to the Futuna Limestone of Lau, Fiji. The only species found in the Bonya Limestone that were not reported from Lau, Fiji, are *Flosculinella bontangensis* and *Rotalia atjehensis*. Four of the species from the Bonya Limestone occur at Rembang, Java (Douvillé, 1916). The following table names the species common to these three areas.

	Bonya Limestone, Guam	Futuna Limestone, Lau, Fiji	Rembang, Java
Cycloclypeus (*Cycloclypeus*) *indopacificus* Tan	×	×	×
(*Cycloclypeus*) *posteidae* Tan	×	×	----
(*Katacycloclypeus*) *annulatus* Martin	×	×	×
martini Van der Vlerk	×	×	----
Flosculinella bontangensis (L. Rutten)	×	----	×
Lepidocyclina (*Nephrolepidina*) *japonica* Yabe	×	×	----
martini Schlumberger	×	×	×
rutteni Van der Vlerk	×	×	----
sumatrensis (Brady)	×	×	----
Marginopora vertebralis Quoy and Gaimard	×	×	----
Miogypsinoides cupulaeformis (Zuffardi-Comerci)	×	×	----
Operculina ammonoides (Gronovius)	×	×	----
bartschi Cushman	×	×	----
venosa (Fichtel and Moll)	×	×	----

The most striking and largest species of the Bonya assemblage is *Cycloclypeus* (*Katacycloclypeus*) *annulatus*, which occurred at 7 of the 19 localities. Various species of *Lepiodocyclina* occurred at 12 of the 19 localities. At five localities, *Cycloclypeus* (*Katacycloclypeus*) and *Lepidocyclina* occurred together. *Flosculinella bontangensis* was found at only two localities. The distribution of these species in the Bonya Limestone is shown in the following table:

Distribution of species of Cycloclypeus (Katacycloclypeus), Flosculinella *and* Lepidocyclina *in the Bonya Limestone*

Specie	Locality														
	Fi 3	Fi 5	Gi 2	Gj 1	Gj 6	Gj 7	Gj 9	Hi 2	Ih 5	Jj 1	Jj 3	Jj 5	Jj 9	Rr 13	Ts 2
C. (*K.*) *annulatus*	----	----	×	×	----	×	×	----	×	----	----	×	----	----	×
martini	----	----	----	----	----	×	----	----	----	----	----	----	×	----	×
F. bontangensis	----	----	----	----	×	----	----	----	----	----	×	----	----	----	----
L. (*N.*) *japonica*	×	----	----	×	----	×	----	----	×	×	----	----	×	----	----
martini	----	×	----	----	----	×	----	----	×	----	----	----	×	×	----
rutteni	----	----	----	----	----	----	----	----	----	----	----	----	----	----	×
sumatrensis	×	×	----	----	×	×	----	×	----	----	----	×	×	----	----

Four localities assigned to the Bonya Limestone had a very small fauna. These are localities Gi 4 (with *Operculina venosa* and *Rotalia atjehensis*), Ih 10 (with *O. bartschi* and *R. atjehensis*), Ih 14 (with *O. bartschi*, *Operculina venosa* and *R. atjehensis*), and Jj 8 (with *Marginopora vertebralis*).

ALIFAN LIMESTONE

The distribution of the species found in 48 samples from 17 localities in the Alifan Limestone Formation is shown on tables 4 and 5. The faunas from the lower part of the formation in the Santa Rosa-Yona and the Mount Alifan-Lamlam-Fena Basin areas (table 4) will be discussed first.

Rotalia atjehensis, a species which was found in most of the samples from the Bonya Limestone, was present in all the samples that contained larger Foraminifera from these two areas. *Miogypsinoides cupulaeformis*, the only other species recorded, was found at three localities in the Santa Rosa-Yona area. In comparison, this species was present in the Bonya Limestone at seven localities. Although a careful search was made, no specimens, or even fragments, were found that would suggest the presence of other species of larger Foraminifera in the samples from these two areas.

The presence of *Rotalia atjehensis* in all the samples that contained Foraminifera from the lower part of the Alifan Limestone and the presence of *Miogypsinoides cupulaeformis* in certain of the samples, suggest that the lower part of the formation may correlate with a part of the Bonya Limestone. If a correlation could be made, the unit would be either the same age or slightly younger than the upper part of the Bonya Limestone.

The disappearance of the other species which were found in that part of the Bonya Limestone that might

TABLE 4.—*Distribution of species in lower part of the Alifan Limestone*

[Specimens in thin sections: a, abundant; c, common; r, rare]

Species	Locality and sample number																															
	Yona and Santa Rosa area															Mount Alifan-Lamlam-Fena basin area																
	Jl 3	Rs 1	Ts 9	Ts 16										Tt 7		Di 2	Eh 3								Fj 5		Gj 2	Gj 8		Gj 10		
	2	1	1	1	3	4	5	6	9	10	11	12	13	1	2	1	1	2	3	4	5	6	7	8	1	2	1	1	2	1	2	3
Miogypsinoides cupulaeformis (Zuffardi-Comerci)	r	---	r	---	---	---	---	---	r	r	---	r	r	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Rotalia atjehensis Van der Vlerk	a	r	a	a	a	a	a	c	a	a	a	a	a	r	c	r	c	c	c	c	c	c	r	r	c	c	r	r	r	c	r	c

be equivalent to a part of the Alifan Limestone may be the result of environmental factors. It is well established that certain species of rotalids are able to maintain themselves both in shallow and brackish water (Hedberg, 1934, p. 475) where other species are not able to survive.

Bemmelen (1949, p. 123) published a diagram which shows the "facies alterations of the Tertiary in the 'Atjeh I' terrain of Sumatra." One of the zones recognized is a *Rotalia* zone. The conditions illustrated by this diagram appear to represent a situation comparable to that in the *Rotalia* zone of the Alifan Limestone.

In south Guam certain limestones that were mapped as an upper part of the Alifan Limestone contain a different association of larger Foraminifera (table 5). This part of the Alifan Limestone has a fauna that is more closely related to post-Miocene faunas than to those of Tertiary *f*. If species with known long stratigraphic ranges, such as operculinoids, are disregarded, *Cycloclypeus* (*Cycloclypeus*) *carpenteri* becomes the critical species for age determination.

Cycloclypeus (*Cycloclypeus*) *carpenteri* has been reported as ranging from Tertiary *g* to Recent (Umbgrove, 1931, table, p. 80), but Tan (1932, p. 77) has stated: " * * * we are of the opinion that *Cycl. carpenteri* characterizes a Post-Miocene age."

The limestones mapped as Alifan thus contain faunas that seemingly are of two distinct ages. The *Rotalia* fauna appears to be related to the Tertiary *f* fauna of the Bonya Limestone, and the *Cycloclypeus-Operculina* fauna is seemingly post-Miocene in age and related to known Pleistocene faunas.

Stratigraphic ranges of the larger Foraminifera from mid-Miocene to Recent, however, are not completely known. Therefore, it is entirely possible that *Cycloclypeus carpenteri* did exist from Tertiary *g* (Miocene) to Recent. The field evidence shows that the upper part of the Alifan Limestone, which contains the *Cycloclypeus-Operculina* fauna, is pre-Mariana in age.

MIOCENE, TERTIARY g

BARRIGADA LIMESTONE

Thirty-three samples from 23 localities in the Barrigada Limestone were examined, and the distribution of the species found is shown in table 6. Three species of larger Foraminifera are present, of which *Operculina rectilata* is the largest and most distinctive.

Operculina lucidisutura and *O. rectilata* were described from samples recovered from the Bikini drill holes (Cole, 1954, p. 575), and later were found in the Eniwetok drill holes (Cole, 1957b, p. 745). These species occurred in strata assigned to Tertiary *g* (Miocene).

Table 5—*Distribution of species in upper part of the Alifan Limestone*

[Specimens in thin sections: a, abundant; c, common; r, rare; p, probably this species]

Species	Locality and sample number															
	Cn 1	Ig 7	Ig 8		Ig 9									Ih 11	Ih 12	
	1	1	1	2	2	3	4	5	6	7	8	9	10	3	2	4
Amphistegina madagascariensis d'Orbigny	---	---	---	---	---	---	---	---	---	---	---	---	---	---	p	p
Cycloclypeus (*Cycloclypeus*) *carpenteri* H. B. Brady	r	p	r	---	---	---	---	---	---	p	c	p	---	---	---	---
Heterostegina suborbicularis d'Orbigny	r	---	---	---	---	c	---	---	---	---	---	---	---	---	---	---
Marginopora vertebralis Quoy and Gaimard	---	---	r	---	---	---	---	---	---	---	---	---	---	---	---	---
Operculina bartschi Cushman	---	r	---	c	r	---	---	r	c	---	---	---	---	---	---	---
venosa (Fichtel and Moll)	---	r	c	r	---	---	r	---	r	r	r	---	p	---	---	---
Peneroplis carinatus d'Orbigny	---	r	r	---	---	---	---	---	r	---	---	---	---	---	---	---
Rotalia calcar (d'Orbigny)	---	---	---	---	---	---	---	---	---	---	---	---	---	r	---	---

TABLE 6.—*Distribution of species in the Barrigada Limestone*

[Specimens in thin sections: a, abundant; c, common; r, rare; p, probably this species]

Species	Locality and sample number																																
	Np 1	Np 2	Nq 2		Nq 14	Nr 1	Oq 1	Oq 2	Os 1		Ot 1		Ou 6		Ov 4		Ov 5		Ov 7	Pr 2		Pv 7	Pv 10			Qr 1	St 8	St 34	Sv 1		Sv 3	Sv 4	Sv 5
	2	1	1	2	1	4	1	1	2	3	2	3	2	3	1	3	1	2	3	3	4	1	2	3	4	1	1	1	3	4	1	1	1
Cycloclypeus (Cycloclypeus) postindopacificus Tan	p	c	p	----	----	----	----	----	----	r	r	p	c	c	----	r	r	r	----	c	r	r	c	r	c	p	----	----	r	r	p	----	r
Operculina lucidisutura Cole	----	c	c	r	----	r	----	r	r	----	r	----	----	----	----	----	----	----	r	----	----	----	c	----	----	----	r	c	----	----	----	r	r
rectilata Cole	----	r	----	----	r	----	r	----	----	----	c	----	r	r	a	c	r	r	----	----	----	c	c	c	c	----	----	c	c	c	r	r	a

In all the drill holes, these operculinid species occurred stratigraphically higher than *Miogypsinoides cupulaeformis*, a species that occurs also on Guam in the Bonya and Alifan Limestones. Inasmuch as the Bonya Limestone is known from field evidence to underlie both the Barrigada Limestone and the lower part of the Alifan Limestone, the stratigraphic distribution of the species in both areas seems to be the same.

JANUM FORMATION

The Janum Formation is placed in Tertiary *g* largely on field evidence. Thin sections from three samples (Ts 5–14, Ts 5–15, Ts 5–16) were examined for larger Foraminifera. These thin sections contained abundant pelagic-type smaller Foraminifera, but no diagnostic larger ones were observed except in the thin sections from sample Ts 5–15, which contained several small *Lepidocyclina*. At least one of these lepidocyclines appeared to be in a small pebble.

Although the lepidocyclines were studied in detail, it was impossible to be absolutely certain of their specific identification because they were present only as off-center and tangential vertical sections. These sections most nearly resemble those of *Lepidocyclina* (*Nephrolepidina*) *martini*. As this is a Tertiary *f* species, and as the specimens are believed to be reworked, the paleontologic evidence, slight as it is, substantiates the field evidence that the Janum Formation is Tertiary *g* in age. Moreover, thin sections from a white porous limestone (sample Ts 5–10), which occurs at the base of the Janum Formation, contain *Operculina rectilata* and *Cycloclypeus* (*Cycloclypeus*) *postindopacificus*. These species, which are characteristic of the Barrigada Limestone elsewhere, occur in limestone that is lithologically similar to the Barrigada Limestone. This basal limestone, however, contains, in addition, smaller Foraminifera that occur in the overlying Janum Formation. The Janum Formation thus either may be a deeper-water facies of the Barrigada Limestone, or a unit slightly younger than the typical Barrigada Limestone.

PLEISTOCENE, MARIANA LIMESTONE

The distribution of Pleistocene species from three localities in the Mariana Limestone, represented by three samples, and from three localities in the fore-reef facies of the Mariana Limestone, represented by four samples, is shown in table 7. The typical, corralliferous part of the Mariana Limestone seemingly does not contain larger Foraminifera.

The fore-reef facies was deposited as a fore-reef accumulation during Pleistocene time. All the species

TABLE 7.—*Distribution of species in the Mariana Limestone*

[a, abundant; c, common; r, rare]

Species	Locality and sample number						
	Fore-reef facies				Mariana Limestone		
	Jh 1		Ji 1	Uu 3	Cm 3	Cm 4	Ov 6
	1	2	1	1	1	1	2
Amphistegina madagascariensis d'Orbigny	a	c	----	c	r	----	a
Baculogypsina sphaerulata (Parker and Jones)	r	r	r	c	----	----	----
Calcarina spengleri (Gmelin)	a	a	r	a	----	----	----
Cycloclypeus (*Cycloclypeus*) *carpenteri* H. B. Brady	----	----	c	----	----	----	----
Heterostegina suborbicularis d'Orbigny	----	----	----	r	----	c	----
Marginopora vertebralis Quoy and Gaimard	r	r	----	----	----	----	----
Operculina bartschi Cushman	----	----	----	----	----	----	c

found are still living. Although certain species, *Operculina bartschi* for example, in this fauna are known to occur in Tertiary *f* deposits on Guam, other species, such as *Cycloclypeus carpenteri*, are thought to have shorter stratigraphic ranges. *Calcarina spengleri*, which in the Bikini drill holes did not appear to range below 95 feet (Todd and Post, 1954, p. 551), probably represents a Pleistocene and Recent species.

CORRELATION WITH OTHER AREAS

The faunas of larger Foraminifera found on Guam, prove that most of the localities can be referred to the time scale developed and later modernized by Van der Vlerk (1955, p. 72) for Indonesia. Moreover, correlation can be made between Guam, Saipan, the drill holes on Bikini and Eniwetok Atolls, and Lau, Fiji. Table 8 shows the salient features of this correlation and some of the diagnostic species on which it is based.

PALEOECOLOGY

Paleoecological conditions that prevail on Guam are reflected in part by the genera and the abundance of species of larger Foraminifera at the different localities. It should be recognized, however, that some of the tests were transported from the substratum on which the animal lived after these tests were abandoned by the protoplasm in the reproductive cycle.

The fauna of the fore-reef facies of the Mariana Limestone, dominated by *Amphistegina* and *Calcarina*, most probably lived on a reef flat of the kind developed at Bikini Atoll. Cushman (1921, p. 352) stated that *Calcarina* "* * * is very common in the Philippine collection, especially in warm shallow waters, where it is sometimes abundant." Cushman, Todd, and Post (1954, p. 319) stated that at Bikini Atoll the fauna of the reef flat "* * * is characterized by large percentages of *Calcarina spengleri* * * *." These tests accumulated, however, as detrital deposits off the reef.

The upper Alifan fauna of south Guam and the Barrigada fauna are characterized by *Cycloclypeus* and *Operculina*. *Cycloclypeus* develops best in the deeper water of seaward slopes. *Operculina* apparently favors partially protected situations but tolerates deeper water and lower temperature than does *Calcarina*. These faunas accumulated on the reef slope, but presumably in place without transportation of the tests.

The Bonya Limestone contains numerous specimens of *Rotalia* at most of the localities. Associated with these forms are rare specimens of *Cycloclypeus*, *Operculina*, and *Lepidocyclina*, as well as other genera. Cushman (1921, p. 348) stated, concerning a living rotalid similar to the species in the Bonya limestone: "* * * the species is characteristic of the protected waters among the islands of the Archipelago, and on the western border along the China Sea, but is not represented at the stations on the eastern coast bordered by the Pacific." The accumulation of the Bonya Limestone probably occurred under conditions similar to those in the Philippine area described by Cushman. That part of the Bonya Limestone represented by localities Gj 9 and Ts 2, at which *Cycloclypeus* is abundant, must have been deposited in less protected, deeper water on seaward slopes.

In contrast to these two situations postulated for the accumulation of Bonya Limestone, the *Rotalia*-bearing sediments of the lower Alifan Limestone were deposited

TABLE 8.—*Generalized correlation between Guam, Saipan, and Eniwetok Atoll*

Stages	Stratigraphic units on Guam	Characteristic fossils	Stratigraphic units on Saipan	Section at Eniwetok Atoll (in feet)
Pliocene–Pleistocene	Mariana Limestone	*Calcarina spengleri* *Cycloclypeus carpenteri*	Mariana Limestone	0– 615
Tertiary *g*	Barrigada Limestone	*Cycloclypeus postindopacifus* *Operculina rectilata*	Not present	615– 860
Tertiary *f*	Alifan Limestone	*Cycloclypeus carpenteri* *Rotalia atjehensis* *Miogypsinoides cupulaeformis*	Not present	860–1,080
	Bonya Limestone	*Katacycloclypeus annulatus* *Lepidocyclina martini* *rutteni*		
Tertiary *f* or *e*	Umatac Formation Bolanos Pyroclastic Member	Reworked Tertiary *e* specimens	Tagpochau Limestone	1,080–2,687
Tertiary *e*	Maemong Limestone Member	*Miogypsinoides dehaartii* *Heterostegina borneensis*		
Tertiary *c*	Alutom Formation	*Camerina fichteli*		2,687–2,780 (without diagnostic fossils)
Tertiary *b*		*Asterocyclina* (3 sp.) *Biplanispira* (2 sp.) *Fabiania saipanensis* *Pellatispira* (2 sp.) *Spiroclypeus vermicularis*	Matansa Limestone Densinyama Formation Hagman Formation	2,780–4,553

not only in protected, shallow areas but also under conditions not favorable for the development of other genera. The only other genus found in this part of the Alifan Limestone was *Miogypsinoides,* which occurred rarely at a few localities.

The Tertiary *e* fauna of the Maemong Limestone Member characterized by *Heterostegina,* presumably accumulated in warm water approximately 30 fathoms deep under protected conditions similar to those postulated for the accumulation of the *Heterostegina*-bearing sediments at Eniwetok (Cole, 1957b, p. 751). Because the miogypsinids are extinct, any postulate on the conditions under which they lived must be based on genera still living and with which they occur as fossils. Inasmuch as *Heterostegina* is generally associated with miogypsinids in the Caribbean region, the writer believes that these two larger Foraminifera normally lived under the same ecological conditions.

Schlanger (written communication) has shown that there are marked differences in the structure of the limestones from the *Heterostegina*-bearing sediments of the Maemong Limestone Member and those of the miogypsinid-bearing beds. It would seem that the zonation of these larger Foraminifera on Guam should be the result of different environmental conditions.

There is also the possibility that this zonation may be chronologic rather than ecologic. At Eniwetok Atoll the two zones apparently overlap, but it should be recalled that this evidence is based on the occurrence together of *Heterostegina borneensis* and *Miogypsinoides dehaartii* in only one sample of cuttings. In the numerous samples from Saipan, in the Bikini Atoll drill holes, and at numerous localities in the Malayan Archipelago, *Heterostegina borneensis* has not been found with *Miogypsinoides dehaartii* and *Miogypsina* (*Miogypsina*). Van der Vlerk (1955), Cole (1957a), and others, therefore, had assumed that the zonation was chronologically rather than ecologically controlled.

SPECIES NOT DESCRIBED OR ILLUSTRATED

Inasmuch as many of the species found in the samples from Guam are identical with species discussed and illustrated in recent articles on Saipan (Cole and Bridge, 1953; Cole, 1957a), Bikini Atoll (Cole, 1954), and Eniwetok Atoll (Cole, 1957b), these species will not be discussed or illustrated in this article. The following list records the species that are not included in "Description of Species":

Eocene:

Asterocyclina matanzensis Cole
penuria Cole
Biplanispira fulgeria (Whipple)
mirabilis (Umbgrove)
Camerina pengaronensis (Verbeek)
Discocyclina omphala (Fritsch)
Eorupertia plecte (Chapman)
Fabiania saipanensis Cole
Gypsina vesicularis (Parker and Jones)
Halkyardia bikiniensis Cole
Heterostegina saipanensis Cole
Operculina saipanensis Cole
Pellatispira orbitoidea (Provale)
provaleae Yabe
Spiroclypeus vermicularis Tan

Miocene (Tertiary *e*):

Borelis pygmaeus Hanzawa
Cycloclypeus (*Cycloclypeus*) *eidae* Tan
Eorupertia semiornata (Howchin)
Gypsina marianensis Hanzawa
Heterostegina borneensis Van der Vlerk
Lepidocyclina (*Eulepidina*) *ephippioides* Jones and Chapman
(*Nephrolepidina*) *verbeeki* Newton and Holland
Marginopora vertebralis Quoy and Gaimard
Miogypsina (*Miogypsina*) *thecideaeformis* (L. Rutten)
Miogypsinoides bantamensis Tan
dehaartii (Van der Vlerk)
grandipustula Cole
Sorites martini (Verbeek)
Spiroclypeus higginsi Cole
orbitoideus H. Douvillé
yabei Van der Vlerk

Miocene (Tertiary *g*) and Pleistocene:

Amphistegina madagascariensis d'Orbigny
Baculogypsina sphaerulata (Parker and Jones)
Calcarina spengleri (Gmelin)
Heterostegina suborbicularis d'Orbigny
Peneroplis carinatus d'Orbigny
Rotalia calcar (d'Orbigny)

DESCRIPTION OF SPECIES

Family CAMERINIDAE

Genus CAMERINA Bruguière, 1792

Camerina djokdjokarta (Martin)

Plate 2, figures 5, 6, 8, 10, 14, 16, 18

1881. *Nummulina djokdjokartae* Martin, Geol. Reichs-Mus. Leiden Samml., ser. 1, v. 1, p. 109, 110, pl. 5, figs. 8–11.
1934. *Camerina djokdjokartae* (Martin). Caudri, Tertiary Deposits of Soemba, Amsterdam, p. 67–72, text fig. 19 [references].
1957. *Camerina djokdjokarta* (Martin). Cole, U.S. Geol. Survey Prof. Paper 280–I, p. 329, p. 102, fig. 21.
1957. *Camerina djokdjokarta* (Martin). Cole, U.S. Geol. Survey Prof. Paper 260–V, p. 752, pl. 232, figs. 24–27.

Occurrence elsewhere.—In Tertiary *b* (Eocene) of Java, Soemba, Saipan, and drill hole E–1 on Eniwetok Atoll at a depth of 2930–2940 feet.

Remarks.—This species is a pustulate *Camerina* characterized externally by pustules and, in transverse section, by distinct and heavy pillars.

Camerina fichteli (Michelotti)

Plate 1, figures 1–17; plate 2, figures 7, 9, 11–13, 15, 17

1841. *Nummulites fichteli* Michelotti, Soc. italiana sci. Nat. Mem., atti, v. 22, p. 296, pl. 3, fig. 7.

1934. *Camerina fichteli* (Michelotti). Caudri, Tertiary deposits of Soemba, Amsterdam, p. 72–81 [references].

The test is evenly biconvex. The surface is smooth and covered by a reticulate mesh that represents the sutures. Slightly eroded specimens have irregular shallow pits in the abraded areas.

Median sections that are not centered show the reticulate character of the sutures pl. 2, figs. 15, 17).

Measurements of seven median sections follow:

Measurements of median sections of Camerina fichteli (*Michelotti*)

Locality	Fk 3						Ej 1-1
Specimen	Pl. 1, fig. 3	Not illustrated	Pl. 1, fig. 2	Pl. 1, fig. 10	Pl. 1, fig. 9	Pl. 1, fig. 1	Pl. 1, fig. 11
Height (mm)	2.9	4.1	3.05	3.85	3.9	4.1	3.7
Width (mm)	2.9	3.7	2.85	3.75	3.8	3.9	3.6
Embryonic chambers:							
Diameters of initial chamber (μ)	170×180	130×150	160×180	180×185	120×150	100×120	140×160
Diameters of second chamber (μ)	80×170	70×180	90×190	100×190	100×160	90×140	80×160
Distance across both chambers (μ)	270	210	260	290	240	210	230
Number of volutions	6	6¼	5⅛	6½	5½	7¼	6
Number of chambers:							
First volution	6	7	7	7	7	----	7
Final volution	23	24	24	28	23	30	22
All volutions	91	105	87	130	84	150	94

Measurements of six traverse sections follow:

Measurements of transverse sections of Camerina fichteli (*Michelotti*)

Locality	Fk 3					Ej 1-1
Specimen	Pl. 1, fig. 16	Pl. 1, fig. 13	Pl. 1, fig. 17	Pl. 1, fig. 12	Pl. 1, fig. 14	Pl. 1, fig. 15
Height (mm)	3.5	2.95	3.55	3.9	3.8	3.15
Thickness (mm)	1.3	1.1	1.27	1.9	1.55	1.37
Embryonic chambers:						
Distance across both chambers (μ)	240	190	300	220	150	240
Maximum height (μ)	160	150	210	150	60	190
Surface diameter of umbonal plugs (μ)	320	270	300	350–600	600	300–350
Surface diameter of secondary pillars (μ)	50	50–80	50–100	100	100	50–100

Occurrence elsewhere.—At numerous Tertiary *c* and Tertiary *d* localities in the Malayan Archipelago.

Remarks.—Caudri (1934, p. 72) wrote:

> In the group of the true reticulate, in contrast to *Camerinae* from other groups, only a few species are well described. Moreover, the species are not always easy to recognize, so that they have been cancelled in part or identified with one another. Generally, at first sight, all reticulate *Camerinae* are determined as *C. Fichteli-intermedia.* In the literature an enormous geographic area is assigned to this species * * *

The reticulate *Camerina fichteli* represents the megalospheric generation, of which the microspheric generation is known as *C. intermedia.* Inasmuch as the specific name *C. fichteli* has priority, the name for both generations is *C. fichteli.* This species is accepted as diagnostic of Tertiary *c*+*d* in the Malayan Archipelago (Van der Vlerk, 1955, p. 75).

On Guam, specimens that have the characteristics by which *Camerina fichteli* is recognized elsewhere occur with an Eocene assemblage of species that are diagnostic of Tertiary *b*. Two questions therefore are raised: are the specimens from Guam the same as specimens identified as *C. fichteli* in the Malayan Archipelago? what is the stratigraphic range of this species?

The best illustrations of specimens assigned to *Camerina fichteli* from the Malayan Archipelago were given by Rutten (1915, pl. 2, figs. 3, 4), Van der Vlerk (1929, figs. 9, 30, 31), Doornink (1932, pl. 4, figs. 4–11; pl. 5, fig. 1; text fig. a, p. 285), Bursch (1947, pl. 1, figs. 4–6, 26; pl. 2, figs. 6, 7; pl. 5, fig. 5), and Cole (1953, pl. 1, fig. 13; pl. 2, fig. 7). The specimens illustrated by Van der Vlerk, Doornink, and Bursch are similar in that in median section the embryonic apparatus is moderate in size and the chambers are only slightly longer than they are high. The specimens illustrated by Rutten and Cole have larger embryonic chambers, and the chambers are longer than they are high. These specimens are similar to those from Java to which Doornink (1932, p. 299) gave the name *C. divina*.

Inasmuch as the specimens from Guam are so similar to the short-chambered type of reticulate *Camerina* usually assigned to *C. fichteli*, they are assigned to this species. It is probable, however, that the long-chambered type with the large embryonic apparatus also represents this species, as the length of the chambers and the size of the embryonic apparatus is variable. This variation is demonstrated by the illustrations (pl. 2, figs. 11–13) and by the median-section statistics given for specimens from Muara Djaing on the Tabalong River, southeast Borneo. These specimens were discussed first by Douvillé (1905, p. 442). He identified them as *Nummulites subbrogniarti* Verbeek, a species which he considered to be the same as *C. fichteli.* Later authors generally accepted *N. subbrogniarti* as a synonym of *C. fichteli,* but Doornink (1932, p. 269) argued for the separation of *C. subbrogniarti* from *C. fichteli.* Caudri (1934, p. 75) reviewed Doornink's conclusions but did not offer any final solution to the problem.

Measurements of five median sections of specimens from Muara Djaing, southeast Borneo, follow:

Specimen	Pl. 2, fig. 12	Pl. 1, fig. 13 [1]	Pl. 2, fig. 11	Pl. 2, fig. 13	Not illustrated
Height ... mm	2.65	3.3	3.85	2.15	3.9
Width ... mm	2.5	3.25	3.9	2.0	3.9
Embryonic chambers:					
Diameters of initial chamber ... μ	310×320	360×430	270×270	380×480	220×250
Diameters of second chamber ... μ	140×295	190×380	110×390	220×410	90×210
Distance acrosss both chambers ... μ	460	560	390	620	320
Number of volutions	4¾	6¾	7	3⅛	7⅛
Number of chambers:					
First volution	6	7	7	10	5
Final volution	About 18	21	About 22	About 20	About 17
All volutions	About 60	92	About 96	About 48	About 92

[1] See also Cole, 1953.

Measurements of three transverse sections of specimens from Muara Djaing, southeast Borneo, follow:

Specimen	Pl. 2, fig. 7	Pl. 2, fig. 9	Pl. 2, fig. 7 [1]
Height ... mm	2.27	4.0	3.85
Thickness ... mm	0.98	1.55	1.6
Embryonic chambers:			
Distance across both chambers ... μ	370	400	280
Maximum height ... μ	310	340	240
Surface diameter of umbonal plugs ... μ	----	370–450	----
Surface diameter of secondary pillars ... μ	50–100	50–70	50–100

[1] See also Cole, 1953.

Although reticulate *Camerina* have not been recorded to date from the Eocene of the Malayan Archipelago, they do occur in the Eocene of Europe (Boussac, 1911, p. 79). The associated Eocene species on Guam are thought to be reworked specimens. (See p. E4.)

Genus OPERCULINA [2] d'Orbigny, 1826

Operculina ammonoides (Gronovius)

Plate 5, figures 13–24, 26–30, 33–35

1781. *Nautilus ammonoides* Gronovius, Zooph. Gron., p. 282, pl. 19, figs. 5, 6.

1954. *Operculinella* sp. cf. *O. venosa* (Fichtel and Moll). Kleinpell, B. P. Bishop Mus. Bull. 211, p. 44, pl. 3, fig. 4.

1954. *Operculinella? oneataensis* Kleinpell, B. P. Bishop Mus. Bull. 211, p. 50, pl. 4, figs. 5–8.

1959. *Operculina ammonoides* (Gronovius). Cole, Am. Paleontology, Bull., v. 39, No 181, p. 356, pl. 28, figs. 1–9, 11, 15; pl. 29, figs. 3, 5–10, 12, 15; pl. 30, figs. 2–8; pl. 31, figs. 5–7 [additional references].

Although Cole (1959, p. 356) discussed this species in detail, the specimens used in the present study are again described here.

The test is involute lenticular to evolute compressed. The sutures are flush with the surface or raised and beaded. There is either a single umbonal mass flush with the surface, or a group of slightly elevated umbonal beads.

Measurements of seven thin sections of specimens from Guam and of five thin sections of specimens from Lau, Fiji, and Espiritu Santo are given.

[2] The author (Cole, 1960, p. 197) now considers *Operculina* d'Orbigny, 1826, is a synonym of *Camerina* Bruguière, 1792.

Measurements of sections of Operculina ammonoides (*Gronovius*)

Type of section	Median				Transverse			Median	Transverse	Median	Transverse	
Locality	Gj 9–2			Gj 9–1	Gj 9–2			L307, Lakemba, Lau, Fiji		Espiritu Santo, New Hebrides		
Specimen	Pl. 5, fig. 33	Pl. 5, fig. 34	Pl. 5, fig. 27	Pl. 5, fig. 26	Pl. 5, fig. 29	Not illustrated	Pl. 5, fig. 30	Pl. 5, fig. 35	Pl. 5, fig. 28	Pl. 5, fig. 23	Pl. 5, fig. 22	Pl. 5, fig. 21
Height ... mm	1.8	2.3	2.5	2.7	2.0	2.0	2.3	2.85	2.35	1.9	2.05	1.88
Width ... mm	1.67	1.95	2.3	2.1	----	----	----	2.7	.93	1.65	----	----
Thickness ... mm	----	----	----	----	.96	1.0	.96	----	----	----	.9	.81
Embryonic chambers:												
Diameters of initial chamber ... μ	50×60	----	----	----	----	----	----	70×90	----	80×90	----	----
Diameters of second chamber ... μ	40×80	----	----	----	----	----	----	30×100	----	50×110	----	----
Distance across both chambers ... μ	100	----	----	----	----	----	----	140	----	150	----	----
Numbers of whorls	3⁹⁄₁₀	4¼	4+	4+	----	----	----	4½	----	3¹⁄₁₀	----	----
Number of chambers in first volution	9	9	----	----	----	----	----	9	----	9	----	----
Number of chambers in final volution	24	25	26	24	----	----	----	25	----	19	----	----
Total number of chambers	69	67	----	----	----	----	----	88	----	46	----	----
Surface diameter of umbonal plugs ... μ	----	----	----	----	530	450	500	----	460	----	350	150

Occurrence elsewhere.—Recent to Tertiary *e*: Saipan; Palau Islands; Lau, Fiji.

Remarks.—In many samples from the modern seas in the Indo-Pacific region, operculinids occur together that have a considerable variation in the shape of the test. Specimens vary from small unornamented evenly lenticular tests to relatively large compressed evolute tests. Some workers have combined the operculinids into one species (Hofker, 1927, p. 61); others have divided them into many species (Cushman, 1921, p. 375–384). More recent workers have considered a modest number of species to be present (Chapman and Parr, 1938, p. 290–293; Cole, 1959, p. 354). It is easy to recognize how these divergent opinions could be held if one has a sample from the modern seas that contains an abundance of operculinids.

The taxonomic problem is complex not only because the specimens are variable and intergrade but also because of the interpretations which authors have given to generic and specific names. Cole (1959, p. 351) reviewed these problems and demonstrated that *Operculinella* and *Operculinoides* are synonyms of *Operculina*. Moreover, he found that two species, *Operculina ammonoides* and *Operculinella venosa*, which had been confused with each other, could be recognized as distinct species.

Specimens from the modern sea at Espiritu Santo (pl. 5, figs. 13–15, 19–21, 24), previously identified and discussed by Cole (1959, p. 350), are similar to those from the Bonya Limestone of Guam, except that the revolving wall, as viewed in transverse section, is thinner. The specimens from Guam are identical with those from Saipan previously referred to *Operculinella venosa* (Cole, 1957a, p. 331). Specimens from station L 307, Lakemba, Lau, Fiji, identified by Kleinpell (1954, p. 50) as *Operculinella? oneataensis*, are so similar to the specimens from Guam that they are referred to *Operculina ammonoides*.

Operculina bartschi Cushman[3]

Plate 3, figures 1–17; plate 4, figure 1

1921. *Operculina bartschi* Cushman, U.S. Natl. Mus. Bull. 100, p. 376, 377, text fig. 13.
1925. *Operculina bartschi* Cushman. Yabe and Hanzawa, Tōhoku Imp. Univ. Sci. Repts., ser. 2 (Geol.), v. 7, no. 2, p. 52, pl. 6, figs. 6–12; pl. 7, figs. 11, 12.
1925. *Operculina bartschi* Cushman var. *punctata* Yabe and Hanzawa, Tōhoku Imp. Univ. Sci. Repts., ser. 2 (Geol.), v. 7, no. 2, p. 52, 53, pl. 6, figs. 13–15; pl. 7, figs. 15–18.
1935. *Operculina bartschi* Cushman. Hanzawa, Tōhoku Imp. Univ. Sci. Repts., ser. 2 (Geol.), v. 18, no. 1, p. 22, 23, pl. 2.
1945. *Operculina bartschi* Cushman. Cole, B. P. Bishop Mus. Bull. 181, p. 277, 278, pl. 12, figs. H–K; pl. 14, fig. I.
1950. *Operculina bartschi* Cushman. Cole, U.S. Geol. Survey Prof. Paper 221–B, p. 22, 23, pl. 5, figs. 3–5.

The test is evolute and either flat and thin or with a small subcentral umbo surrounded by a flat rim. The sutures are raised, recurved, and normally beaded. There is a small subcentral zone of papillae over the embryonic chambers. A few specimens either have a few beads or thickly studded zones of beading between the sutures.

Measurements of median and transverse sections of specimens from Guam and measurements from four thin sections of specimens from Lau, Fiji, follow:

[3] The author (Cole, 1961a, p. 120) now considers *Operculina bartschi* Cushman is a synonym of *Camerina complanata* (Defrance).

Measurements of sections of Operculina bartschi *Cushman*

Type of section	Median	Transverse	Median		Transverse	Median	Transverse	Median		Transverse	Median			Transverse
Locality	Gj 9–1		Gj 9–2			Gj 9–4		Ov 6–2			L389, Lakemba, Lau, Fiji			
Specimen	Pl. 3, fig. 4	Pl. 3, fig. 15	Not illustrated	Pl. 3, fig. 2	Pl. 3, fig. 3	Pl. 3, fig. 13	Not illustrated	Pl. 3, fig. 5	Pl. 3, fig. 14	Pl. 3, fig. 16	Pl. 4, fig. 1	Not illustrated		Pl. 3, fig. 1
Height (mm)	2.65	2.1	2.1	2.65	2.55	3.0	2.75	2.5+	3.15	3.56	2.8	3.15	3.85	2.8
Width (mm)	2.1		1.8	2.15		2.5		2.2	2.8		2.8	2.3	3.65	
Thickness (mm)		.57			.6		.95			.85				.8
Embryonic chambers:														
Diameters of initial chamber (μ)			20×30	60×65		80×80		50×50	50×50		70×85	70×70	65×80	
Diameters of second chamber (μ)			20×50	50×70		40×90		30×50	40×90		50×110	50×80	40×50	
Distance across both chambers (μ)			50	120		130		90	105		140	130	110	
Number of whorls	4+		3¾	4		3¾		4	4⅒		3½		3¾	
Number of chambers in first volution			9	7		7		9	8		8		9	
Number of chambers in final volution	17		13	14		18		21	20		17	14	23	
Total number of chambers			39	50		48		58	56		44		54	
Surface diameter of axial plug (μ)		300			300		700							400

Occurrence elsewhere.—Recent to Tertiary *e*: Recent, Philippine Islands; Pleistocene, Ryukyu Islands; Tertiary *f*, Formosa, Palau Islands, Lau, Fiji; Tertiary *e*, Saipan.

Remarks.—The specimens from Guam are similar to specimens from the Tertiary *f* of Lau, Fiji. Four additional thin sections of specimens from station L 389, Lakemba, Lau, Fiji, were prepared for comparison, and two of these are illustrated on plate 3, figure 1, and plate 4, figure 1. Although the specimens from Lau, Fiji, have thicker chamber walls, they are otherwise identical with those from Guam. The degree of thickening of the walls is undoubtedly controlled by environmental conditions.

The external appearance of this species is distinctive. Internally, the wavy, crenulated chamber walls, which cause marked irregularity in the outlines of the chambers, are an additional feature that distinguishes this species from others. The irregular chamber walls are found in specimens from Guam, Lau, and the Ryukyu Islands (Yabe and Hanzawa, 1925, pl. 7, figs. 12, 13, 15).

Operculina eniwetokensis Cole

Plate 5, figures 11, 12, 25

1957. *Operculina eniwetokensis* Cole, U.S. Geol. Survey Prof. Paper 260–V, p. 756, pl. 232, figs. 15–23.

Measurements of two median sections and one transverse section are given as follows:

Type of section	Median		Transverse
Locality	Hi 6–1		
Specimen	Pl. 5, fig. 12	Pl. 5, fig. 25	Pl. 5, fig 11
Height mm	1.9	1.85	1.57
Width mm	1.6	1.61	
Thickness mm			.5
Embryonic chambers:			
Diameters of initial chamber μ	40×45		
Diameters of second chamber μ	30×50		
Distance across both chambers μ	80		70
Number of volutions	3		
Chambers in first whorl	8		
Chambers in final whorl	14	14	
Total number of chambers	38		
Surface diameter of umbonal plug μ			220

Occurrence elsewhere.—At a depth of 3,963–3,988 feet (core 10) in Eniwetok drill hole F–1 in Tertiary *b* (Eocene).

Remarks.—This small, fragile *Operculina* appears to be identical with the specimens from the Eniwetok drill hole F–1.

Operculina lucidisutura Cole

Plate 5, figure 10

1954. *Operculina lucidisutura* Cole, U.S. Geol. Survey Prof. Paper 260–O, p. 575, pl. 204, figs. 1–6.

Occurrence elsewhere.—In the drill holes on Bikini Atoll and Eniwetok Atoll in Tertiary *g*.

Remarks.—Small evolute specimens with comparatively few rapidly expanding chambers in the final volution were found in the operculinid zone of the Barrigada Limestone. One of these is illustrated for comparison with the types from the Bikini drill hole 2B.

Operculina rectilata Cole

Plate 4, figures 2–9

1954. *Operculinoides rectilata* Cole, U.S. Goel. Survey Prof. Paper 260–O, p. 575, pl. 204, figs. 11–15; pl. 205, figs. 15–17.

Occurrence elsewhere.—In drill holes on Bikini and Eniwetok Atolls in Tertiary *g*.

Remarks.—This species can be distinguished from the closely related *Operculina amplicuneata* by thicker walls and the fusion of the revolving walls into solid masses on either side of the embryonic apparatus. The side walls of the test, as seen in transverse sections, tend to be parallel.

Cole (1957b, p. 754) has stated that the apparent differences between *Operculina rectilata* and *Operculina amplicuneata* may be the result of environmental rather than evolutionary controls. However, he retained both names because of a stratigraphic differentiation.

Operculina subformai (Provale)

Plate 2, figures 1–4

1908. *Nummulites* (*Gumbelia*) *sub-Formai* Provale, Riv. Italiana paleontologia, v. 14, p. 64–66, pl. 4, figs. 16–20.

1957. *Operculinoides subformai* (Provale). Cole, U.S. Geol. Survey Prof. Paper 260–V, p. 755, pl. 232, figs. 1–6.

The test is small, and evenly lenticular, with radiating rows of slightly elevated pustules.

Measurements of two median and two transverse sections from locality J1 2–1 are given as follows:

Type of section	Median		Transverse	
Specimen	Pl. 2, fig. 3	Pl. 2, fig. 4	Pl. 2, fig. 1	Pl. 2, fig. 2
Height mm	1.25	1.65	1.35	1.9
Width mm	1.3	1.55		
Thickness mm			.77	.9
Embryonic chambers:				
Diameters of initial chamber μ	45×40	60×60		
Diameters of second chamber μ	10×50	25×70		
Distance across both chambers μ	70	100		
Number of volutions	4	3¾		
Chambers in first whorl	5	6		
Chambers in final whorl	13	17		
Total number of chambers	37	41		
Surface diameter of umbonal plugs μ			250	450

Occurrence elsewhere.—In Tertiary *b* (Eocene) of Borneo and in Eniwetok drill hole F–1 at a depth of 4,500–4,525 feet (core 14).

Operculina venosa (Fichtel and Moll)

Plate 3, figures 18–22; plate 4, figures 10–17

1798. *Nautilus venosus* Fichtel and Moll, Test. Micro. p. 59, pl. 8, figs. *e–h*.

1859. *Amphistegina cumingii* Carpenter, Philos. Trans., p. 32, pl. 5, figs. 13–17

1918. *Operculinella cumingii* (Carpenter). Yabe, Tōhoku Imp. Univ. Sci. Repts., ser. 2 (Geol.), v. 4, no. 3, p. 122–126, pl. 17, figs. 8–12.

1959. *Operculina venosa* (Fichtel and Moll). Cole, Am. Paleontology Bull., v. 39, no. 181, p. 361, pl. 28, figs. 12–14, 17, 18; pl. 29, figs. 1, 2, 11, 13, 14; pl. 30, figs. 1, 9, 10; pl. 31, fig. 1 [additional references].

The test is involute and evenly lenticular in young individuals, but in the gerontic stage, the initial lenticular part is partly surrounded by a broad, thin, flat rim, which is produced by a rapid expansion in height of the chambers. The sutures are flush with the surface of the test but show faintly on the rim. The specimen (pl. 3, fig. 21) that illustrates the external appearance has a height of 3.3 mm and a width of 2.8 mm. The central part has a diameter of 2.1 mm, and the rim has a maximum width of 1.2 mm.

Measurements of two median sections follow:

Locality	Gj 9–2	Gj 9–4
Specimen	Pl. 3, fig. 20	Pl. 3, fig. 22
Height mm	2.9	3.1
Width mm	2.3	3.05
Embryonic chambers:		
Diameters of initial chamber μ	45×50	40×40
Diameters of second chamber μ	40×60	30×50
Distance across both chambers μ	100	80
Number of whorls	4	4
Number of chambers in first volution	8	9
Number of chambers in final volution	10	14
Total number of chambers	35	43

Two transverse sections were prepared; one of a specimen in which the rim was just developing, and the other of a specimen in which the rim was well developed. The specimen (pl. 3, fig. 19) without a definite rim has a height of 2.8 mm and thickness of 1.1 mm. The specimen (pl. 3, fig. 18) with a well-developed rim has a height of 3.4 mm, of which 2.3 mm represents the inflated part and 1.1 mm, the rim. The thickness through the inflated part is 1.1 mm, and the thickness of the rim is 0.22 mm. This specimen has well-developed axial plugs, with surface diameters of about 500μ.

Occurrence elsewhere.—Recent, Philippine Islands; Tertiary *f*, Lau, Fiji.

Remarks.—Cole (1953, p. 33) expressed the opinion that *Operculinella* was not a valid genus, as he considered that the development of the broadly flaring, complanate rim found in the larger specimens of *O. cumingii* (=*O. venosa*) was a gerontic development. Later, he (Cole, 1959, p. 352) concluded that *Operculinella* was a synonym of *Operculina.*

The specimens (pl. 4, figs. 10–17) from the Alifan limestone of south Guam could be studied only by means of accidental sections. These specimens however, seemingly are the same as the others referred to this species.

Genus HETEROSTEGINA d'Orbigny, 1826

Heterostegina aequatoria Cole

Plate 5, figures 31, 32

1957. *Heterostegina aequatoria* Cole, U.S. Geol. Survey Prof. Paper 260–V, p. 756, 757, pl. 234, figs. 1–12.

The only available median section has 14 operculine chambers before the first heterostegine chamber is developed.

Occurence elsewhere.—At a depth of 3,655–3,665 feet (core 9) in Eniwetok drill hole F–1 in Tertiary *b* (Eocene).

Remarks.—*Heterostegina suborbicularis* d'Orbigny, which occurs also in samples from Tertiary *b* in the Eniwetok drill holes (Cole, 1957b, p. 762), has more operculine chambers than *H. aequatoria;* and the heterostegine chambers of *H. suborbicularis* have fewer chamberlets, even in the final volution.

Genus CYCLOCLYPEUS W. B. Carpenter, 1856

Subgenus CYCLOCLYPEUS W. B. Carpenter, 1856

Cycloclypeus (Cycloclypeus) carpenteri Brady

Plate 6, figures 5, 6; plate 8, figures 1, 2

1954. *Cycloclypeus* (*Cycloclypeus*) *carpenteri* H. B. Brady. Cole, U.S. Geol. Survey Prof. Paper 260–O, p. 581, pl. 205, figs. 9–14.

Occurence elsewhere.—Widespread in the Indo-Pacific region from Pliocene to Recent.

Remarks.—The embryonic apparatus (pl. 6, fig. 5) of a specimen dredged by the Bikini resurvey expedition during the summer of 1947 from the seaward slope off the north end of Bikini Atoll in water 580 to 800 feet deep is illustrated for comparison with that of a fossil specimen from Guam.

Cycloclypeus (Cycloclypeus) indopacificus Tan

Plate 7, figures 1–6, 8–10; plate 8, figure 3

1932. *Cycloclypeus indopacificus* var. *douvillei* Tan, Dienst Mijnb., Wetensch. Meded., no. 19, p. 68–74, pl. 15, fig. 8; pl. 20, figs. 3, 5, 6; pl. 21, figs. 2, 6.

1945. *Cycloclypeus* (*Cycloclypeus*) *indopacificus douvillei* Tan. Cole, B. P. Bishop Mus. Bull. 181, p. 280, 281, pl. 16, figs. A–E.

1945. *Cycloclypeus* (*Cycloclypeus*) *indopacificus terhaari* Tan. Cole, B. P. Bishop Mus. Bull. 181, p. 281, pl. 17, figs. A–K; pl. 19, figs. B, C.

The test normally has a small distinct umbo surrounded by a broad, thin flange, the surface of which may show low, broad discontinuous annular inflations. Distinct large papillae, which are nearly flush with the surface, are scattered irregularly over the umbo. The rim has regular concentric rings of small elevated papillae.

Measurements of four nearly complete specimens, three of which are illustrated, follow:

Locality	Gj 9-4			
Specimen	Pl. 7, fig. 6	Pl. 7, fig. 8	Pl. 7, fig. 5	Not illustrated
Diameter mm	9.2	12.0	6.0	13
Diameter of umbo mm	1.8	2.1	1.2	1.5
Character of umbo	Distinct	Distinct	Distinct	Indistinct

Measurements of three equatorial sections follow:

Locality	Gj 9-4		Gj 9-2
Specimen	Pl. 7, fig. 9	Pl. 7, fig. 4	Pl. 7, fig 1
Diameter mm	5.6+	7.5+	8.4+
Embryonic chambers:			
Diameters of initial chamber μ	180×190	180×200	170×190
Diameters of second chamber μ	180×320	150×330	90×290
Distance across both chambers μ	370	350	270
Number of nepionic chambers	5	5	5
Number of nepionic whorls	.9	.9	.8

Occurrence elsewhere.—In Tertiary *f* of Java and Lau, Fiji.

Remarks.—Although Tan (1932, p. 65) gave names to several variants of the elemental species *Cycloclypeus* (*Cycloclypeus*) *indopacificus*, it seems doubtful that they could be recognized, even if abundant well-preserved material were available for a statistical study of the type that Tan used in erecting his classification. Cole (1945, p. 279) gave a brief criticism of this classification, and the difficulties enumerated become more apparent when dealing with the fragmentary and poorly preserved material from Guam.

The specimens here assigned to the species *Cycloclypeus* (*Cycloclypeus*) *indopacificus*, however, are similar to those studied by Tan. This species, moreover, is normally associated with *Cycloclypeus* (*Katacycloclypeus*) *annulatus* in Java.

Three specimens (pl. 7, figs. 2, 3, 10) from locality L389, Lakemba, Lau, Fiji, originally identified (Cole, 1945, p. 281) as *Cycloclypeus* (*Cycloclypeus*) *indopacificus terhaari* Tan, are illustrated for comparison with the specimens from Guam. The embryonic and nepionic chambers are very similar to those of the specimens from Guam, except for the first nepionic chamber, which is larger in the specimens from Guam. Another specimen (Cole, 1945, pl. 17, fig. D) from this same locality at Lakemba has an initial nepionic chamber as large as those of the specimens from Guam.

Cycloclypeus (Cycloclypeus) posteidae Tan

Plate 6, figures 7–12

1932. *Cycloclypeus posteidae* Tan, Dienst Mijnb., Wetensch. Meded., no. 19, p. 59–62, pl. 13, fig. 3; pl. 14, figs. 1–6; pl. 15, figs. 1–3; pl. 18, figs. 2, 7; pl. 22, figs. 3, 4, 8.
1945. *Cycloclypeus* (*Cycloclypeus*) *eidae* Cole [not Tan], B. P. Bishop Mus. Bull. 181, p. 280, pl. 14, fig. B, [not figs. A, C, D, which are *C.* (*C.*) *indopacificus* Tan].
1945. *Cycloclypeus* (*Cycloclypeus*) *posteidae pentekaidekasepta* Tan. Cole, B. P. Bishop Mus. Bull. 181, p. 280, pl. 15, figs. A–E.

The test is small and thin. There is a distinct umbo covered by raised irregularly arranged papillae. The rim commonly has low annuli and pronounced papillae in concentric circles.

Measurements of seven equatorial sections follow:

Measurements of equatorial sections of Cycloclypeus (Cycloclypeus) posteidae *Tan*

Locality	Gj 9–1		Gj 9–2	Gj 9–4			Jj 9–3
Specimen	Not illustrated		Pl. 6, fig. 11	Not illustrated	Pl. 6, fig. 10	Pl. 6, fig. 7	Pl. 6, fig. 9
Diameter mm	3.5	3.0	4.1	2.3	2.75	2.75	2.7
Embryonic chambers:							
Diameters of initial chamber μ	65×50	60×60	60×50	50×45	45×50	60×60	70×75
Diameters of second chamber μ	45×100	50×140	40×120	40×100	40×70	40×115	45×140
Distance across both chambers μ	120	130	115	100	90	110	135
Number of nepionic chambers	12±	10±	10	12±	14	18	13
Number of coils of nepionic chambers	1½	1¼	1¼	1½	1½	1¾	1½

Occurrence elsewhere.—Borneo; Vanua Mbalavu, Lau, Fiji.

Remarks.—This species is similar to *Cycloclypeus* (*Cycloclypeus*) *eidae* but has fewer nepionic chambers. The specimens from Saipan (Cole, 1953, p. 27) that were referred to *C.* (*C.*) *eidae* have smaller, less pronounced papillae and more nepionic chambers than do the specimens from Vanua Mbalavu, Lau, Fiji, and from Guam, which are assigned to *C.* (*C.*) *posteidae* (pl. 6, fig. 12).

The variety which Tan named *Cycloclypeus* (*Cycloclypeus*) *posteidae hexaseptus* is sufficiently distinct to be a separate species.[4] The embryonic chambers of this species are relatively large, and it has about six

[4] In a later study, based on specimens from Yap, Cole (Cole, Todd, and Johnson, 1960, p. 97) decided that *Cycloclypeus hexaseptus* is a synonym of *C. indopacificus*.

nepionic chambers. Although the embryonic apparati of *C. hexaseptus* and *C. indopacificus* are similar, as both may have six nepionic chambers, these chambers make slightly more than one complete volution (pl. 8, fig. 7) around the embryonic chambers in *C. hexaseptus* and somewhat less than a complete volution in *C. indopacificus* (pl. 7, figs. 1–4, 9, 10).

Although Tan (1932, p. 61) gave names to two other variants of *Cycloclypeus* (*Cycloclypeus*) *posteidae*, on the basis of 15 nepionic chambers in one variant and 12 nepionic chambers in the other, these varietal names should be suppressed, as otherwise similar specimens from the same population may have from 10 to 18 nepionic chambers.

Cycloclypeus (*Cycloclypeus*) *eidae* is characteristic of Tertiary *e*, where it occurs with *Spiroclypeus* and *Lepidocyclina* (*Eulepidina*) and *C.* (*C.*) *posteidae* is found normally in Tertiary *f*, but there may be some overlap in their stratigraphic range (Cole, 1957a, p. 325).

Cycloclypeus (Cycloclypeus) postindopacificus Tan

Plate 7, figures 11, 12

1932. *Cycloclypeus postindopacificus* var. *postindopacifica* Tan, Dienst Mijnb., Wetensch. Meded., no. 19, p. 66, 67, pl. 15, fig. 7; pl. 18, fig. 3.

One equatorial section (pl. 7, fig. 11), has a diameter of about 1.0 mm. The initial chamber of the embryonic apparatus has a diameter of 160μ, and the distance across both embryonic chambers is 300μ. There are four nepionic chambers. Another equatorial section (pl. 7, fig. 12) has a diameter of 2.2 mm. The initial chamber has a diameter of 160μ and the distance across both chambers is 320μ. There are five nepionic chambers.

Occurrence elsewhere.—Madoera.

Remarks.—The embryonic apparatus of these specimens is similar to that of the specimen illustrated by Tan (1932, pl. 15, fig. 7).

Subgenus KATACYCLOCLYPEUS Tan, 1932

Cycloclypeus (Katacycloclypeus) annulatus Martin

Plate 6, figures 13, 14; plate 7, figure 7; plate 8, figures 4–6, 8–11; plate 9, figures 14, 17

1880. *Cycloclypeus annulatus* Martin, Die Tertiärschiten auf Java, p. 157, pl. 28, figs. 1, 1a–i.

1916. *Cycloclypeus annulatus* Martin. Douvillé, Geol. Reichs-Mus. Leiden Samml., ser. 1, v. 10, p. 30–32, pl. 6, figs. 2, 3 [not pl. 5, fig. 6; pl. 6, figs. 1, 4].

1945. *Cycloclypeus* (*Katacycloclypeus*) *annulatus* Martin. Cole, B. P. Bishop Mus. Bull. 181, p. 282, 283, pl. 19, fig. A; pl. 20, figs. G, H [references].

The test is large and thin and has a low central umbo surrounded by several annular inflations which are very pronounced in the central part but flattened as the periphery is approached. The umbo is covered with irregularly arranged papillae. Concentric rings of papillae occur on the remainder of the test. These papillae are more pronounced on the annular inflations than in the intervening troughs.

Measurements of four nearly complete specimens, two of which are illustrated, follow:

Locality	Gj 9–1		Gj 9–2	
Specimen	Not illustrated	Pl. 9, fig. 14	Pl. 7, fig. 7	Not illustrated
Diameter mm	15.0	21.+	16.0	17.0
Diameter of central umbo mm	2.0	2.0	2.5	1.5
Number of pronounced annular inflations	2	4	2	2

Measurement of seven equatorial sections follow:

Measurement of equatorial sections of Cycloclypeus (Katacycloclypeus) annulatus *Tan*

Locality	Gj 9–1		Gj 9–2		Gj 9–4		
Specimen	Pl. 8, fig. 10	Pl. 8, fig. 9	Not illustrated	Pl. 8, fig. 5	Pl. 8, fig. 11	Pl. 8, fig. 8	Pl. 8, fig. 4
Diameter mm	3. 3+	3. 35+	5. +	2. 5+	6. 1+	7. 5+	5. +
Embryonic chambers:							
Diameters of initial chamber μ		260×300	–×210	320×340		190×200	
Diameters of second chamber μ		190×450	–×400	230×530		120×500	
Distance across both chambers μ	440	470	340	560	430	310	430
Number of nepionic chambers	3	2	2	2	2	2	2
Number of nepionic whorls	0. 7	0. 7	0. 7	0. 5	0. 6	0. 7	0. 8

Occurrence elsewhere.—In Tertiary *f* of Java, Borneo, Madoera, and Lau, Fiji.

Remarks.—The fragility of the large specimens of this species cause difficulty in separating specimens from the matrix and obtaining material for thin sections. It was, moreover, easy to confuse the fragments which were obtained with other pieces representing the associated species *Cycloclypeus* (*Cycloclypeus*) *indopacificus*, as individuals of *C.* (*C.*) *indopacificus* often develop irregular annular inflations that are somewhat similar to those of *C.* (*Katacycloclypeus*) *annulatus* (Tan, 1932, p. 71).

Douvillé (1916) published excellent illustrations of the external appearance of *Cycloclypeus* (*Katacycloclypeus*) *annulatus* (Douvillé, 1916, pl. 6, figs. 2, 3) and other specimens (Douvillé, 1916, pl. 5, fig. 6; pl. 6, figs. 1, 4), which he identified as this species from the vicinity of Rembang, Java. Tan (1932, p. 68) assigned the latter specimens to *C. Cycloclypeus indopacificus*. In the terminology which he used, specimens with six nepionic septa are named *C. indopacificus douvillei*, and those with four nepionic septa are called *C. postindopacificus postdouvillei*.

The embryonic chambers of *Cycloclypeus* (*Katacycloclypeus*) *annulatus* are large, and there are two or three nepionic chambers, with two nepionic chambers occurring most commonly. Several specimens (pl. 9, fig. 17) have irregular embryonic chambers produced by the fusion of two gametes.

Part of an equatorial section (pl. 8, fig. 6) of a specimen from Vanua Mbalavu, Lau, Fiji, is illustrated for comparison with the specimens from Guam.

Cycloclypeus (Katacycloclypeus) martini Van der Vlerk

Plate 6, figures 1–4

1923. *Cycloclypeus martini* Van der Vlerk, Geol. Reichs-Mus. Leiden Samml., ser. 1, v. 10, p. 138–140, pls. 1, 2.
1945. *Cycloclypeus* (*Katacycloclypeus*) *martini* Van der Vlerk. Cole, B. P. Bishop Mus. Bull. 181, p. 283, pl. 20, figs. I, J.

The test is composed of a broad central boss surrounded by a single annulus. Papillae occur on the central boss and annulus.

The embryonic chambers are large. The initial chamber has diameters of 220μ by 280μ. The second chamber has diameters of 130μ by 450μ. The distance across both chambers is 370μ. These chambers are followed by one large operculine chamber with diameters of 170μ by 290μ. There are four noncontinuous rings of heterostegine chambers before the regular annular rings commence. The first heterostegine chamber is divided into three chamberlets.

Occurrence elsewhere.—In Tertiary *f* of Borneo, Java, Vanua Mbalavu, and Lau, Fiji.

Remarks.—The types (Van der Vlerk, 1923, pl. 2, fig. 3) and specimens from Lau, Fiji (Cole, 1945, pl. 20, fig. J), assigned to this species have only one nepionic chamber, but the specimens from Guam, which are otherwise similar, have four nepionic chambers.

Family ALVEOLINELLIDAE

Genus FLOSCULINELLA Schubert, 1910

Flosculinella bontangensis (L. Rutten)

Plate 9, figures 1–3

1913. *Alveolinella bontangensis* L. Rutten, Geol. Reichs-Mus. Leiden Samml., ser. 1, v. 9, p. 221–224, pl. 14.
1929. *Alveolinella bontangensis* L. Rutten. Van der Vlerk, Dienst Mijnb., Wetensch. Meded., no. 9, p. 14, 15, figs. 1–5.
1937. *Flosculinella bontangensis* (L. Rutten). Reichel, Soc. Paléont. Suisse Mém., v. 59, p. 113–115, pl. 11, fig. 7; text figs. 23, 24.

Occurrence elsewhere.—In Tertiary *f* of Borneo, Java, Philippines, and Soemba.

Remarks.—This species, of which few specimens were found, is represented only by accidental sections in thin sections made from hand specimens of limestone.

Family ROTALIIDAE

Genus ROTALIA Lamarck, 1804

Rotalia atjehensis Van der Vlerk

Plate 5, figures 1–4, 8, 9

1924. *Rotalia beccarii* (Linn.) var. *atjehensis* Van der Vlerk, Dienst Mijnb., Wetensch. Meded. no. 1, p. 25, 26, pl. 5, figs. 21–24.
1931. *Rotalia schroeteriana* Hanzawa [not Parker and Jones], Tōhoku Imp. Univ. Sci. Repts., ser. 2 (Geol.), v. 12, no. 2A, p. 157, pl. 26, figs. 6–8.
1939. *Rotalia schroeteriana* Cole [not Parker and Jones], Jour. Paleontology, v. 13, no. 2, p. 187, 188, pl. 24, figs. 10–12.

Occurrence elsewhere.—Tji Talahab, Java; N. Atjeh, Sumatra; Hitotô, Kwantō Mountainland, Japan.

Remarks.—This species, with numerous well-developed distinct umbical pillars, is definitely a *Rotalia*, whereas specimens commonly called *Rotalia beccarii* should be placed in the genus *Streblus*. *S. beccarii* and related species have the umbilicus either filled with a solid plug or a series of fused pillars (Cole, 1947, p. 243).

Genus STREBLUS Fischer, 1817

Streblus saipanensis Cole

Plate 5, figures 5–7

1953. *Streblus saipanensis* Cole, U.S. Geol. Survey Prof. Paper 253, p. 27, 28, pl. 5, figs. 8, 9.
1957. *Streblus saipanensis* Cole. Cole, U.S. Geol. Survey Prof. Paper 280–I, p. 338, pl. 103, figs. 17, 18.

Occurrence elsewhere.—Saipan.

Remarks.—Transverse sections of this species are illustrated for comparison with those of *Rotalia atjehensis*. *Streblus saipanensis* has a single umbonal pillar, whereas *R. atjehensis* has numerous umbonal pillars. *S. saipanensis* is restricted to Tertiary *e*, and *R. atjehensis* seems to be confined to Tertiary *f*.

Family MIOGYPSINIDAE Tan

Genus MIOGYPSINOIDES Yabe and Hanzawa, 1928

Miogypsinoides cupulaeformis (Zuffardi-Comerci)

Plate 9, figures 15, 16

1929. *Miogypsina cupulaeformis* Zuffardi-Comerci, Soc. geol. Italiana Boll., v. 47 (1928), p. 142, pl. 9, figs. 12, 13, 20.
1945. *Miogypsina neodispansa* Cole [not Jones and Chapman], B. P. Bishop Mus. Bull. 181, p. 297, pl. 14, figs. E–H.

1954. *Miogypsinoides cupulaeformis* (Zuffardi-Comerci). Cole, U.S. Geol. Survey Prof. Paper 260-O, p. 601, 604, pl. 221, fig. 1; pl. 222, figs. 4–11.

Occurrence elsewhere.—In Tertiary *f* of Borneo, Lau, Fiji, and drill holes on Bikini and Eniwetok Atolls.

Family ORBITOIDIDAE Schubert

Genus LEPIDOCYCLINA Gümbel, 1870

Subgenus NEPHROLEPIDINA [5] H. Douvillé, 1911

Lepidocyclina (Nephrolepidina) japonica Yabe

Plate 10, figures 1–9, 11, 13, 14, 18

1906. *Lepidocyclina japonica* Yabe, Geol. Soc. Tokyo Jour., v. 13, p. 317, 2 text figs.
1909. *Lepidocyclina tournoueri* var. *angulosa* Provale, Riv. Italiana paleontologia, v. 15, p. 90, 91, pl. 2, figs. 13–15.
1939. *Lepidocyclina angulosa* (Provale). Caudri, Geol.-Mijnb. genootsch. Nederland en Kolonien Verh., geol. ser., v. 12, p. 197–203, pl. 7, figs. 32–35 [references].
1939. *Lepidocyclina japonica* Yabe. Caudri, Geol.-Mijnb. genootsch. Nederland en Kolonien Verh., geol. ser., v. 12, p. 209–211, pl. 7, figs. 50–56 [references].
1945. *Lepidocyclina* (*Nephrolepidina*) *angulosa* Provale. Cole, B. P. Bishop Mus. Bull. 181, p. 287, 288, pl. 24, figs. A–G.
1945. *Lepidocyclina* (*Nephrolepidina*) *japonica* Yabe. Cole, B. P. Bishop Mus. Bull. 181, p. 288, pl. 24, figs. H, I.

Specimens with large papillae, formerly called *Lepidocyclina angulosa*, will be described first, and a description of specimens which resemble the types of *L. japonica* will follow.

The test is small, with a lenticular central part bordered by a narrow rim. There is an apical group of pronounced papillae. The remainder of the test is covered by a reticulate mesh which represents the outlines of the large lateral chambers.

Measurements of four equatorial sections follow:

Locality	Gj 7–2			Jj 9–3
Specimen	Pl. 10, fig. 14	Pl. 10, fig. 13	Pl. 10, fig. 9	Pl. 10, fig. 18
Diameter mm	2.0	3.1	2.9	3.85
Embryonic chambers:				
Diameters of initial chamber μ	160×190	150×170	160×150	150×180
Diameters of second chamber μ	70×280	110×290	90×280	120×310
Distance across both chambers μ	240	290	270	300
Thickness of outer wall μ	45	50	50	45
Equatorial chambers:				
Near center:				
Radial diameter μ	30	50	50	40
Tangential diameter μ	30	50	40	40
Near periphery:				
Radial diameter μ	60	60	80	60
Tangential diameter μ	40	40–50	50	45

The embryonic chambers are nephrolepidine and have a thick outer wall. There is an almost complete ring of periembryonic chambers (pl. 10, fig. 14) surrounding the embryonic chambers.

The equatorial chambers are short spatulate near the center of the test, but become elongate spatulate at the periphery. These chambers are arranged in undulations similar in pattern to those found in stellate lepidocyclines, but externally there is no suggestion of rays.

Measurements of four vertical sections follow:

Locality	Gj 7–2			Jj 9–3
Specimen	Pl. 10, fig. 7	Pl. 10, fig. 4	Pl. 10, fig. 5	Pl. 10, fig. 8
Diameter mm	3.7	2.55	2.55	3.6
Thickness mm	2.0	1.63	1.27	1.85
Embryonic chambers:				
Height μ	210	130	130	190
Length μ	325	180	220	420
Thickness of outer wall μ	40	20	30–40	40
Equatorial layer:				
Height at center μ	70	70	60	60
Height at periphery μ	115	150	120	110
Lateral chambers:				
Number	15	11	10	13
Length μ	250-290	110–130	150	120–220
Height μ	40–45	40–50	40	30–50
Thickness of floors and roofs μ	20	25	20	20
Surface diameter of pillars μ	350	370–450	170–250	100–520

The following description pertains to specimens which at first were referred to *Lepidocyclina japonica*.

The equatorial sections normally are identical with those from specimens with large papillae (*Lepidocyclina angulosa*). One equatorial section (pl. 10, fig. 11), however, has rather large, thin-walled embryonic chambers, and the second chamber does not surround the initial chamber. This section is described.

The initial chamber has internal diameters of 240μ by 390μ, and the second chamber has measurments of 200μ by 450μ. The distance across both chambers is 450μ. The thickness of the outer wall is 20μ. The equatorial chambers have the same size and shape, as they do in the other specimens.

Measurements of three vertical sections are given.

Locality	Gj 7–2		Jj 9–3
Specimen	Pl. 10, fig. 3	Pl. 10, fig. 4	Pl. 10, fig. 1
Diameter mm	1.9	2.25+	2.27+
Thickness mm	1.0	1.06	----------
Embryonic chambers:			
Height μ	160	100	----------
Length μ	200	165	370
Thickness of outer wall μ	30	25	35
Equatorial layer:			
Height at center μ	50	60	50
Height at periphery μ	70	90	100
Lateral chambers:			
Number	9	10	8
Length μ	120	50–150	110–170
Height μ	35–50	40	40–50
Thickness of floors and roofs μ	15–20	15–20	10
Surface diameter of pillars μ	100–150	----------	----------

Occurrence elsewhere.—In Tertiary *f* of Vanua Mbalavu, Lau, Fiji, as *Lepidocyclina* (*Nephrolepidina*) *angulosa* and *L.* (*N.*) *japonica*, with *Cycloclypeus* (*Katacycloclypeus*) *martini* (Cole, 1945, p. 274); Bogor zone, west Java, with *L.* (*N.*) *martini*, *Cycloclypeus* (*Katacycloclypeus*) *annulatus* and other species of *Lepidocyclina* (Van Bemmelen, 1949, p. 649); Koetei, East Borneo.

[5] The author (Cole, 1961b, p. 142) now considers *Nephrolepidina* H. Douvillé, 1911, is a synonym of *Eulepidina* H. Douvillé, 1911.

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Remarks.—Cole (1945, p. 288) suggested that *Lepidocyclina* (*Nephrolepidina*) *japonica* and *L.* (*N.*) *angulosa* intergrade. This conclusion is substantiated by the suite of specimens from Guam, inasmuch as the only difference that could be found between the specimens was the degree of development of the pillars. Although some specimens have large pillars and others are devoid of pillars, there are specimens with small or medium pillars. Therefore, these two species are combined.

Lepidocyclina (Nephrolepidina) cubiculirhomboidea Cole

Plate 9, figure 11

1954. *Lepidocyclina* (*Nephrolepidina*) *cubiculirhomboidea* Cole, U.S. Geol. Survey Prof. Paper 260–O, p. 587, 588, pl. 213, figs. 10–19.

Occurrence elsewhere.—In the drill holes on Bikini and Eniwetok Atolls in Tertiary *e* (Miocene).

Remarks.—A few specimens that occur in only one set of thin sections appear to be this species. Inasmuch as only vertical sections were found, it is impossible to make a complete diagnosis.

Lepidocyclina (Nephrolepidina) martini Schlumberger

Plate 10, figures 10, 12, 15–17; plate 11, figures 9–17

1900. *Lepidocyclina martini* Schlumberger, Geol. Reichs-Mus. Leiden Samml., ser. 1, v. 6, p. 131–133, pl. 6, figs. 5–8

1939. *Lepidocyclina martini* Schlumberger. Caudri, Geol.-Mijno. genootsch. Nederland en Kolonien Verh., geol. ser., v. 12, p. 212–218, figs. 57–60 [references].

1945. *Lepidocyclina* (*Nephrolepidina*) *martini* Schlumberger. Cole, B. P. Bishop Mus. Bull. 181, p. 288, 289, pl. 25, figs. A–M.

The test is small, radiate, and compressed lenticular. There are normally about six short rays developed at the margin of the test, but these rays do not extend inward to the apical areas. Small papillae are irregularly scattered over the surface.

Measurements of five equatorial sections are given as follows:

Measurements of equatorial sections of Lepidocyclina (Nephrolepidina) martini *Schlumberger*

Locality	Gj 7-2		Jj 9-3		62, Vanua Mbalavu, Lau, Fiji
Specimen	Pl. 10, fig. 15	Pl. 10, fig. 12	Pl. 11, fig. 14	Pl. 11, fig. 17	Pl. 11, fig. 11
Diameter (mm)	1.85+	2.35	2.2	2.4	------------
Embryonic chambers:					
Diameters of initial chamber (μ)	80×80	120×130	120×110	140×110	130×130
Diameters of second chamber (μ)	40×180	20×260	60×220	50×280	80×240
Distance across both chambers (μ)	140	160	200	200	240
Thickness of outer wall (μ)	40	40	50	60	50
Equatorial chambers:					
In rays:					
Tangential diameter (μ)	20	30	30	30	35
Radial diameter (μ)	50	50	70	70	80
In inter-ray areas:					
Tangential diameter (μ)	40	40	50	40	40
Radial diameter (μ)	50	40	60	70	60

The initial chamber is small and nearly square. It is either completely surrounded by the second chamber, except along the common boundary between the chambers, or partly embraced by the second chamber.

The radiate character of the test is shown by the arrangement of the equatorial chambers. The chambers that form the rays are normally tangentially shortened.

Measurements of four vertical sections follow.

Measurements of vertical sections of Lepedocyclina (Nephrolepidina) martini *Schlumberger*

Locality	Gj 7-2	Jj 9-3	Fi 5-1	62, Vanua Mbalavu Lau, Fiji
Specimen	Pl. 10, fig. 17	Pl. 11, fig. 10	Pl. 11, fig. 15	Pl. 11, fig. 13
Diameter mm	2. 4	2. 4+	2. 0	1. 85+
Thickness mm	1. 1	1. 2	. 85	. 85
Equatorial chambers:				
Height μ	80	110	80	120
Length μ	150	200	190	210
Thickness of outer wall μ	30	50	40	45
Equatorial layer:				
Height at center μ	60	30	40	40
Height at periphery μ	110	60	60	60
Lateral chambers:				
Number	8	9	6	5
Length μ	130–200	90–150	170–200	150–170
Height μ	40–50	30–40	30–40	40–50
Thickness of floors and roofs μ	15	30	20	20
Surface diameter of pillars μ	100	120–170	70	100

Occurrence elsewhere.—In Tertiary *f* of Madoera, Rembang, Java, and Vanua Mbalavu, Lau, Fiji.

Remarks.—An equatorial section (pl. 11, fig. 11) and a vertical section (pl. 11, fig. 13) of specimens previously identified as *Lepidocyclina* (*Nephrolepidina*) *martini* from Vanua Mbalavu, Lau, Fiji, are illustrated for comparison with the specimens from Guam. In addition, several specimens (pl. 10, fig. 10; pl. 11, figs. 9, 12, 16) found in thin sections made from hand specimens of limestone are illustrated for comparison with matrix-free specimens. One of these specimens (pl. 10, fig. 16) is believed to represent a part of a microspheric specimen.

Certain specimens (pl. 11, fig. 16) found in the above thin sections resemble specimens from Lau, Fiji (Cole, 1945, pl. 23, fig. H), which were identified as *Lepidocyclina* (*Nephrolepidina*) *taiwanensis* by Yabe and Hanzawa (1930, p. 30). The types of *L.* (*N.*) *taiwanensis* are based on accidental sections and apparently represent two species, one associated with a typical Tertiary *e* fauna of the *Miogypsinoides dehaartii* zone, and the other with a Tertiary *f* fauna.

Specimens from Taikankō, Mizuho-ku in the Kwarenkō District, Formosa, represented by such illustrations as figure 7, plate 5 of Yabe and Hanzawa (1930), are identical with specimens from Lau, Fiji (Cole, 1945, pl. 22, fig. G). The identification of certain specimens from Lau, Fiji, with *Lepidocyclina* (*Nephrolepidina*) *taiwanensis* was based on these similarities.

The resemblance of certain specimens from Guam to those previously studied from Lau, Fiji, and to specimens that were identified as *Lepidocyclina* (*Nephrolepidina*) *martini*, however, led to a critical study of all the illustrations available. Eventually, these conclusions should be rechecked by study and comparison of the actual specimens.

Certain of the Formosan specimens assigned to *Lepidocyclina* (*Nephrolepidina*) *taiwanensis*, and those from Lau, Fiji, that are referred to this same species, have elongate spatulate equatorial chambers and relatively small thick-walled embryonic chambers. The lateral chambers are arranged in regular tiers, and they are open, with rectangular cavities. Although one cannot be absolutely certain from the available illustrations, the arrangement of the equatorial chambers suggests that the test is radiate.

As all these characteristics are those of *Lepidocyclina (Nephrolepidina) martini*, it is suggested that the specimens from Taikankō, Formosa, and those from Lau, Fiji, are *L. (N.) martini*, not *L. (N.) taiwanensis*.

The other specimens from Formosa assigned to *Lepidocyclina (Nephrolepidina) taiwanensis*, which are associated with *Miogypsinoides dehaartii*, are apparently *L. (N.) sumatrensis*, of the kind formerly called *L. (N.) parva* (Cole, 1957b, p. 774). The species from Formosa called *L. (N.) taiwanensis* is therefore in part synonymous with *L. (N.) martini*, and in part with *L. (N.) sumatrensis*.

Lepidocyclina (Nephrolepidina) rutteni Van der Vlerk

Plate 11, figures 1–8

1924. *Lepidocyclina rutteni* Van der Vlerk, Dienst Mijnb., Wetensch. Meded., no. 1, p. 17–21, pl. 3, figs. 1–4.
1939. *Lepidocyclina rutteni* Van der Vlerk. Caudri, Geol.-mijnb. genootsch. v. Nederland en Kolonien Verh., geol. ser., v. 12, p. 218–221, pl. 8, figs. 61–65 [references].
1945. *Lepidocyclina (Nephrolepidina) rutteni* Van der Vlerk. Cole, B. P. Bishop Mus. Bull. 181, p. 289, 290, pl. 27, figs. A–G.

This species is characterized by having spatulate to hexagonal equatorial chambers and thin-walled open overlapping lateral chambers, the floors and roofs of which are slightly arched.

Occurrence elsewhere.—Tertiary *f* of Java; Borneo; Lau, Fiji.

Remarks.—Although this species was observed only in thin sections made from hand specimens of limestone, it is so distinctive that there is no question regarding its identification. Through the courtesy of I. M. Van der Vlerk, the writer received specimens of this species, one of which is illustrated (pl. 11, fig. 2). The lateral chambers of this specimen from Tjepoe, Java, are identical with those of the specimens from Guam.

Several of the specimens from Guam have a trigonal shape but otherwise are similar to normal specimens, especially the specimen illustrated on plate 11, figure 1.

The larger trigonal specimen (pl. 11, fig. 4) resembles Formosan specimens named *Lepidocyclina (Nephrolepidina) sumatrensis*, forma *mirabilis* by Yabe and Hanzawa (1930, p. 31). Specimens from both Guam and Formosa appear to have short-spatulate to hexagonal equatorial chambers of the kind that characterize *L. (N.) rutteni*, whereas the equatorial chambers of *L. (N.) sumatrensis* are normally rhombic.

Lepidocyclina (Nephrolepidina) sumatrensis (Brady)

Plate 9, figure 4–10, 19

1957. *Lepidocyclina (Nephrolepidina) sumatrensis* (Brady). Cole, U.S. Geol. Survey Prof. Paper 260–V, p. 773–775, pl. 239, figs. 1–4; pl. 241, figs. 1–30; pl. 242, figs. 3–20.

This species has rhombic equatorial chambers and, in vertical section, the lateral chambers are arranged in rather regular tiers. The floors and roofs of these chambers are gently arched. The type of the species has pillars, but other specimens, to which the subspecific name *inornata* has been given, are without pillars.

Remarks.—Specimens with pillars (pl. 9, figs. 5, 8) occur most frequently in Tertiary *e*, whereas those without pillars (pl. 9, fig. 6) occur most commonly in Tertiary *f* on Guam. However, as there is intergradation, and as the writer does not consider the presence or absence of pillars to have any special taxonomic significance, all these kinds are assumed to represent one species.

Certain specimens (pl. 9, figs. 7, 9, 10) have very thin roofs and floors in either part of or all the lateral chambers. The specimens in which only a few of the lateral chambers are very open with thin roofs and floors have the remaining lateral chambers of the same kind as in typical specimens of *Lepidocyclina sumatrensis*. Insofar as could be observed, this condition was produced by the organism and is not the result of fossilization. These specimens, therefore, may be pathologically modified.

Family DISCOCYCLINIDAE Vaughan and Cole

Genus ASTEROCYCLINA Gümbel, 1870

Asterocyclina praecipua Cole

Plate 9, figures 12, 13, 18

1957. *Asterocyclina praecipua* Cole, U.S. Geol. Survey Prof. Paper 260–V, p. 780, pl. 245, figs. 11, 12, 16, 18–20.

This is a small species characterized by well-developed, elevated papillae. The embryonic chambers are small. The vertical sections have large pillars, the lateral chambers are low, and the floors and roofs are thick.

Occurrence elsewhere.—At a depth of 4,316–4,341 feet (core 12) in drill hole F–1 on Eniwetok Atoll in Tertiary *b* (Eocene).

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INDEX

[Italic numbers indicate descriptions]

PLATES 1–11

PLATE 1

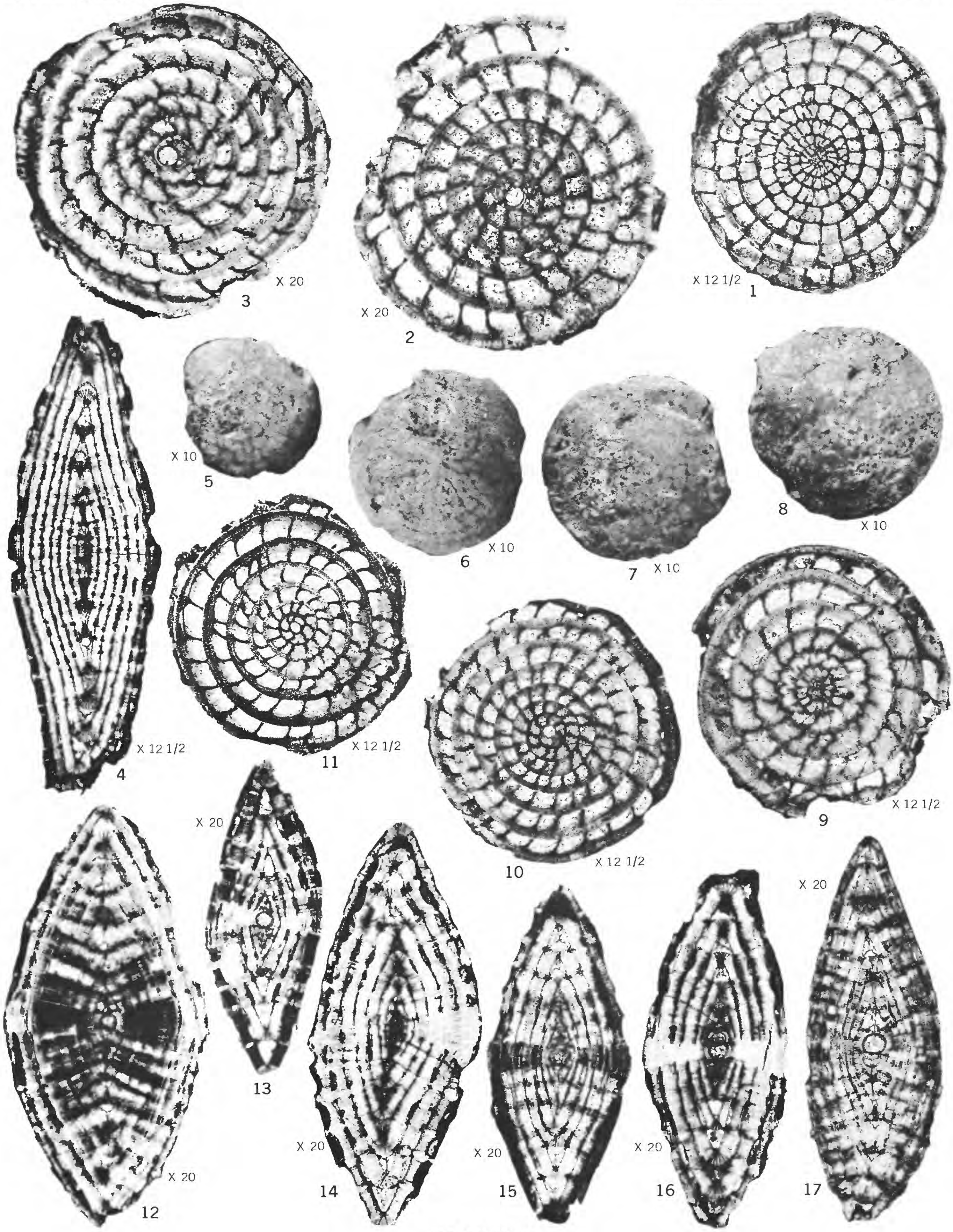
FIGURES 1–17. *Camerina fichteli* (Michelotti) (p. E13).

1–3, 9–11. Median sections; 1, 9–11, ×12.5; 2, 3, ×20. 1–3, 9, 10, locality Fk 3–1. USNM 625491–625495. 11, locality Ej 1–1. USNM 625496.

4. Transverse section ×12.5 of a microspheric specimen; locality Fk 3–1. USNM 625497.

5–8. External views, ×10, illustrating the shape of the test and the reticulate character of the sutures; locality Fk 3–1. USNM 625498–625501.

12–17. Transverse sections, ×20. 12–14, 16, 17, locality Fk 3–1. USNM 625502–625506. 15, locality Ej 1–1. USNM 625507.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X 20
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CAMERINA

PLATE 2

FIGURES 1–4. *Operculina subformai* (Provale) (p. E16).

1, 2. Transverse sections, ×20; locality J1 2–1. USNM 625508–625509.

3, 4. Median sections, ×20; locality J1 2–1. USNM 625510–625511.

5, 6, 8, 10, 14, 16, 18. *Camerina djokdjokarta* (Martin) (p. E12).

5, 6. Transverse sections, ×20; locality Fn 2–1. USNM 625512–625513.

8. Transverse section, ×20; locality Hi 6–1. USNM 625514.

10. Median section, ×20; locality Hi 6–1. USNM 625515.

14. Median section, ×20; locality Fn 2–1. USNM 625516.

16. Transverse section, ×12.5, of microspheric specimen; locality Fn 2–1. USNM 625517.

18. Part of a median section, ×12.5 of a microspheric specimen; locality Fn 2–1. USNM 625518.

7, 9, 11–13, 15, 17. *Camerina fichteli* (Michelotti) (p. E13).

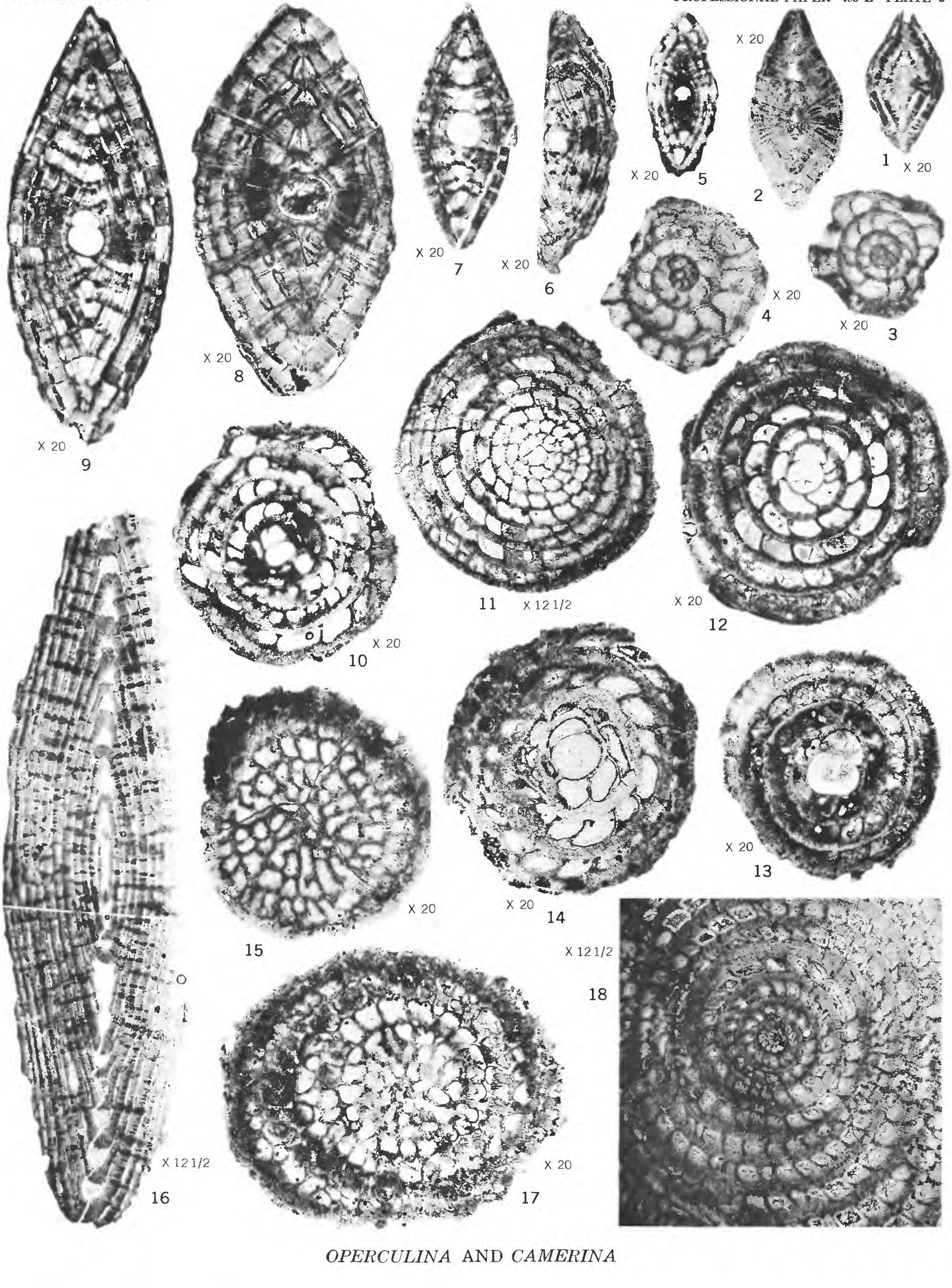
7, 9. Transverse sections, ×20, introduced for comparison; locality Muara Djaing on the Tabalong River, southeastern Borneo; specimens presented to the writer by the late T. Wayland Vaughan. USNM 625519–625520.

11–13. Median sections, 11, ×12.5, 12, 13, ×20; same locality as figures 7, 9. USNM 625521–625523.

15, 17. Sections, ×20, parallel to and above the median plane to illustrate the reticulate character of the sutures.

15. Locality Fk 3–1. USNM 625524.

17. Same locality as figures 7, 9. USNM 625525.



OPERCULINA AND *CAMERINA*

PLATE 3

FIGURES 1–17. *Operculina bartschi* Cushman (p. E15).

1. Transverse section, ×20, of a specimen introduced for comparison; locality L389, Lakemba, Lau, Fiji. USNM 625526.
2. Median section, ×20; locality Gj 9–2. USNM 625527.
3. Transverse section, ×20; locality Gj 9–2. USNM 625528.
4. Median section, ×20; locality Gj 9–1. USNM 625529.
5. Median section, ×20; locality Ov 6–2. USNM 625530.

6–12, 17. All external views, ×10.

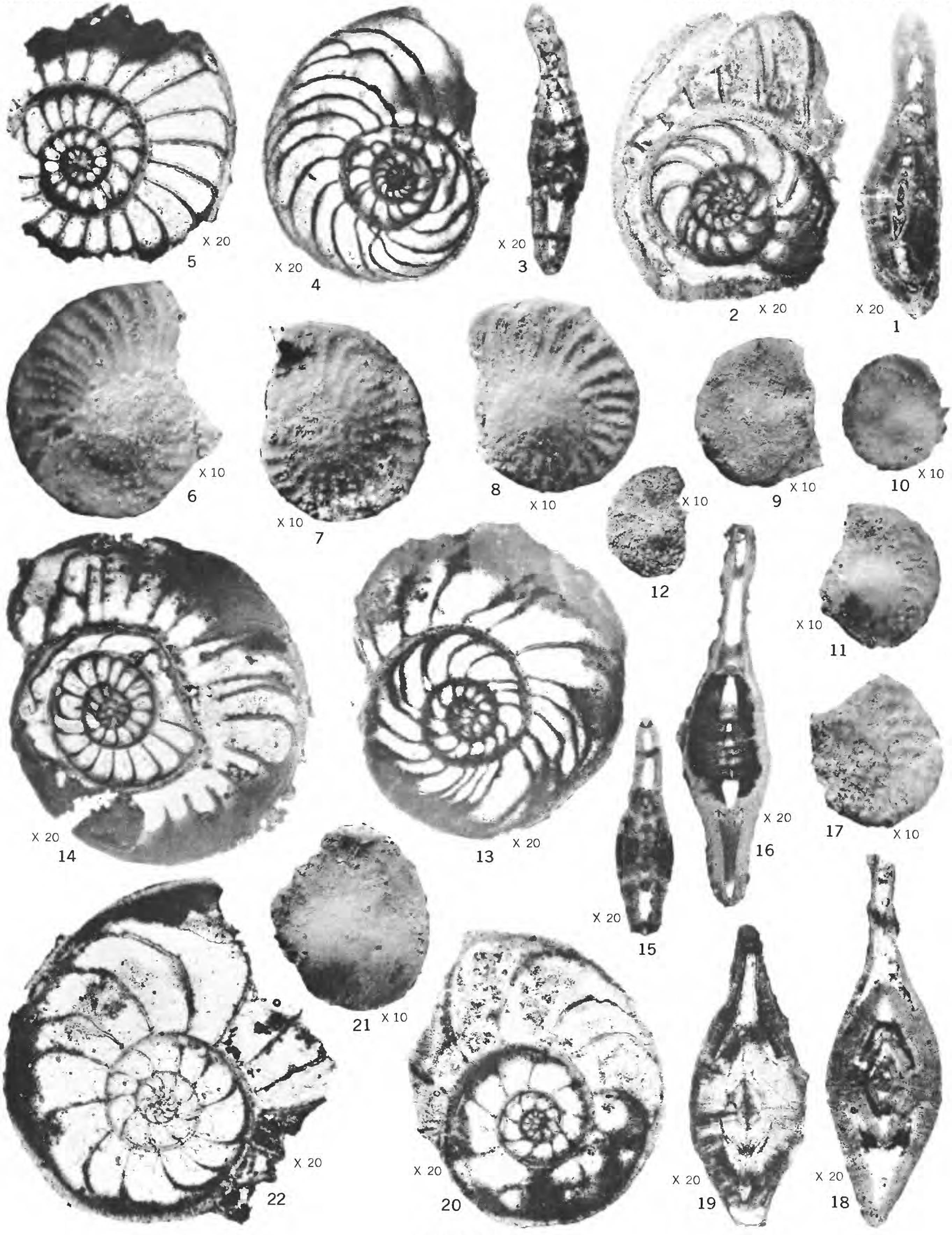
6–8. Large, ornate specimens; locality Ov 6–2. USNM 625530–625533.

9–12, 17. Small specimens; locality Gj 9–2. USNM 625534–625538.

13. Median section, ×20; locality Gj 9–4. USNM 625539.
14. Median section, ×20; locality Ov 6–2. USNM 625540.
15. Transverse section, ×20; locality Gj 9–1. USNM 625541.
16. Transverse section, ×20, not centered; locality Ov 6–2; USNM 625542.

18–22. *Operculina venosa* (Fichtel and Moll) (p. E16).

18. Transverse section, ×20, of a specimen with a wide, thin flange; locality Gj 9–1. USNM 625543.
19. Transverse section, ×20, of a specimen without a pronounced flange; locality Gj 9–2. USNM 625544.
20. Median section, ×20; locality Gj 9–2. USNM 625545.
21. External view, ×10, of a specimen with a wide, thin flange; locality Gj 9–2. USNM 625546.
22. Median section, ×20; locality Gj 9–4. USNM 625547.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18

OPERCULINA

PLATE 4

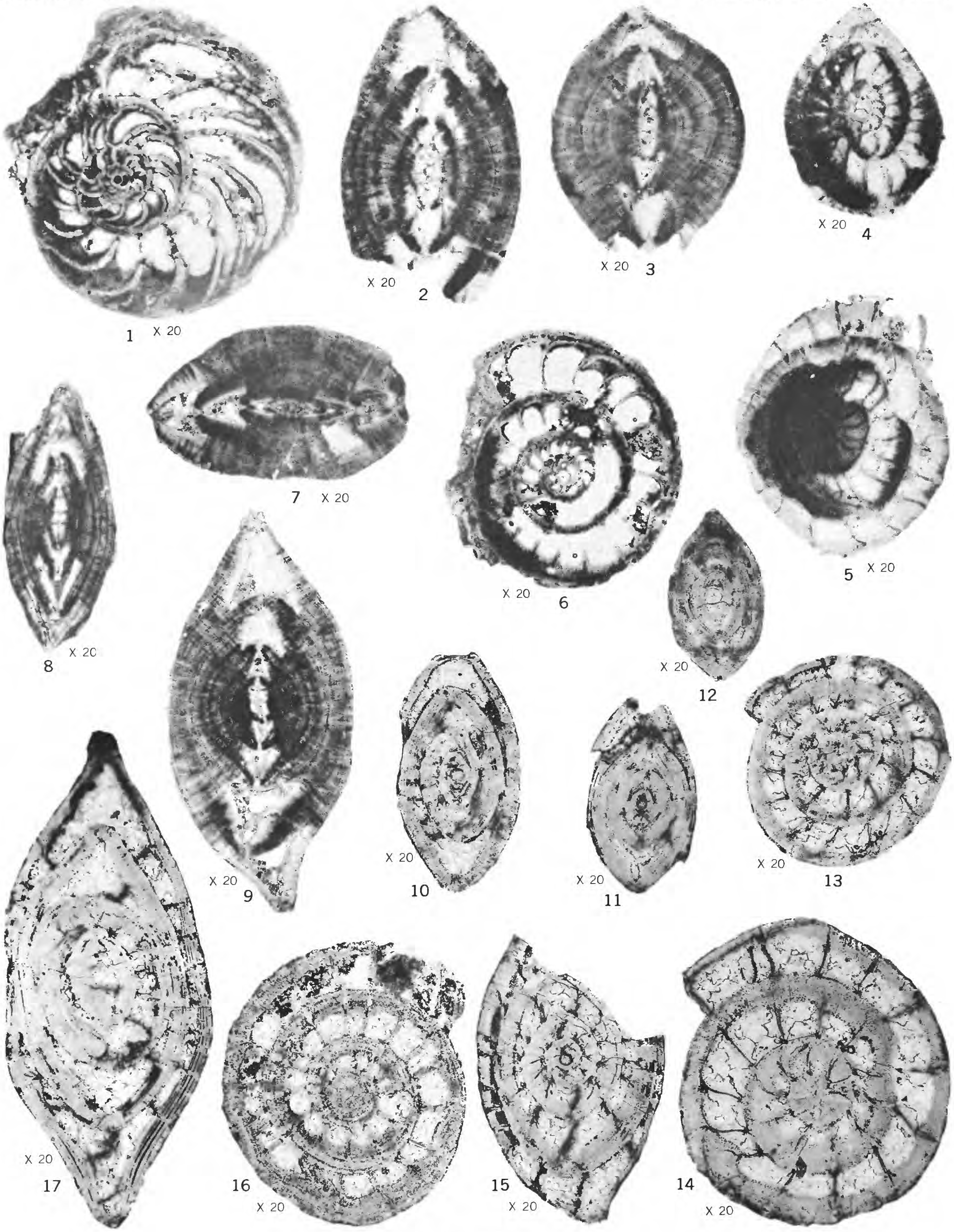
FIGURE 1. *Operculina bartschi* Cushman (p. E15).
Median section, ×20, introduced for comparison; locality L389, Lakemba, Lau, Fiji. USNM 625548.

2–9. *Operculina rectilata* Cole (p. E16).

2. Transverse section, ×20, slightly oblique; locality Sv 1–4. USNM 625549.
3. Transverse section, ×20, of an inflated specimen; locality Sv 1–4. USNM 625550.
4. Median section, ×20, strongly oblique, illustrating the embryonic chambers; locality Sv 1–4. USNM 625551.
5. Median section, ×20, slightly oblique, illustrating the shape of the chambers; locality Sv 1–4. USNM 625552.
6. Median section, ×20, centered; locality Ts 5–10. USNM 625553.
7. Transverse section, ×20; locality Sv 1–4. USNM 625554.
8. Transverse section, ×20, nearly centered; locality Ts 5–10. USNM 625555.
9. Transverse section, ×20, of a probable microspheric specimen; locality Ot 1–2. USNM 625556.

10–17. *Operculina venosa* (Fichtel and Moll) (p. E16).

10, 11. Transverse sections, ×20, of a megalospheric specimen; locality Ig 8–1. USNM 625557–625558.
12. Transverse section, ×20, of a megalospheric specimen; locality Ig 9–7. USNM 625559.
13, 14. Median sections, ×20, not centered; locality Ig 8–1. USNM 625560–625561.
15. Median section, ×20, strongly oblique, illustrating the embryonic chambers; locality Ig 8–1. USNM 625562.
16. Median section, ×20, not centered; locality Ig 9–7. USNM 625563.
17. Transverse section, ×20, not centered, of a probable microspheric specimen; locality Ig 8–1. USNM 625564.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15 X 20
14 X 20

OPERCULINA

PLATE 5

FIGURES 1–4, 8, 9. *Rotalia atjehensis* Van der Vlerk (p. E20).
1–3, 9. All are median sections, ×20
1. Locality Ts 16–10. USNM 625565.
2. Locality Gj 9–2. USNM 625566.
3. Locality Ih 5–3. USNM 625567.
9. Locality Ts 9–1. USNM 625568.
4, 8. Both are transverse sections, ×20
4. Locality Ih 5–3. USNM 625569.
8. Locality Gj 9–2. USNM 625570.

5–7. *Streblus saipanensis* Cole (p. E20).
5, 6. Transverse sections, ×40; locality Ii 6–35. USNM 625571–625572.
7. Transverse section, ×20; locality Ii 6–35. USNM 625573.

10. *Operculina lucidisutura* Cole (p. E16).
Slightly oblique median section, ×20; locality Ot 1–2. USNM 625574.

11, 12, 25. *Operculina eniwetokensis* Cole (p. E16).
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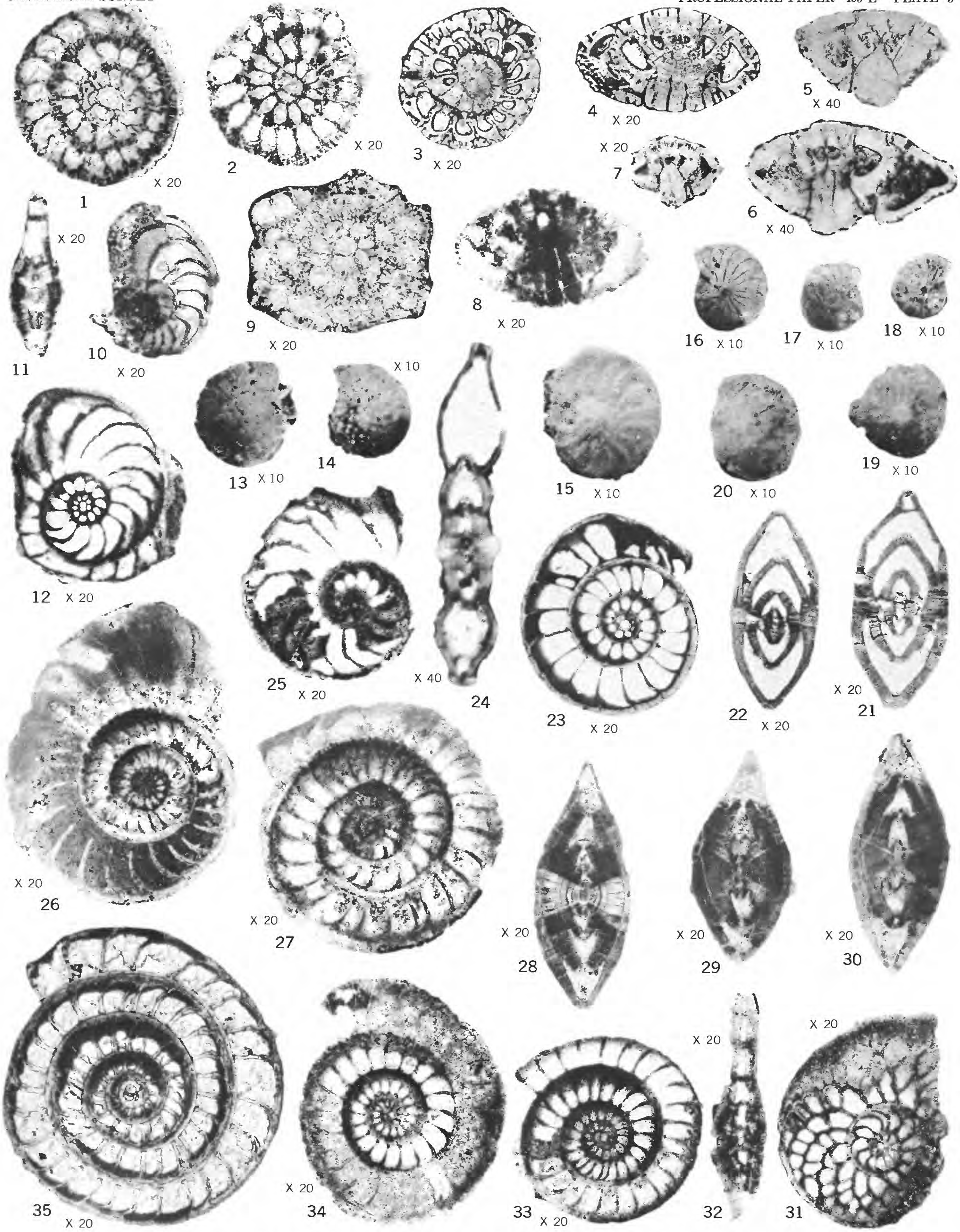
12, 25. Median sections, ×20; locality Hi 6–1. USNM 625576–625577.

13–24, 26–30, 33–35. *Operculinoides ammonoides* (Gronovius) (p. E14). 13–20. All are external views, ×10.
13–15, 19, 20. Locality Gj 9–2. USNM 625578–625581; 625596.
16–18. Specimens from the modern sea, introduced for comparison; gift of Mrs. E. R. Applin; locality Espiritu Santo, New Hebrides. USNM 625582–625584.
21, 22, 24, 28–30. All are transverse sections, ×20, except 24, ×40.
21, 22. Specimens from the modern sea, introduced for comparison; same locality as figures 16–18. USNM 625585–625586.
24. Transverse section of a specimen with a depressed revolving suture from the modern sea, introduced for comparison; same locality as figs. 16–18. USNM 625597.
28. Specimen from Lau, Fiji, introduced for comparison; locality L307, Lakemba, Lau, Fiji. USNM 625587.
29, 30. Locality Gj 9–2. USNM 625588–625589.
23, 26, 27, 33–35. All are median sections, ×20.
23. Specimen from the modern sea introduced for comparison; same locality as figures 16–18. USNM 625590.
26. Locality Gj 9–1. USNM 625591.
27, 33, 34. Locality Gj 9–2. USNM 625592–625594.
35. Specimen from Lau, Fiji, introduced for comparison; same locality as figure 28; USNM 625595.

31, 32. *Heterostegina aequatoria* Cole (p. E17).
31. Transverse section, ×20; locality Hi 6–1. USNM 625598.
32. Median section, ×20; locality Hi 6–1. USNM 625599.



HETEROSTEGINA, OPERCULINA, ROTALIA AND *STREBLUS*

PLATE 6

FIGURES 1–4. *Cycloclypeus* (*Katacycloclypeus*) *martini* Van der Vlerk (p. E20).

1. Part of an equatorial section, ×40; locality Gj 7–2. USNM 625600.
2. Part of an equatorial section, ×20; locality Jj 9–3. USNM 625601.
3. Part of a slightly oblique transverse section, ×12.5; locality Ts 2–1a. USNM 625602.
4. External view, ×10; locality Jj 9–3. USNM 625603.

5, 6. *Cycloclypeus* (*Cycloclypeus*) *carpenteri* H.B. Brady (p. E17).

5. Part of an equatorial section, ×40, showing the embryonic and three nepionic chambers, the first one of which is large and not subdivided into chamberlets; locality Bikini Atoll from water 580 to 800 feet deep. USNM 625604.
6. Part of a slightly oblique equatorial section, ×40, showing the same characteristics as does figure 5; locality Ig 9–8. USNM 625605.

7–12. *Cycloclypeus* (*Cycloclypeus*) *posteidae* Tan (p. E18).

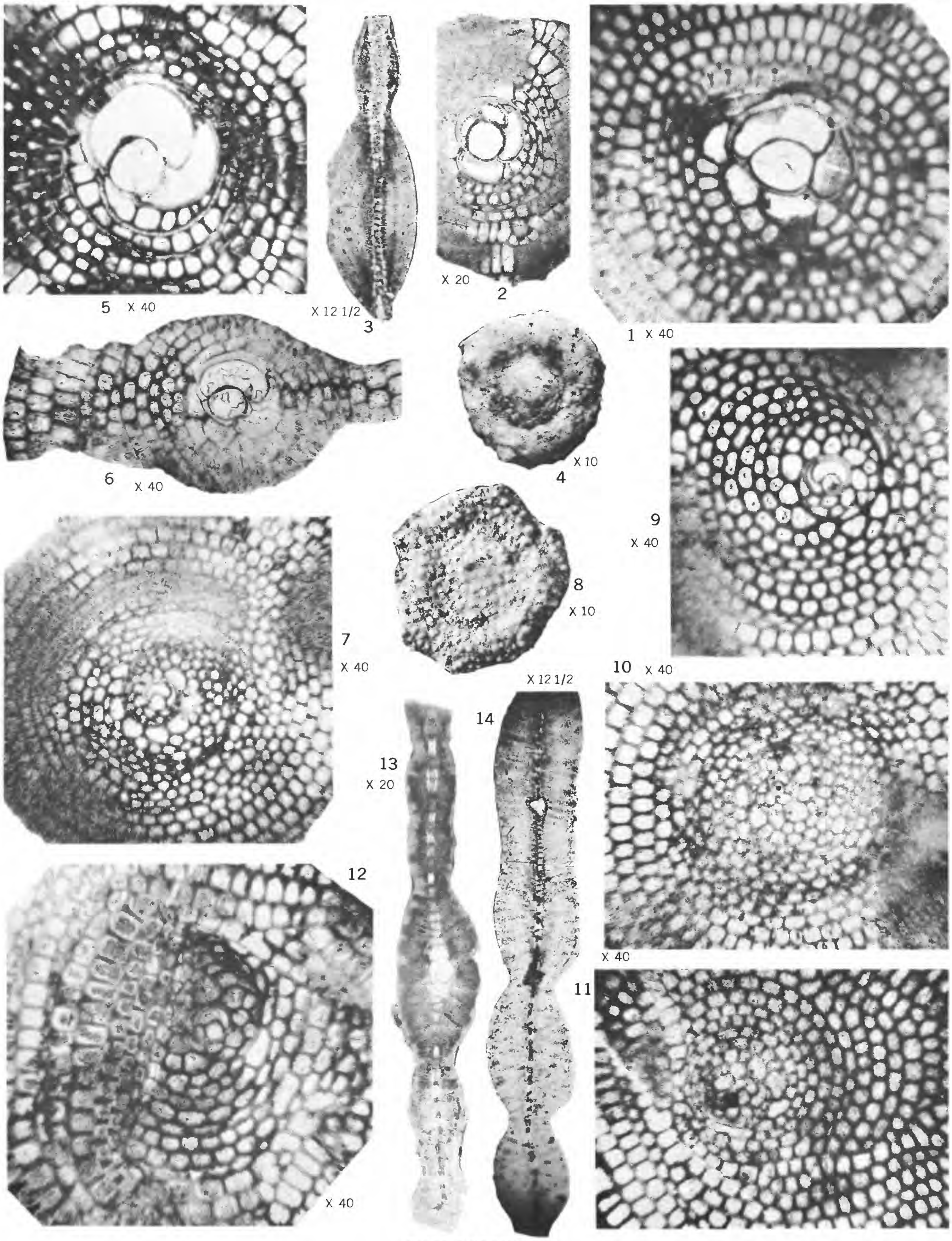
7, 9–12. Parts of equatorial sections, ×40.

7. Locality Gj 9–4. USNM 625606.
9. Locality Jj 9–3. USNM 625607.
10. Locality Gj 9–4. USNM 625608.
11. Locality Gj 9–2. USNM 625609.
12. Introduced for comparison; locality 62, Vanua Mbalavu, Lau, Fiji. USNM 625610.

8. External view, ×10; locality Gj 9–4. USNM 625611.

13, 14. *Cycloclypeus* (*Katacycloclypeus*) *annulatus* Martin (p. E19).

13. Part of a transverse section, ×20, of a megalospheric specimen; locality Gj 9–4. USNM 625612.
14. Part of a transverse section, ×12.5, of a microspheric individual; locality Ih 5–7. USNM 625613.



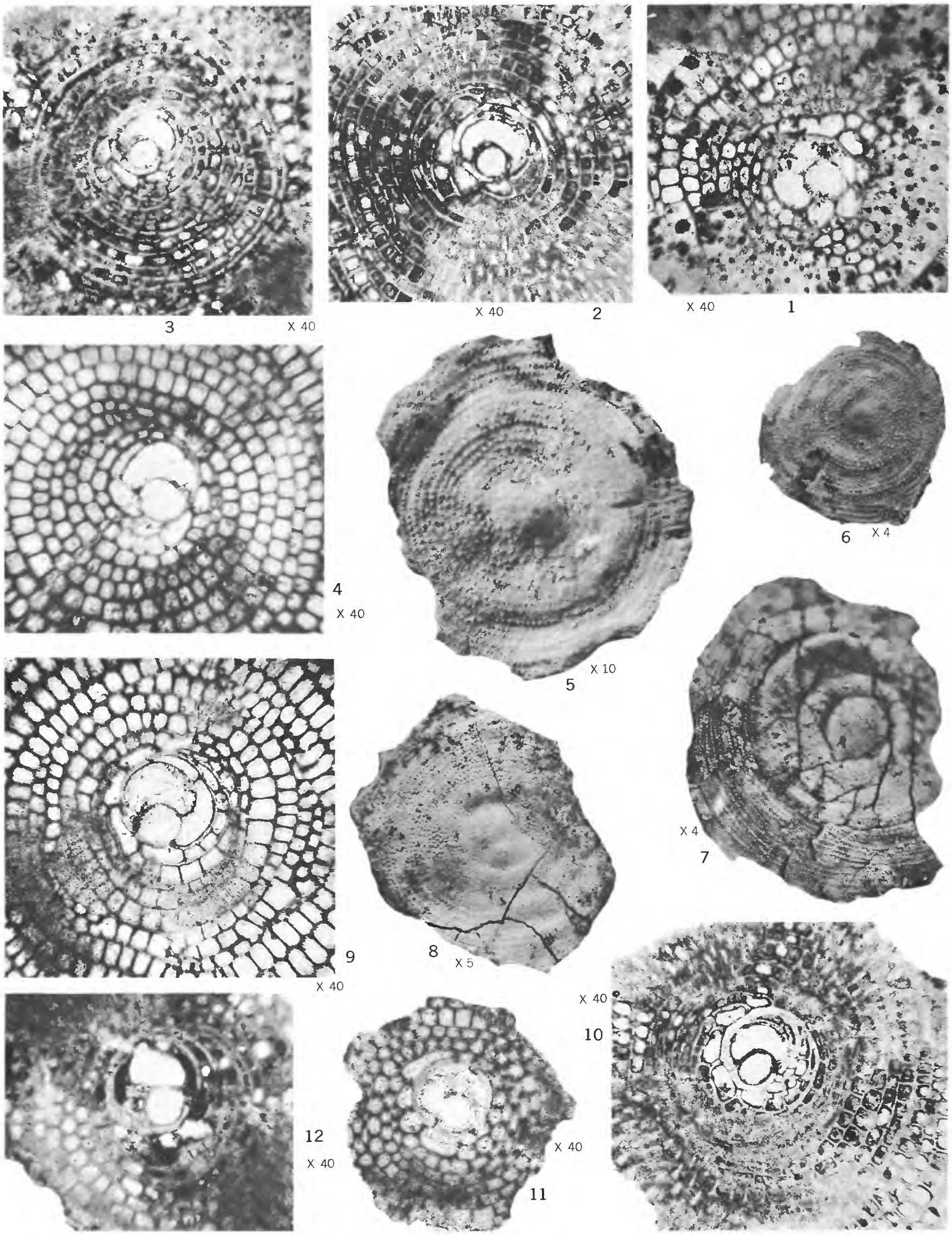
CYCLOCLYPEUS

PLATE 7

FIGURES 1–6, 8–10. *Cycloclypeus* (*Cycloclypeus*) *indopacificus* Tan (p. E17).
1–4, 9, 10. Parts of equatorial sections, ×40.
1. Locality Gj 9–2. USNM 625614.
2, 3, 10. Comparison specimens previously identified as *C.* (*C.*) *indopacificus terhaari* Tan; locality L389, Lakemba, Lau, Fiji. USNM 625615–625617.
4, 9. Locality Gj 9–4. USNM 625618–625619.
5, 6, 8. External views, 5, ×10; 6, 8, ×4; locality Gj 9–4. USNM 625620–625622.

7. *Cycloclypeus* (*Katacycloclypeus*) *annulatus* Martin (p. E19).
External view, ×4; locality Gj 9–2. USNM 625623.

11, 12. *Cycloclypeus* (*Cycloclypeus*) *postindopacificus* Tan (p. E19).
Parts of equatorial sections, ×40.
11. Locality Sv 1–4. USNM 625624.
12. Locality Ts 5–10. USNM 625625.



CYCLOCLYPEUS

PLATE 8

FIGURES 1, 2. *Cycloclypeus* (*Cycloclypeus*) *carpenteri* H. B. Brady (p. E17).

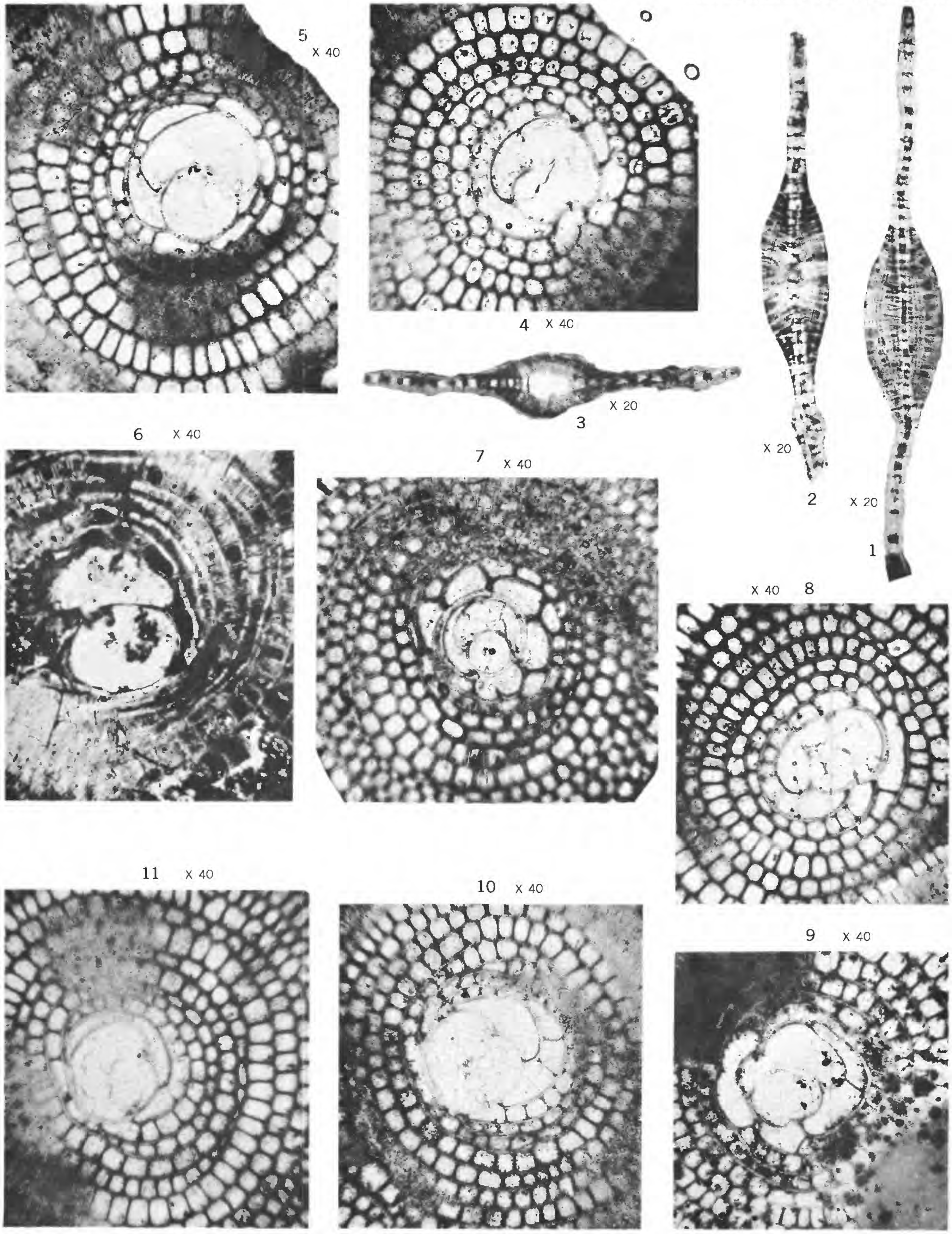
1. Transverse section, ×20, nearly centered; locality Ig 7–1. USNM 625626.
2. Transverse section, ×20, centered; locality Ig 9–8. USNM 625627.

3. *Cycloclypeus* (*Cycloclypeus*) *indopacificus* Tan (p. E17).
Transverse section, ×20; locality Gj 9–4. USNM 625628.

4–6, 8–11. *Cycloclypeus* (*Katacycloclypeus*) *annulatus* Martin (p. E19).
Parts of equatorial sections, ×40, illustrating the embryonic and nepionic chambers.

4. With two nepionic chambers; locality Gj 9–4. USNM 625629.
5. With one large and one small nepionic chamber on opposite sides of the embryonic chambers; locality Gj 9–2. USNM 625630.
6. Comparison specimen; locality 62, Vanua Mbalavu, Lau, Fiji. USNM 625631.
8. With irregularly developed embryonic chambers and two nepionic chambers; locality Gj 9–4. USNM 625632.
9. With irregularly developed nepionic chambers; locality Gj 9–1. UNSM 625633.
10. With three nepionic chambers the first of which is not subdivided into chamberlets; locality Gj 9–1. USNM 625634.
11. With irregularly developed embryonic chambers and two nepionic chambers; locality Gj 9–4. USNM 625635.

7. *Cycloclypeus* (*Cycloclypeus*) *hexaseptus* Tan (p. E18).
Part of an equatorial section, ×40, identified previously as *C.* (*C.*) *posteidae hexasepta* Tan; locality 62, Vanua, Mbalavu, Lau, Fiji. USNM 625636.



CYCLOCLYPEUS

PLATE 9

FIGURES 1–3. *Flosculinella bontangensis* (L. Rutten) (p. E20).

1. Axial section, ×40, not centered; locality Gj 6–1. USNM 625637.

2, 3. Oblique sections, ×40; locality Jj 3–2. USNM 625638–625639.

4–10, 19. *Lepidocyclina* (*Nephrolepidina*) *sumatrensis* (Brady) (p. E24).

4. Vertical section, ×20, of a small specimen; locality Fi 3–2. USNM 625640.

5. Vertical section, ×20, of a medium size specimen with low lateral chambers and heavy pillars; locality Ii 6–39. USNM 625641.

6. Vertical section, ×20, of an inflated specimen without pillars, generally called *L.* (*N.*) *sumatrensis inornata*; locality Fi 3–3. USNM 625642.

7, 9, 10. Vertical sections, ×20, of specimens illustrating two distinct kinds of lateral chambers in each specimen; locality Ii 6–14. USNM 625643–625645.

8. Vertical section, ×20, of a specimen with open lateral chambers and few strong pillars; locality Ii 6–39. USNM 625646.

19. Part of an equatorial section, ×40; locality Ii 6–39. USNM 625647.

11. *Lepidocyclina* (*Nephrolepidina*) *cubiculirhomboidea* Cole (p. E22). Vertical section, ×20; locality Eh 2–4. USNM 625648.

12, 13, 18. *Asterocyclina praecipua* Cole (p. E24).

12. Vertical section, ×20, of a magalospheric specimen; locality Jl 2–1. USNM 625649.

13. Part of an equatorial section, ×40, of a megalospheric specimen; locality Fk 3. USNM 625650.

18. Vertical section, ×20, of a microspheric individual; locality Fk 3. USNM 625651.

14, 17. *Cycloclypeus* (*Katacycloclypeus*) *annulatus* Martin (p. E19).

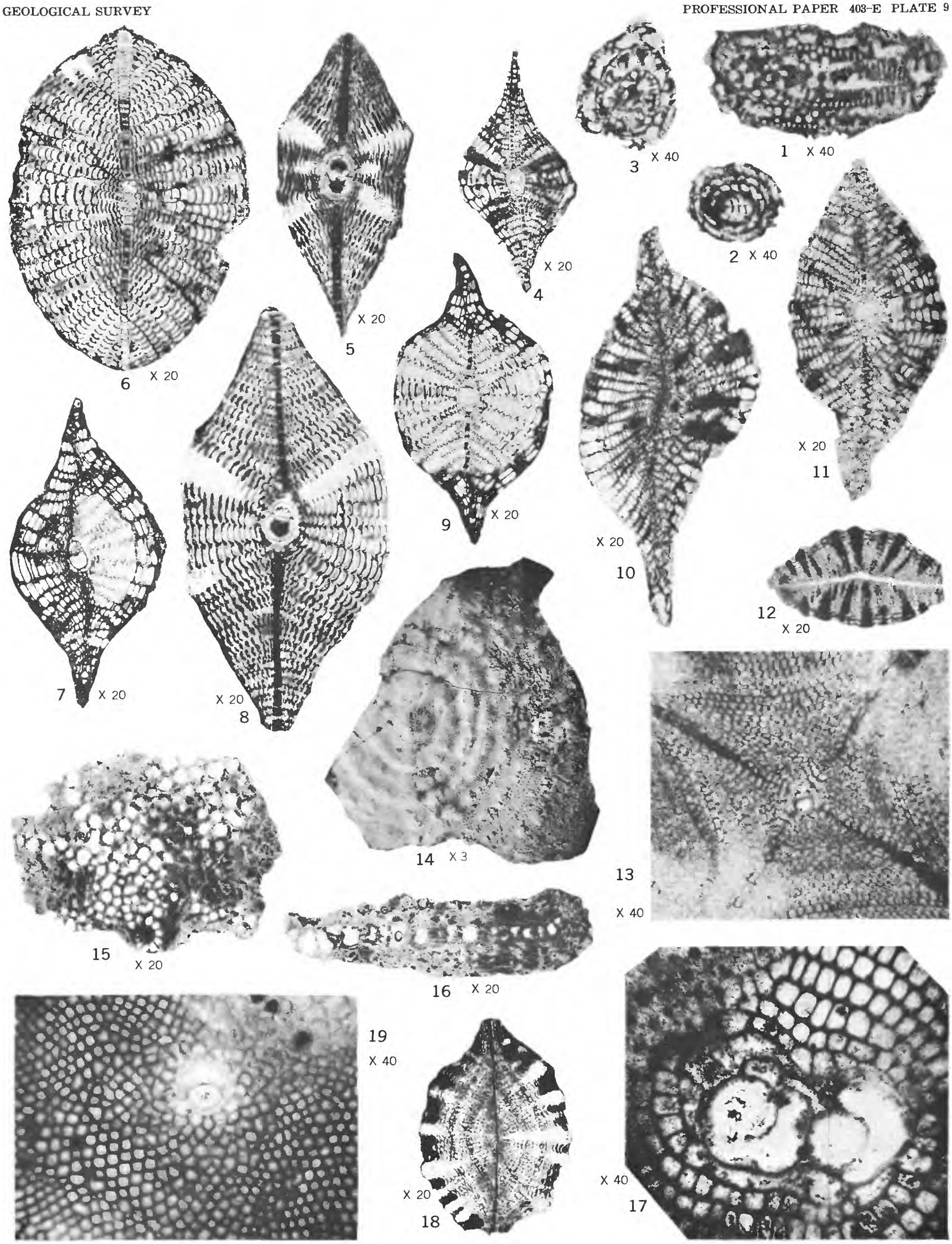
14. External view, ×3, of a specimen with four well-developed annular inflations; locality Gj 9–1. USNM 625652.

17. Part of an equatorial section, ×40, showing two sets of embryonic chambers; locality Gj 9–2. USNM 625653.

15, 16. *Miogypsinoides cupulaeformis* (Zuffardi-Comerci) (p. E20).

15. Equatorial section, ×20; locality Gj 9–1. USNM 625654.

16. Vertical section, ×20; locality Gj 9–1. USNM 625655.



ASTEROCYCLINA, CYCLOCLYPEUS, FLOSCULINELLA, LEPIDOCYCLINA, AND *MIOGYPSINOIDES*

PLATE 10

FIGURES 1–9, 11, 13, 14, 18. *Lepidocyclina* (*Nephrolepidina*) *japonica* Yabe (p. E21).

1–8. Vertical sections, ×20.

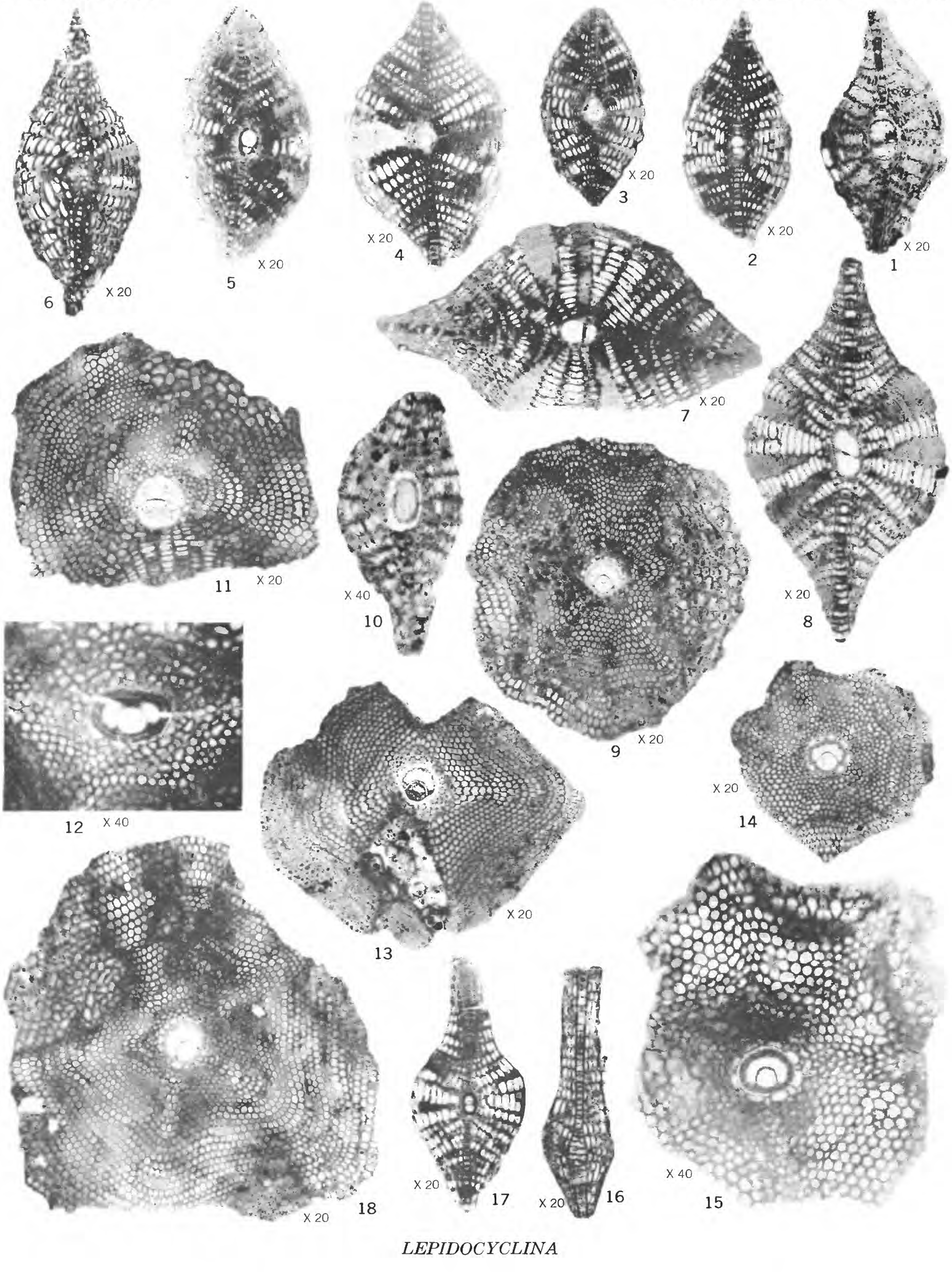
1. Vertical section of a specimen with large embryonic chambers; locality Jj 9–3. USNM 625656.
2, 3. Vertical sections of specimens with small embryonic chambers and small pillars; locality Gj 7–2. USNM 625657–625658.
4, 5, 7. Locality Gj 7–2. USNM 625660–625662.
6. Locality Fi 3–1. USNM 625663.
8. Locality Jj 9–3. USNM 625664.

9, 11, 13, 14, 18. Median sections, ×20.

9, 13, 14. Locality Gj 7–2. USNM 625665–625667.
11. Median section of a specimen with large embryonic chambers; locality Jj 9–3. USNM 625659.
18. Locality Jj 9–3. USNM 625668.

10, 12, 15–17. *Lepidocyclina* (*Nephrolepidina*) *martini* Schlumberger (p. E22).

10. Vertical section, ×40, of a small specimen; locality Ih 5–4. USNM 625669.
12. Part of an equatorial section, ×40, illustrating the embryonic and equatorial chambers; locality Gj 7–2. USNM 625670.
15. Equatorial section, ×40, illustrating the embryonic and periembryonic chambers and the stellate arrangement of the equatorial chambers; locality Gj 7–2. USNM 625671.
16. Part of a vertical section, ×20, through a ray of probable microspheric specimen; locality Gj 7–1. USNM 625672.
17. Vertical section, ×20, of a megalospheric specimen that was cut along one ray (upper part); locality Gj 7–2. USNM 625673.



LEPIDOCYCLINA

PLATE 11

FIGURES 1–8. *Lepidocyclina* (*Nephrolepidina*) *rutteni* Van der Vlerk (p. E24).

1. Vertical section, × 20, of a trigonal specimen; locality Ts 2–1b. USNM 625674.
2. Vertical section, × 20, nearly centered, of a specimen introduced for comparison, identified and presented to the writer by I. M. van der Vlerk; locality Tjepoe, Java. USNM 625675.
3. Vertical section, × 12.5, slightly oblique, showing a segment of the equatorial chambers as well as the lateral chambers; locality Ts 2–1b. USNM 625676.
4. Vertical section, × 20, of a large trigonal specimen; locality Ts 2–1b. USNM 625677.
5. Vertical section, × 20, not centered, showing the equatorial layer and lateral chambers; locality Ts 2–1b. USNM 625678.
6. Segment of figure 3, × 40, illustrating the shape of the equatorial chambers. USNM 625679.
7. Vertical section, × 20, strongly oblique, illustrating lateral chambers and small pillars; locality Ts 2–1b. USNM 625680.
8. Vertical section, × 40, of a small megalospheric specimen; locality Ts 2–1b. USNM 625681.

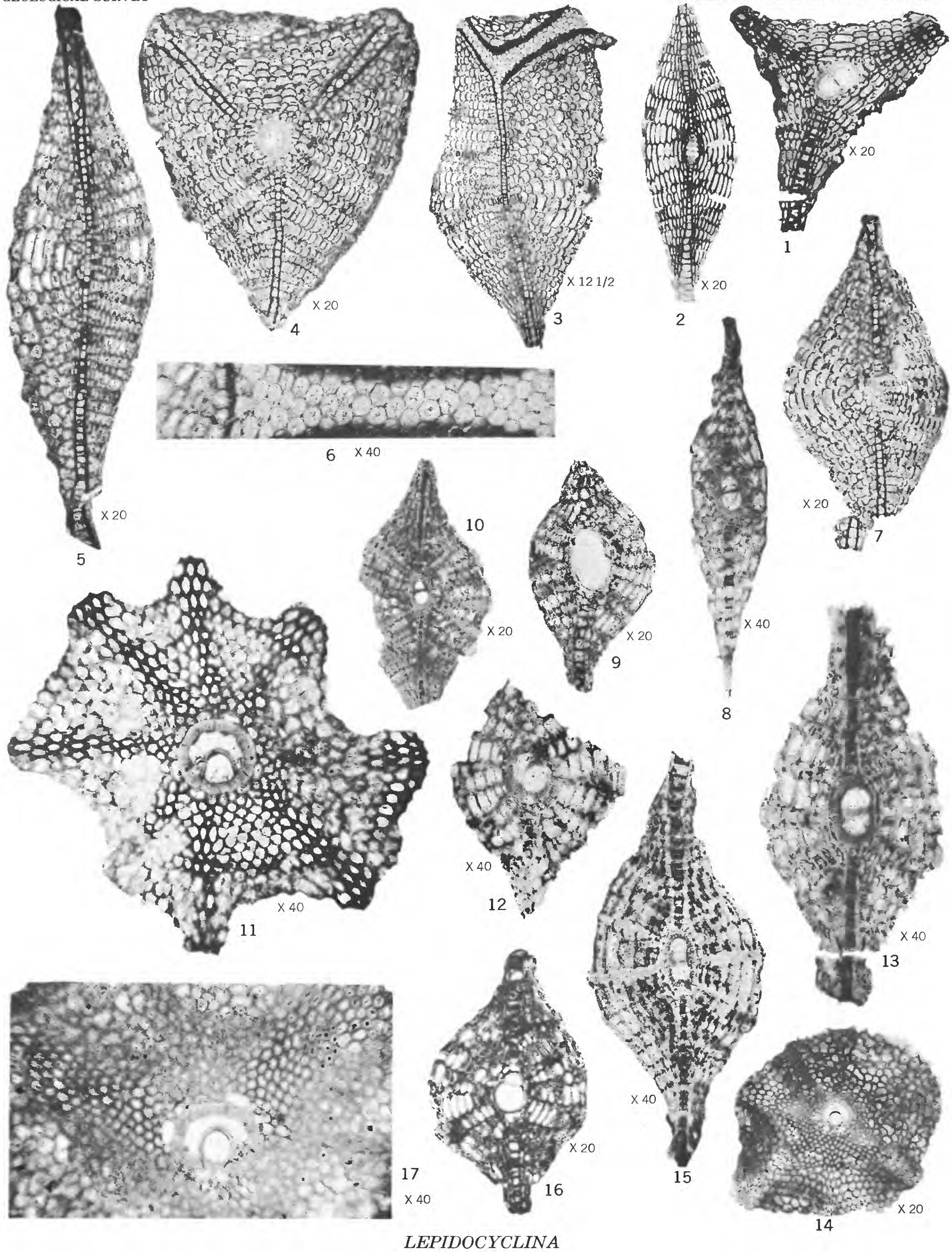
9–17. *Lepidocyclina* (*Nephrolepidina*) *martini* Schlumberger (p. E22).

9, 10, 12, 13, 15, 16. Vertical sections, 9, 10, 16, × 20; 12, 13, 15, ×40.

- 9. Locality Fi 5–1. USNM 625682.
- 10. Locality Jj 9–3. USNM 625683.
- 12. Locality Ih 5–4. USNM 625684.
- 13. Specimen introduced for comparison; locality 62, Vanua, Mbalavu, Lau, Fiji. USNM 625685.
- 15. Locality Fi 5–1. USNM 625686.
- 16. Locality Fi 5–2. USNM 625687.

11, 14, 17. Equatorial sections, 11, 17, × 40; 14, × 20.

- 11. Specimen introduced for comparison; the same locality as figure 13. USNM 625688.
- 14. Locality Jj 9–3. USNM 625689.
- 17. Locality Jj 9–3. USNM 625690.



LEPIDOCYCLINA