NUMMULITES (FORAMINIFERA) FROM THE UPPER EOCENE KOPILI FORMATION OF ASSAM, INDIA

by BIMAL K. SAMANTA

ABSTRACT. Four species of *Nummulites* are described and illustrated from the Kopili Formation, Garo Hills, Assam, India. This is the first account of the genus *Nummulites* from the Upper Eocene *Pellatispira*-bearing horizon in the Indian region.

OUTCROPS of marine Upper Eocene rocks with larger foraminifera are known to occur in three areas in the India–Pakistan region (Samanta 1968, fig. 1): Surat–Broach in Western India (Rao 1941), the Sulaiman Range in West Pakistan (Eames 1952) and Assam in Eastern India (Nagappa 1951, Samanta 1965). *Nummulites* has been reported to occur in association with the typical Upper Eocene genus *Pellatispira* in all three areas but so far there is no published account of the genus from this horizon.

In Assam the Kopili Formation contains a rich Upper Eocene larger foraminiferal assemblage including such stratigraphically important genera as *Asterocyclina*, *Discocyclina*, *Nummulites*, and *Pellatispira*. An investigation of the larger foraminifera of the Kopili Formation in the Garo Hills has been carried out by the writer and an account of the genus *Nummulites* is given in the present paper.

KOPILI FORMATION

Evans (1932, pp. 173–5) first called this unit the Kopili alternations 'Stage' and sometimes Kopili 'Stage'. Later workers have changed the name to Kopili Formation, since by original designation it is basically a rock unit. In the type section (Kopili River section of the Kopili–Khorungma region) the succession is reported to be about 450 m. thick and consists of alternations of sandstone, mudstone, shales, carbonaceous rocks, and shell-bearing sandstone. It conformably overlies the Sylhet Limestone and is apparently conformably overlain by the Barail group of rocks. The formation outcrops along the southern fringe of the Shillong Plateau, from the Garo Hills in the west to the Mikir Hills in the east.

In the Garo Hills the Kopili Formation is best exposed in the Simsang River section between Siju Artheka (90° 41′ E., 25° 20′ N.) and Matmagitik (90° 40′ E., 25° 18′ N.). It conformably overlies the Siju Limestone and is apparently conformably overlain by Barail-equivalent rocks (Samanta 1968, p. 128, table 1). The lower part of the formation is richly fossiliferous and contains abundant larger foraminifera, including such stratigraphically important genera as *Asterocyclina*, *Discocyclina*, *Nummulites*, and *Pellatispira*. Of these, *Discocyclina* is the most abundant. Because of their much larger size in comparison to other larger foraminifera, discocyclines constitute the most conspicuous element of the foraminiferal fauna. *Nummulites* is represented by small to medium sized striate and reticulate forms and occurs in almost all foraminiferal samples. In contrast

[Palaeontology, Vol. 11, Part 5, 1968, pp. 669–82, pls. 128–9]

to *Discocyclina* and *Nummulites*, *Asterocyclina* and *Pellatispira* occur in fewer samples and are much less abundant in numbers of individuals.

The following larger foraminifera are identified from the Kopili Formation, Garo Hills (see also Samanta 1968, p. 129, table 2):

Asterocyclina matanzensis Cole
Discocyclina archiaci (Schlumberger)
D. assamica Samanta
D. augustae Weijden
D. dispansa (Sowerby)
D. eamesi Samanta
D. javana (Verbeek)
D. omphalus (Fritsch)
D. pygmaea Henrici
D. sella (d'Archiac)
D. sowerbyi Nuttall
D. sp. cf. *D. trabayensis* Neumann
Nummulites chavannesi de la Harpe
N. sp. aff. *N. chavannesi* de la Harpe
N. fabianii (Prever)
N. pengaronensis Verbeek
Pellatispira inflata Umbgrove
P. sp. cf. *P. irregularis* Umbgrove
P. madaraszi (Hantken)
P. sp. cf. *P. orbitoidea* (Provale)

Of these, *D. augustae*, *D. sella*, *N. chavannesi*, *N. fabianii*, and *P. madaraszi* are recorded from the Priabonian of North Italy, while *A. matanzensis*, *D. javana*, *D. omphalus*, *D. pygmaea*, *D. sella*, *N. pengaronensis*, and the four species of *Pellatispira* are abundantly represented in the T b of the Indonesian region. The larger foraminiferal assemblage, therefore, indicates a definite Upper Eocene age for the lower part of the Kopili Formation.

Material. The material was collected from five localities in the Garo Hills, previously described (Samanta 1965, p. 416, text-fig. 3). All the four species of *Nummulites* are represented by sufficient material. Presence of free specimens permits a detailed study of these forms. Table 1 shows the distribution of the species in the Garo Hills.

TABLE 1. *Distribution of* Nummulites *in the Kopili Formation, Garo Hills, Assam*

	Localities				
Species	*Sa*	*Rn*	*Rgt*	*N*	*K*
Nummulites chavannesi de la Harpe					X
N. sp. aff. *N. chavannesi* de la Harpe		X		X	X
N. fabianii (Prever)	X	X			X
N. pengaronensis Verbeek	X	X	X	X	X

Acknowledgements. The author is indebted to Dr. J. R. Haynes for critically reading the manuscript; Dr. F. E. Eames for helpful discussions; Professors H. Hagn and E. Montanaro Gallitelli for comparative material; Drs. F. Bieda and V. Roveda for literature; Professor Alan Wood for providing facilities in his Department; and Mr. H. Williams for help in preparing the plates.

SYSTEMATIC PALAEONTOLOGY

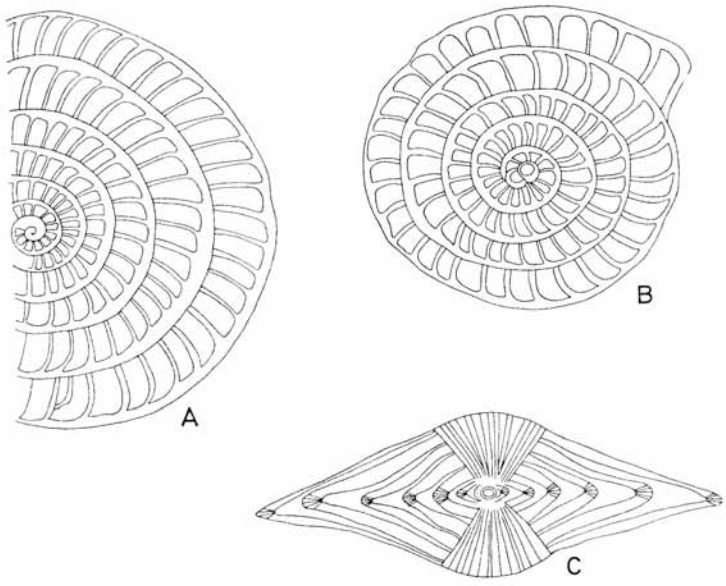
Family NUMMULITIDAE de Blainville 1825
Subfamily NUMMULITINAE de Blainville 1825
Genus NUMMULITES Lamarck 1801

Nummulites chavannesi de la Harpe

Plate 128, figs. 11, 12; Plate 129, figs. 9–14; text-fig. 1

1877 *Nummulites chavannesi* de la Harpe, p. 232 (*nom. nud.*).
1883*a* *Nummulites bouillei* var. *rütimeyeri* de le Harpe, pl. 6. figs. 5–11.
1883*a* *Nummulites chavannesi* de la Harpe, pl. 6. figs. 22–41.
1883*b* *Nummulites rütimeyeri* de la Harpe, pp. 162, 163, pl. 30, figs. 9–11.

1883*b* *Nummulites chavannesi* de la Harpe; de la Harpe, pp. 163, 164, pl. 30, figs. 12–18.
1911*b* *Nummulites chavannesi* de la Harpe; Boussac, pp. 37, 38.
1934 *Nummulites* cf. *chavannesi* de la Harpe; Flandrin, pp. 254, 255, pl. 14, figs. 15, 16.
1934 *Nummulites rütimeyeri* de la Harpe; Flandrin, p. 254, pl. 14, fig. 17.
1938 *Nummulites rütimeyeri* de la Harpe; Flandrin, pp. 34, 35, pl. 3, figs. 9, 10.
1951 *Nummulites rütimeyeri* de la Harpe; Daci, pp. 209, 210, pl. 2, figs. 7, 8.
1951 *Nummulites chavannesi* de la Harpe; Daci, pp. 210, 211, pl. 2, fig. 9.
1957 *Nummulites chavannesi* de la Harpe; Bieda, pp. 46, 47, pl. 4, figs. 8, 9.
1960 *Nummulites chavannesi* de la Harpe; Hagn, p. 70, pl. 1, fig. 2; pl. 2, figs. 4, 5.
1961 *Nummulites chavannesi* de la Harpe; Roveda, pp. 177–81, pl. 14, figs. 1–8.
1963*a* *Nummulites chavannesi* de la Harpe; Bieda, pp. 71, 72, 186, pl. 6, figs. 5–7; pl. 7, figs. 1–3.



TEXT-FIG. 1. *Nummulites chavannesi* de la Harpe. A, Part of the equatorial section of a microspheric specimen. ×20 approx. B, Equatorial section of a megalospheric specimen, ×25 approx. C, Axial section of a megalospheric specimen, ×25 approx. All from locality K.

Material. Megalospheric form—25 specimens examined externally, 5 specimens studied in equatorial section, and 5 in axial section. Microspheric form—6 specimens examined externally, 3 specimens studied in equatorial section, and 2 in axial section.

Description. Megalospheric form. Test small, lenticular, with slightly elevated polar region surrounded by sloping peripheral part; margin acute. Surface ornamented with well-developed polar pustules from which thin, straight to gently curved septal filaments radiate. Diameter of test varies from 1·9 to 3·4 mm., thickness from 0·9 to 1·4 mm., ratio of diameter to thickness from 2·2 to 2·7, and diameter of polar pustules from 0·4 to 0·6 mm.

About $4\frac{1}{2}$ to 6 regularly coiled whorls open rapidly. Spiral lamina thin and in outer

whorls height of spiral cavity about 4 to 6 times thickness of spiral lamina. Septa nearly perpendicular to spiral lamina, straight with sharp curvature near distal end. About 8–11 septa occur in 1st whorl; 15–20 in 2nd; 19–28 in 3rd; 24–9 in 4th; and 28–32 in 5th.

Small, subcircular first chamber followed by subequal, reniform second chamber. Separating wall either straight or curved outwards. Diameters of first chamber vary from 0·055×0·050 mm. to 0·095×0·075 mm. and those of second chamber from 0·055×0·045 mm. to 0·100×0·060 mm. Distance across both chambers varies from 0·105 to 0·180 mm. Equatorial chambers quadrate in shape and about twice as high as long.

In axial section first chamber circular and about 0·05 mm. in height. Chamber cavity triangular in shape. Alar prolongations wide open. Marginal cord distinct. Wedge-shaped polar plugs always very conspicuous and about 0·6 mm. in diameter near surface.

Microspheric form. Test small with well-developed, slightly elevated polar pustules; margin acute. Septal filaments thin, radiate, nearly straight. Diameter of test varies from 3·8 to 5·0 mm., thickness from 1·8 to 2·0 mm., ratio of diameter to thickness from 2·1 to 2·4 mm., and diameter of polar pustules from 0·8 to 1·0 mm.

There are about 9 whorls in diameter of 4·2 mm. Whorls regularly coiled and open rather rapidly. In outer whorls height of spiral cavity about 3 times thickness of spiral lamina. Septa nearly perpendicular and straight with sharp curvature at top. Chambers quadrate, about 2 to 3 times higher than long.

In axial sections alar prolongations wide open. Marginal cord distinct. Well-developed polar plugs wedge-shaped, about 1·0 mm. in diameter near surface.

Remarks. The presence of well-defined polar pustules, high equatorial chambers between almost straight septa, and wide alar prolongations distinguish this species from the associated nummulites in the Kopili Formation. The Assam specimens have been compared with European material, provided by Professor H. Hagn. They are closely similar to the Priabonian material described and illustrated by Roveda (1961).

Distribution. *N. chavannesi* has been reported from Italy, Spain, France, Switzerland, Poland, Hungary, Albania, Turkey, Algeria, Egypt, and Somaliland. Its known range is from Upper Eocene to Oligocene.

In the Garo Hills *N. chavannesi* occurs only in the Upper Eocene Kopili Formation (Table 1). There is no report of its occurrence in the other Upper Eocene localities in India and adjacent countries. The present record of *N. chavannesi* extends its geographic distribution considerably.

EXPLANATION OF PLATE 128

Figs. 1–10. *Nummulites pengaronensis* Verbeek. 1, External view of microspheric specimen, ×6. 2, 3, External views of megalospheric specimens; 2, inflated variety, ×6; 3, compressed lenticular variety, ×9. 4, 5, Equatorial sections of megalospheric specimens, ×15; 4, inflated variety; 5, lenticular variety. 6–8, Axial sections of megalospheric specimens showing variation in transverse views of tests; 6, ×15; 7, 8, ×21. 9, Axial section of microspheric specimen, ×9. 10, Equatorial section of microspheric specimen, ×9. 1, 3, 8, 10, from locality Sa; 2, 7, from locality K; 4, 5, from locality Rn; 6, 9, from locality N (see Samanta 1965, p. 416).

Figs. 11, 12. *Nummulites chavannesi* de la Harpe. 11, Axial section of megalospheric specimen, ×21. 12, Equatorial section of megalospheric specimen, ×21. Both from locality K.

Figs. 13–15. *Nummulites* sp. aff. *N. chavannesi* de la Harpe. 13, External view of megalo-spheric specimen, ×15. 14, Equatorial section of megalospheric specimen, ×21. 15, Axial section of megalo-spheric specimen, ×21. All from locality K.

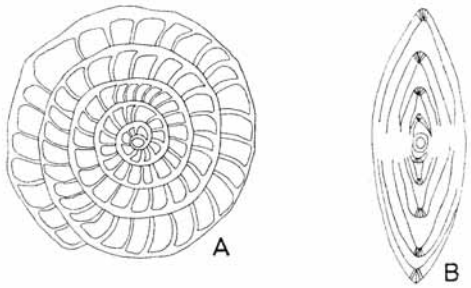
Nummulites sp. aff. *N. chavannesi* de la Harpe

Plate 128, figs. 13–15; text-fig. 2

Material. Only megalospheric specimens were observed. 15 specimens examined externally, 5 specimens studied in equatorial section, and 2 in axial section.

Description. Megalospheric form. Test very small, lenticular, with acute margin. Septal filaments thin and radial. Diameter of test varies from 1·6 to 2·0 mm., thickness from 0·56 to 0·80 mm., and ratio of diameter to thickness from 2·0 to 3·4.

Spire is regular with about $4\frac{1}{2}$ to $5\frac{1}{2}$ whorls increasing regularly in height. Spiral lamina thin, about $\frac{1}{5}$ height of spiral cavity in thickness. Septa are perpendicular to wall and



TEXT-FIG. 2. *Nummulites* sp. aff. *N. chavannesi* de la Harpe (megalospheric form.) A, Equatorial section. B, Axial section. Both from locality K, ×25 approx.

nearly straight with curvature at top. About 8–10 septa occur in 1st whorl; 15–18 in 2nd; 19–25 in 3rd; 24–6 in 4th; and 24–30 in 5th.

Subcircular first chamber followed by subequal, crescentic second chamber. Separating wall gently curved outwards. Diameters of first chamber vary from 0·05×0·03 mm. to 0·08.×0·07 mm.; those of second chamber from 0·055×0·035 mm. to 0·10×0·055 mm. Distance across both chambers varies from 0·09 to 0·15 mm. Equatorial chambers quadrate and higher than long.

In axial section first chamber circular, about 0·06 mm. in height. Alar prolongations wide open. Marginal cord distinct.

Remarks. The present specimens are closely similar to *N. chavannesi* in internal characters, but can easily be distinguished from the latter by the shape of the test and the absence of polar pustules. They are provisionally identified as *N. sp.* aff. *N. chavannesi.*

Distribution. The species occur in localities Rn, N, and K in the Garo Hills (Samanta 1965, p. 416). The presence of similar forms has also been noticed by the writer in the Upper Eocene of Surat-Broach, Western India.

Nummulites fabianii (Prever)

Plate 129, figs. 1–8; text-fig. 3, 4

1905 *Bruguieria fabianii* Prever *in litt.*; Fabiani, pp. 1805, 1811, 1824.
1905 *Bruguieria sub-fabianii* Prever *in litt.*; Fabiani, pp. 1811, 1824.

1906 *Nummulites fabianii* (Prever *in* Fabiani); Boussac, pp. 88–90, pl. 1, figs. 1–5, 7–9; pl. 3, fig. 6.
1911*a* *Nummulites fabianii* Prever *in* Fabiani; Boussac, pp. 40, 72, pl. 10, figs. 1, 2, 28; pl. 17, figs. 8, 11, 13.
1911*b* *Nummulites fabianii* Prever *in* Fabiani; Boussac, pp. 79–84, pl. 1, figs. 6, 13; pl. 4, figs. 9, 10.
1928 *Nummulites fabianii* Prever; de Cizancourt, p. 294, pl. 2, fig. 10.
1930 *Nummulites fabianii* Prever; de Cizancourt, pp. 209, 210, pl. 22, figs. 4, 7; pl. 23, fig. 5.
1934 *Nummulites fabianii* Prever; Flandrin, p. 259, pl. 1, fig. 20.
1951 *Nummulites fabianii* Prever; Daci, pp. 221, 222, pl. 3, figs. 1, 2.
1951 *Nummulites subfabianii* Prever; Daci, pp. 222–4, pl. 3, figs. 4–7.
1957 *Nummulites fabianii* Prever; Bieda, p. 30, pl. 5, fig. 5.
1959 *Nummulites retiatus* Roveda, pp. 201–7, pl. 1, figs. 1–11.
1960 *Nummulites fabianii* (Prever); Hagn, p. 149, pl. 2, figs. 2, 3, 7.
1961 *Nummulites fabianii* (Prever); Roveda, pp. 161–9, pl. 15, figs. 15, 16; pl. 17, figs. 8, 9; pl. 18, figs. 4, 5; pl. 19, figs. 1, 6–8, 14–16.
1963*a* *Nummulites fabianii* Prever; Bieda, pp. 101–4, 195, 196, pl. 15, fig. 9; pl. 16, figs. 1–4.
1963*b* *Nummulites fabianii* Prever; Bieda, pp. 201–4, 214–15, pl. 13, figs. 3, 4.
1965 *Nummulites fabianii* Prever; Bozorgnia and Kalantari, pp. 17, 18; pl. 20, figs. 1–7.

Material. Megalospheric form—20 specimens examined externally, 5 studied in equatorial section, and 7 in axial section. Microspheric form—10 specimens examined externally, 4 studied in equatorial section, and 1 in axial section.

Description. Megalospheric form. Test small, lenticular, with subacute margin. Surface ornamented with spirally arranged rectangular meshes produced by intersections of radial filaments with raised spiral line. Spirally arranged granules joined together by 'transverse lamina' produce raised spiral line. In some specimens granules cluster at poles to form polar pustules. Diameter of test varies from 1·8 to 3·0 mm., thickness from 1·25 to 1·85 mm., and ratio of diameter to thickness from 1·4 to 1·9.

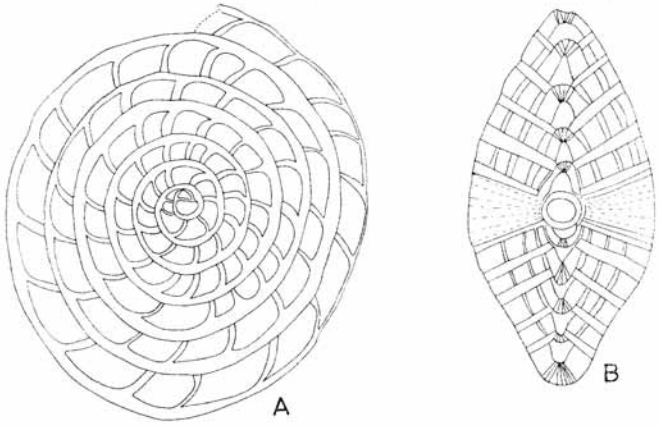
About 5 to $6\frac{1}{2}$ regularly coiled whorls occur, increasing slowly in height. Spiral lamina thick, and in some inner whorls may be as thick as height of spiral cavity. Near periphery height of spiral cavity about 2 to 3 times thickness of spiral lamina. Septa slightly inclined to spiral wall, straight to gently curved in their course. About 6–7 septa occur in 1st whorl; 9–13 in 2nd; 12–16 in 3rd; 15–20 in 4th; and 16–22 in 5th.

Subcircular first chamber followed by smaller, semicircular to reniform second chamber. Separating wall either straight or curved outwards. Diameters of first chamber vary from 0·130×0·095 mm. to 0·20×0·20 mm.; those of second chamber from 0·10×0·05 mm. to 0·175×0·095 mm. Distance across both chambers varies from 0·16 to 0·28 mm. Chambers quadrate in shape. Near centre, chambers almost as long as high, but in ontogeny chambers become considerably longer, so that in outer whorls chambers become twice as long as high.

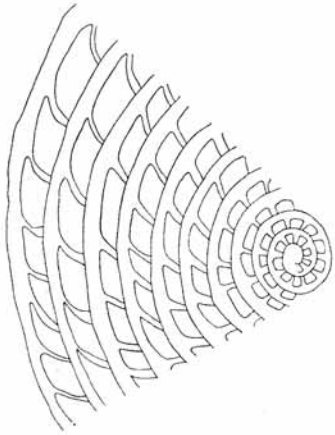
EXPLANATION OF PLATE 129

Figs. 1–8. *Nummulites fabianii* (Prever). 1, External view of microspheric specimen, ×6. 2, 3, Equatorial sections of microspheric specimens, ×9. 4, External view of megalospheric specimen, ×15. 5, 6, Axial sections of megalospheric specimens, ×21. 7, Equatorial section of megalospheric specimen, ×15. 8, Axial section of microspheric specimen, ×7·5. All from locality Rn (see Samanta 1965, p. 416).

Figs. 9–14. *Nummulites chavannesi* de la Harpe. 9, External view of microspheric specimen, ×6. 10, 11, External views of megalospheric specimens, ×12. 12, Axial section of megalospheric specimen, ×21. 13, Equatorial section of megalospheric specimen, ×21. 14, Equatorial section of microspheric specimen, ×15. All from locality K.



TEXT-FIG. 3. *Nummulites fabianii* (Prever) (megalospheric form). A, Equatorial section. B, Axial section. Both from locality Rn, ×25 approx.



TEXT-FIG. 4. *Nummulites fabianii* (Prever). Part of the equatorial section of a microspheric specimen from locality Rn, ×18 approx.

In axial section first chamber circular, about 0·10 to 0·13 mm. in height. Spiral lamina rather thick. There may be reduction in thickness of spiral lamina at periphery. Alar prolongations narrow to moderately open. Marginal cord distinct. Pillars well-developed, start from marginal cord of each whorl, and of uniform thickness throughout length. At poles, pillars cluster together to form polar plugs. Diameter of pillars varies from 0·050 to 0·075 mm. and polar plugs from 0·25 to 0·50 mm.

Microspheric form. Test medium-sized, lenticular, with subacute margin. Surface of

test ornamented with thin, reticulate septal filaments. In young individuals rectangular meshes are discernible but in adult specimens branching filaments produce complex network. Diameter of test varies from 5·1 to 8·4 mm., thickness from 2·7 to 4·2 mm., and ratio of diameter to thickness from 1·9 to 2·2.

In equatorial section about 9 to 13 whorls occur, coiled regularly and increasing slowly in height during ontogeny. Spiral lamina rather thick. In adult whorls height of spiral cavity usually greater than thickness of spiral lamina. Septa inclined to whorl wall, and straight to gently curved in their course. Equatorial chambers longer than high, and in outer whorls 3 to 4 times as long as high.

In axial section, alar prolongations narrow to moderately open. Marginal cord distinct. Pillars moderately developed. Each pillar starts from marginal cord and extends up to surface. Diameter of pillars varies from 0·05 to 0·15 mm. In polar region pillars cluster together to form polar plug-like structures about 0·8 mm. in diameter near surface.

Remarks. Both in external and internal features the present form is distinctive. The reticulate ornamentation, the long equatorial chambers, and the pillared axial section enables the species to be distinguished from the associated nummulites in the Kopili Formation. The Assam specimens were compared with those of *N. fabianii* from North Italy provided by Professor Montanaro-Gallitelli.

Because of their distinctive morphological features and wide geographic distribution in the rocks of Upper Eocene to Oligocene age, the reticulate *Nummulites* have received particular attention and several species have been described. But at present there is considerable difference of opinion about the validity of a number of these forms (see Eames *et al.* 1959; Bieda 1963*b*); consequently, application of reticulate *Nummulites* species in the finer biostratigraphic zonation of Upper Eocene–Oligocene rocks is lacking.

Distribution. N. fabianii is one of the most widely distributed representatives of the genus, reported from the Upper Eocene of Italy, Spain, France, Switzerland, Poland, Hungary, Albania, Rhodes Island, Turkey, Morocco, Algeria, Tunisia, Libya, Egypt, and Iran.

In the Garo Hills *N. fabianii* occurs in the Kopili Formation at localities Sa, Rn, and K (Table 1). It occurs also in two other Upper Eocene localities in the Indian region; in the Sulaiman Range its presence has been noted by Bayliss (1961), while the writer has observed it in Surat-Broach in association with *Pellatispira* spp., etc.

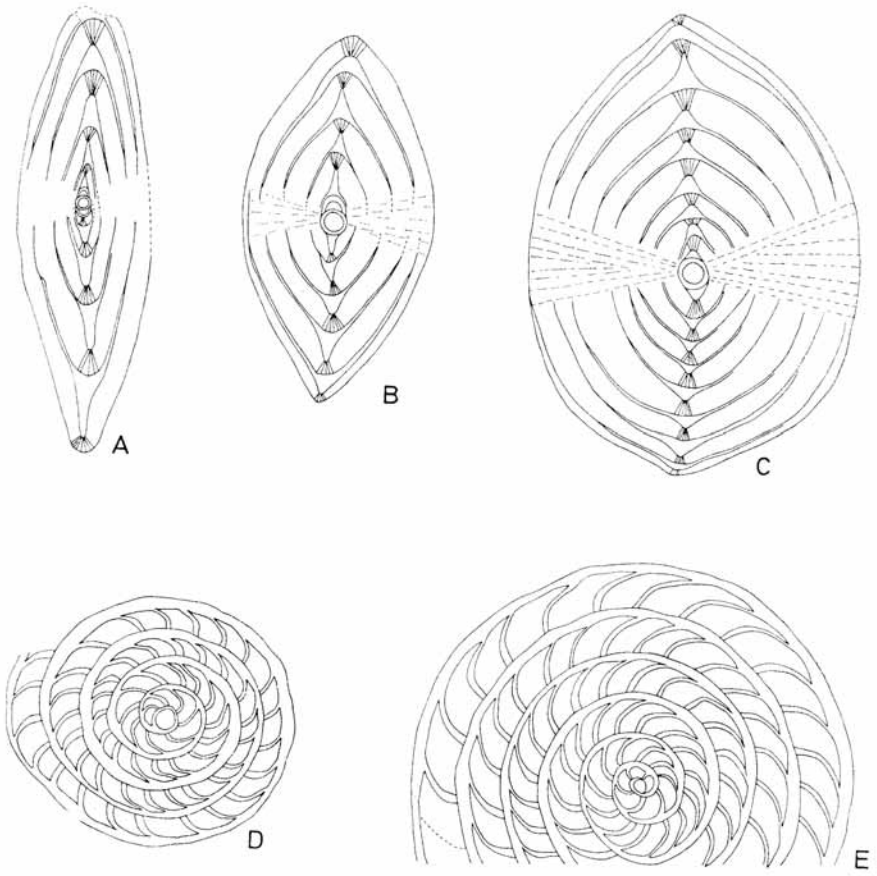
There is no authentic record of reticulate *Nummulites* from the Upper Eocene of the Malayan Archipelago (Cole 1963, Adams 1965). The only report of an occurrence in association with a typical Upper Eocene assemblage from this region was that by Cole (Cloud and Cole 1953, p. 323) who later (1963, pp. E4, E14) postulated that the Upper Eocene species in the assemblage are reworked specimens and that reticulate *Nummulites* do not occur in the Eocene of the Malayan Archipelago. Thus, Assam is the easternmost locality with *N. fabianii*.

Nummulites pengaronensis Verbeek

Plate 128, figs. 1–10; text-figs. 5, 6

1871 *Nummulites pengaronensis* Verbeek, pp. 3–6, pl. 1, figs. 1*a–k*.
1892 *Nummulites nanggoelani* Verbeek, pp. 116, 118.
1896 *Nummulites nanggoelani* Verbeek; Verbeek and Fennema, p. 1152, pl. 8, figs. 111–13.
1896 *Nummulites pengaronensis* Verbeek; Verbeek and Fennema, pp. 1153, 1154.
1912 *Nummulites pengaronensis* Verbeek; Douvillé, pp. 284, 285, pl. 24, fig. 6.

1921 *Nummulites* cf. *pengaronensis* Verbeek; Yabe, pp. 104, 105, pl. 18, fig. 8.
1929 *Nummulites pengaronensis* Verbeek; Vlerk, pp. 20, 21, figs. 12, 35*a*, *b*.
1932 *Camerina pengaronensis* (Verbeek); Doornink, pp. 283, 284, pl. 4, figs. 1–3; pl. 6, fig. 12.
1934 *Camerina pengaronensis* (Verbeek); Henrici, pp. 29, 30, pl. 1, fig. 10.
1934 *Camerina* cf. *pengaronensis* (Verbeek); Caudri, p. 52.
1953 *Camerina saipanensis* Cole, pp. 20, 21, pl. 2, figs. 7–19.
1957 *Camerina pengaronensis* (Verbeek); Cole, pp. 753, 754, pl. 231, figs. 1–17.
1959*a* *Nummulites pengaronensis* Verbeek; Nagappa, pp. 163, 166, pl. 10, figs. 3–5.
1965 *Nummulites* cf. *saipanensis* (Cole); Adams, p. 313, pl. 23, fig. c.



TEXT-FIG. 5. *Nummulites pengaronensis* Verbeek (megalospheric form). A–C, Axial sections, ×25 approx.; A, from locality Sa; B, from locality K; C, from locality N. D, Split specimen from locality Sa, ×20 approx. E, Equatorial section from locality Rn, ×25 approx.

Material. Megalospheric form—75 specimens examined externally, 5 studied in equatorial section, and 12 in axial section. Microspheric form—12 specimens examined externally, 3 studied in equatorial section, and 4 in axial section. In addition, 23 split specimens of megalospheric form and 3 of microspheric form were studied in equatorial view.

Description. Megalospheric form. Test small, compressed, lenticular to globose, with acute margin. Surface marked by thin, radial septal filaments, straight to gently curved at ends. Diameter of test varies from 2·0 to 5·2 mm., thickness from 0·8 to 3·3 mm., and ratio of diameter to thickness from 1·3 to 3·6.

Spire more or less regular with about 5 to 7 whorls increasing regularly in height, with exception of last whorl, which may be narrower than preceding one. Height of spiral cavity in outer whorls about 3 times thickness of spiral lamina. Septa nearly perpendicular to inclined at their base, straight for about half their course, then curve sharply backwards. Thickness of septa decreases considerably from proximal to distal end. About 6–7 septa occur in 1st whorl; 11–14 in 2nd; 17–19 in 3rd; 23–6 in 4th; 24–7 in 5th; 26–9 in 6th; and 29–32 in 7th.

TEXT-FIG. 6. *Nummulites pengaronensis* Verbeek. Part of the equatorial section of a microspheric specimen from locality Sa, ×18 approx.

First chamber circular to elliptical in equatorial section, followed by usually smaller, crescentic to reniform second chamber. Separating wall curved outwards. Diameters of first chamber vary from 0·125×0·120 mm. to 0·275×0·225 mm., those of second chamber from 0·105×0·050 mm. to 0·175×0·075 mm. Distance across both chambers varies from 0·200 to 0·325 mm. Equatorial chambers subquadrate to falciform in shape, usually higher than long, although reverse also quite common.

In axial section first chamber circular, about 0·100 to 0·175 mm. in height. Alar prolongations extremely narrow. Appreciable reduction in thickness of spiral lamina at periphery. Marginal cord distinct. Traces of weakly developed pillar-like structures in polar region.

Microspheric form. Test small- to medium-sized, lenticular, with acute margin. Septal filaments radial, straight. Diameter of test varies from 4·6 to 8·9 mm., thickness from 1·9 to 3·3 mm., and ratio of diameter to thickness from 2·0 to 3·3.

In equatorial section about 9 to 13 whorls occur, regularly increasing in height. Height of spiral cavity greater than thickness of spiral lamina. Septa nearly perpendicular at base, straight for about half their course, then curve sharply backwards. Thickness of septa decreases considerably from proximal to distal end. Chambers subquadrate to falciform, usually higher than long.

In axial section chamber cavity triangular in shape. Alar prolongations extremely narrow. Considerable reduction in thickness of spiral lamina at periphery. Marginal cord weakly developed. In polar region traces of pillar-like structures.

Remarks. Although the Assam specimens show considerable variation in external form

of the test, they are identical in internal structures and are included here under one species. They are characterized externally by the presence of radial septal filaments and the absence of distinct polar pustules, and internally by the characters of the septa in equatorial section and very narrow alar prolongations in axial section.

Nummulites saipanensis (Cole), originally described from Saipan, Mariana Islands (Cole and Bridge 1953), was later considered by its author (Cole 1957) to be synonymous with *N. pengaronensis* Verbeek. This is accepted here. Cole (op. cit.) also included *Nummulites semiglobula* (Doornink), described from Java (Doornink 1932), in the synonymy of *N. pengaronensis*. However, although *N. semiglobula*, as well as *N. gerthi*, bear some resemblance to *N. pengaronensis*, a more detailed study based on the topotype material of these two species is needed before considering them as junior synonyms of *N. pengaronensis*.

Among the European species, *Nummulites stellatus* Roveda described from the Priabonian of North Italy (Roveda 1961), is very closely similar to *N. pengaronensis* in internal morphology.

Sen Gupta (1965), while working on some Middle Eocene *Nummulites* from Western India, regarded *N. pengaronensis* as a junior synonym of *Nummulites beaumonti* d'Archiac and Haime. Under the remarks on *N. beaumonti*, Sen Gupta (op. cit., p. 93) wrote: 'Another synonym of *N. beaumonti* is *N. pengaronensis* Verbeek, a wide-spread Indo-Pacific form. It shows a tight coiling of spiral wall, which is almost uniformly thick, and small embryonic chambers, as does typical *N. beaumonti*. These features are clearly seen in the figures of *N. pengaronensis* published by Cole (1957*a*, pl. 231, figs. 1–17) and have been confirmed by an examination of Cole's material from Eniwetok.' Sen Gupta, therefore, neither examined the type or topotype materials nor consulted the type description and illustrations of *N. pengaronensis* to support his remarks. Further, he did not compare his Indian specimens of *N. beaumonti* with ones from the Indian region identified as *N. pengaronensis* by other workers. (There are good illustrations of microspheric and megalospheric specimens of *N. pengaronensis* from Eastern India (Nagappa 1959*a*, *b*). In both these publications, there are good illustrations of *N. beaumonti* too, and in the latter Nagappa has pointed out (p. 158, pl. 21, figs. 1, 2) the conspicuous difference in the character of the septa in these two species.) A thorough comparison between the two species, including such taxonomically important features as the characters of the equatorial chambers and the septa as seen in equatorial section, has not been made and Sen Gupta's remarks do not appear to be justified.

A comparison of the description and illustrations of *N. beaumonti* provided by Davies (1940) with those of *N. pengaronensis* given by Verbeek (1871), Doornink (1932), and others, shows clearly that they are two distinct species. In equatorial section they can always be separated by the characters of the septa and the equatorial chambers, and in axial section by the width of the alar prolongations and the degree of development of polar plugs. The writer believes that these two species are not only distinct but that they belong to two different groups of species. If *N. pengaronensis* is considered to be a synonym of *N. beaumonti*, or in other words, if the morphological differences between them are not considered to be of specific importance, then the usefulness of species of *Nummulites* in the stratigraphic analysis and correlation of the Lower Tertiary will be greatly reduced. With *N. pengaronensis* as a junior synonym, the stratigraphic range of *N. beaumonti* would be from Middle Eocene to Oligocene (not Middle to Upper

Eocene as mentioned by Sen Gupta (1965, p. 92)) and it would then be difficult to use it as a 'key' species in stratigraphy.

Distribution. N. pengaronensis is a widely distributed Indo-Pacific form and has been reported from the Central Pacific Islands, the East Indies, Burma, Eastern India, and Western Pakistan. Its known stratigraphic range is from the upper part of the Middle Eocene to Oligocene.

In the Garo Hills *N. pengaronensis* ranges from the Upper Member of the Siju Limestone (Middle Eocene) to the overlying Kopili Formation (Upper Eocene). It is the most abundant representative of the genus in the Kopili Formation and occurs in all the five localities (see Table 1).

Although it is known to occur in the Sulaiman Range (Eames 1952), there is no report of the species from the Upper Eocene of Surat-Broach, Western India.

GENERAL REMARKS

The four species of *Nummulites* recorded from the Kopili Formation belong to three different groups. *N. fabianii* (Prever) belongs to the reticulate group of forms characteristic of Upper Eocene to Oligocene. This is the only pillared form in the present assemblage. Of the three remaining striate forms, *N. pengaronensis* with its strongly curved septa and very narrow alar prolongations is distinctly different from *N. chavannesi* and *N.* sp. aff. *N. chavannesi*, characterized by rapid opening of the whorls, straight septa, and wider alar prolongations. In all these four forms the marginal cord is only moderately developed and the size of the tests does not exceed 9 mm. The striate forms are much more abundant than the reticulate one, and occur in almost all foraminiferal samples.

The assemblage of *Nummulites* in the Kopili Formation is markedly different from that in the underlying Upper Member of the Siju Limestone (Samanta 1968). In the latter horizon the assemblage is characterized by the presence of large, highly evolved species showing three 'parts' in the spire as recognized by Schaub (1963). These forms are totally absent in the Kopili Formation. Also, the number of species of *Nummulites* is fewer in the Kopili Formation than in the underlying Siju Limestone. Throughout the range of the genus in the Indian region the most striking change in the assemblages occurs at this horizon. The total absence of the typical representatives of the genus characterizing the older horizons, together with the appearance of a new group of forms in the Kopili Formation, makes the assemblage more akin to that of the Oligocene than to that of underlying Middle Eocene horizon. Indeed, in the absence of reticulate species it is difficult to distinguish the *Nummulites* assemblage of the Upper Eocene from that of the Oligocene.

In the presence of *N. fabianii* and abundant small to medium striate forms, the present assemblage is closely comparable to that recorded in the Priabonian of Europe. It is distinguished from the latter essentially by the absence of the *Nummulites striatus-garnieri* group of forms, which are common in the European Upper Eocene. The *Nummulites* assemblage in the Kopili Formation is, however, quite distinct from that known from the Upper Eocene of the Far East. *N. pengaronensis* is the only species common to the two regions. The *Nummulites yawensis-djokdjokartae* group of forms described from the Upper Eocene of the Malayan Archipelago are absent in the Kopili Formation of Assam. The absence of the well-known and widely distributed Upper Eocene reticulate *Nummulites* in the Far East constitutes the most striking difference between the Upper Eocene *Nummulites* assemblages of the two regions.

REFERENCES

ADAMS, C. G. 1965. The Foraminifera and stratigraphy of the Melinau Limestone, Sarawak, and its importance in Tertiary correlation. *Q. Jl geol. Soc. Lond.* **121,** 283–338, pl. 21–30.

BAYLISS, D. D. 1961. An investigation of certain larger fossil foraminifera from Pakistan. Unpubl. Ph.D. thesis, Univ. Wales, 1–253, pl. 1–26.

BIEDA, F. 1957. Die Fauna Grosser Foraminiferen im Obereozaen der Slowakei. *Geol. Sb., Bratislava*, **8,** 28–71, pl. 2–6.

—— 1963*a*. Larger foraminifers of the Tatra Eocene. *Inst. Geol. Prace*, **37,** 1–215, pl. 1–26.

—— 1963*b*. Septième niveau de grands Foraminifères dans le Flysch des Karpates Polonaises. *Ann. Soc. géol. Pologne*, **33,** 189–218, pl. 11–14.

BOUSSAC, J. 1906. Développement et morphologie de quelques foraminifères de Priabona. *Bull. Soc. géol. Fr.* (4) **6,** 88–97, pl. 1–3.

—— 1911*a*. Études stratigraphiques et paléontologiques sur le Nummulitique de Biarritz. *Ann. Hébert*, **5,** 1–95, pl. 1–24.

—— 1911*b*. Études stratigraphiques sur le Nummulitique alpin. *Mém. Carte géol. Fr.* 1–122, pl. 1–5.

BOZORGNIA, F. and KALANTARI, A. 1965. *Nummulites of parts of Central and East Iran—A thin-section Study*. 1–28, pl. 1–24. Tehran, Iran.

CAUDRI, C. M. B. 1934. Tertiary deposits of Soemba. *Diss. Leiden Natl. Mus. géol., Amsterdam*, 1–224, pl. 1–5.

CIZANCOURT, M. de. 1928. Sur quelques nummulites du flysch Karpatique et sur leur signification pour la stratigraphie des Karpates. *Kosmos, Warsz.* **53,** 287–312, pl. 1, 2.

—— 1930. Sur la stratigraphie et la faune Nummulitique du Flysch de l'Albanie. *Bull. Soc. géol. Fr.* (4) **30,** 195–212, pl. 22, 23.

CLOUD, P. E. JUN. and COLE, W. S. 1953. Eocene Foraminifera from Guam, and their implications. *Science, N.Y.* **117,** 323–4.

COLE, W. S. 1957. Larger Foraminifera from Eniwetok drill holes. *Prof. Pap. U.S. geol. Surv.* **260**-V, 743–84, pl. 231–49.

—— 1963. Tertiary larger Foraminifera from Guam. Ibid. **403**-E, 1–28, pl. 1–11.

—— and BRIDGE, J. 1953. Geology and larger Foraminifera of Saipan Island. Ibid. **253,** 1–45, pl. 1–15.

DACI, A. 1951. Étude paléontologique du Nummulitique entre Küçükçekmece et Catalca. *Rev. Fac. Sc. Univ. Istanbul*, (B) **16,** 89–246, pl. 1–5.

DAVIES, L. M. 1940. The Upper Khirthar beds of north-west India. *Q. Jl geol. Soc. Lond.* **96,** 199–230, pl. 9–12.

DOORNINK, H. W. 1932. Tertiary Nummulitidae from Java. *Verh. geol.-mijnb. Genoot. Ned.* **9,** 267–315, pl. 1–10.

DOUVILLÉ, H. 1912. Quelques foraminiferes de Java. *Samml. geol. Reichsmus. Leiden*, (1) **8,** 279–94, pl. 22–24.

EAMES, F. E. 1952. A contribution to the study of the Eocene in Western Pakistan and Western India: D. Discussion of the faunas of certain standard sections, and their bearing on the classification and correlation of the Eocene in Western Pakistan and Western India. *Q. Jl geol. Soc. Lond.* **107,** 173–96.

—— CLARKE, W. J. and BANNER, F. T. 1959. *Nummulites retiatus*, a synonym of *Nummulites fabianii*. *Revue Micropaléont.* **2,** 113.

EVANS, P. 1932. Explanatory notes to accompany a table showing the Tertiary succession in Assam. *Trans. Min. geol. metall. Inst. India*, **27,** 155–260.

FABIANI, R. 1905. Studio geo-paleontologico dei Colli Berici. *Atti Ist. veneto Sci.* **64,** 1797–1839.

FLANDRIN, J. 1934. La faune de Tizi Renif près Dra el Mizan (Algérie). *Bull. Soc. géol. Fr.* (5) **4,** 251–71, pl. 14–16.

—— 1938. Contribution a l'étude paléontologique du Nummulitique algérien. *Matér. Carte géol. Algér.* (1) Paleont. **8,** 1–155, pl. 1–15.

HAGN, H. 1960. Die stratigraphischen, palaeogeographischen und tektonischen Beziehungen zwischen Molasse und Helvetikum im ostlichen Oberbayern. *Geologica Bav.* **44,** 1–208, pl. 1–12.

HARPE, P. de la. 1877. Note sur les Nummulites des Alpes occidentales. *Verh. schweiz. naturf. Ges.* **60,** 227–32.

HARPE P. de la. 1883*a*. Étude des Nummulites de la Suisse et révision des espèces éocènes des genres *Nummulites* et *Assilina*. *Abh. schweiz. paläont. Ges.* **10,** 141–60, pl. 3–7.

—— 1883*b*. Monographie der in Aegypten und der libyschen Wüste vorkommenden Nummuliten. *Palaeontographica*, **30,** 157–216, pl. 30–35.

HENRICI, H. 1934. Foraminiferen aus dem Eozan und Altmiozän von Timor. Ibid. Suppl. 4, pl. 4, 1–56, pl. 1–4.

NAGAPPA, Y. 1951. The stratigraphical value of *Miscellanea* and *Pellatispira* in India, Pakistan and Burma. *Proc. Indian Acad. Sci.* (B) **33,** 41–8.

—— 1959*a*. Foraminiferal biostratigraphy of the Cretaccous-Eocene succession in the India–Pakistan–Burma region. *Micropaleontology*, **5,** 145–92, pl. 1–11.

—— 1959*b*. Note on *Operculinoides* Hanzawa 1935. *Palaeontology*, **2,** 156–60, pl. 21–23.

RAO, S. R. N. 1941. The Tertiary sequence near Surat and Broach (Western India), with description of foraminifera of the genus *Pellatispira* from the Upper Eocene of this region. *Half-yrly J. Mysore Univ.* N.S. (B) **2,** 5–17, pl. 1, 2.

ROVEDA, V. 1959. *Nummulites retiatus* nouvelle espèce de nummulite réticulée des Abruzzes (Italie). *Revue Micropaléont.* **1,** 201–7, pl. 1.

—— 1961. Contributo allo studio di alcuni macroforaminiferi di Priabona. *Riv. ital. Paleont. Stratigr.* **67,** 153–224, pl. 14–19.

SAMANTA, B. K. 1965. *Discocyclina* from the Upper Eocene of Assam, India. *Micropaleontology*, **11,** 415–30, pl. 1–4.

—— 1968. The Eocene Beds of Garo Hills, Assam, India. *Geol. Mag.* **105,** 124–35.

SCHAUB, H. 1963. Über einige Entwicklungsreihen von *Nummulites* und *Assilina* und ihre stratigraphische bedeutung. *Evolutionary trends in Foraminifera*, 282–97. Amsterdam.

SEN GUPTA, B. K. 1965. Morphology of some key species of *Nummulites* from the Indian Eocene. *J. Paleont.* **39,** 86–96, pl. 15–17.

VERBEEK, R. D. M. 1871. Die Nummuliten des Borneo-Kalksteines. *Neues Jb. Miner. Geol. Paläont.* Jahr. 1871, 1–14, pl. 1–3.

—— 1892. Voorloopig bericht over Nummuliten, Orbitoiden en Alveolinen van Java, en over den ouderdom der gesteenten waarin zij optreden. *Natuurw Tijdschr. Ned.-Indië*, **51,** 101–39, pl. 1.

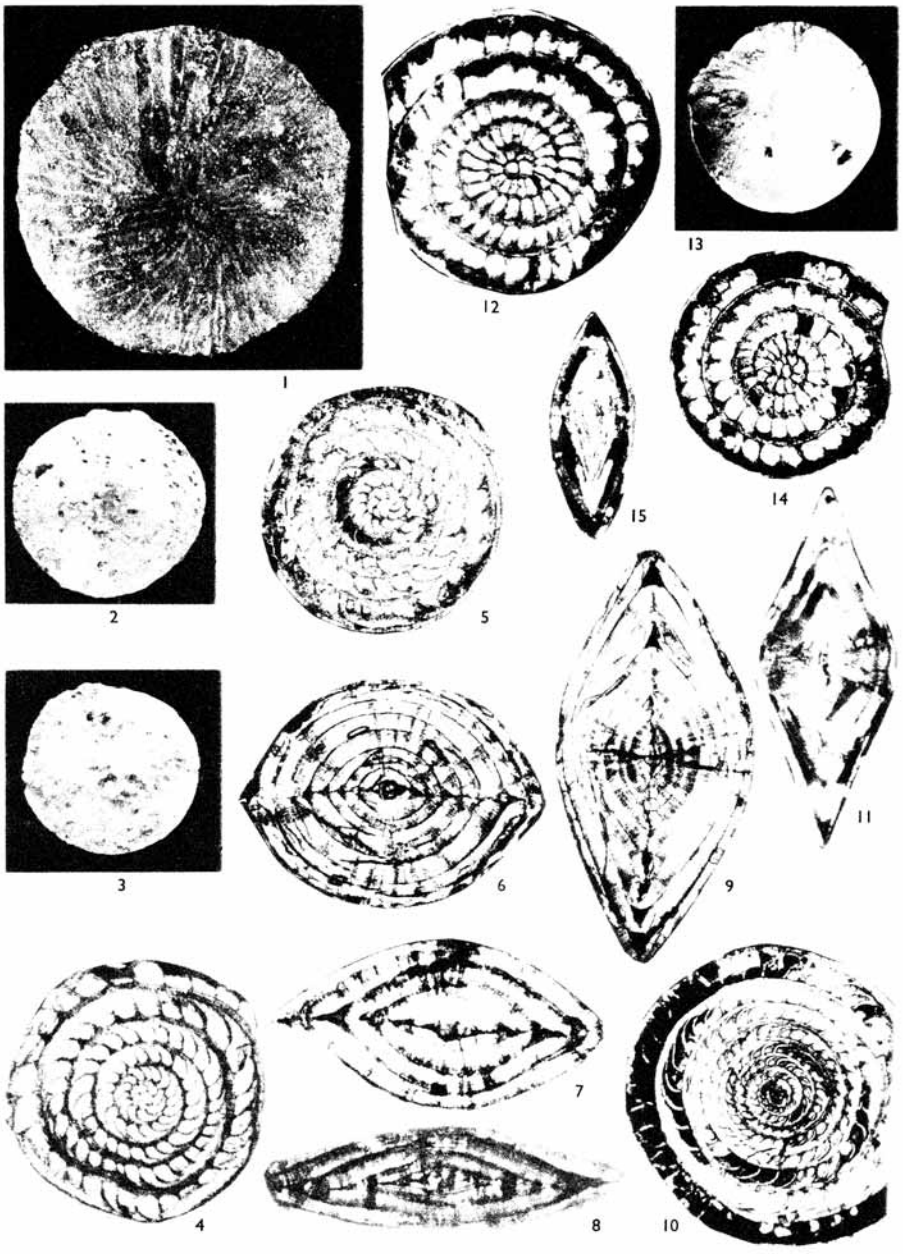
—— and FENNEMA, R. 1896. *Description géologique de Java et Madoura*. 2 vols. 1–1183, pl. 1–11. Amsterdam.

VLERK, I. M. van der. 1929. Groote foraminiferen van N. O. Borneo. *Meded. Dienst Mijnb. Ned.-Indië* **9,** 1–44.

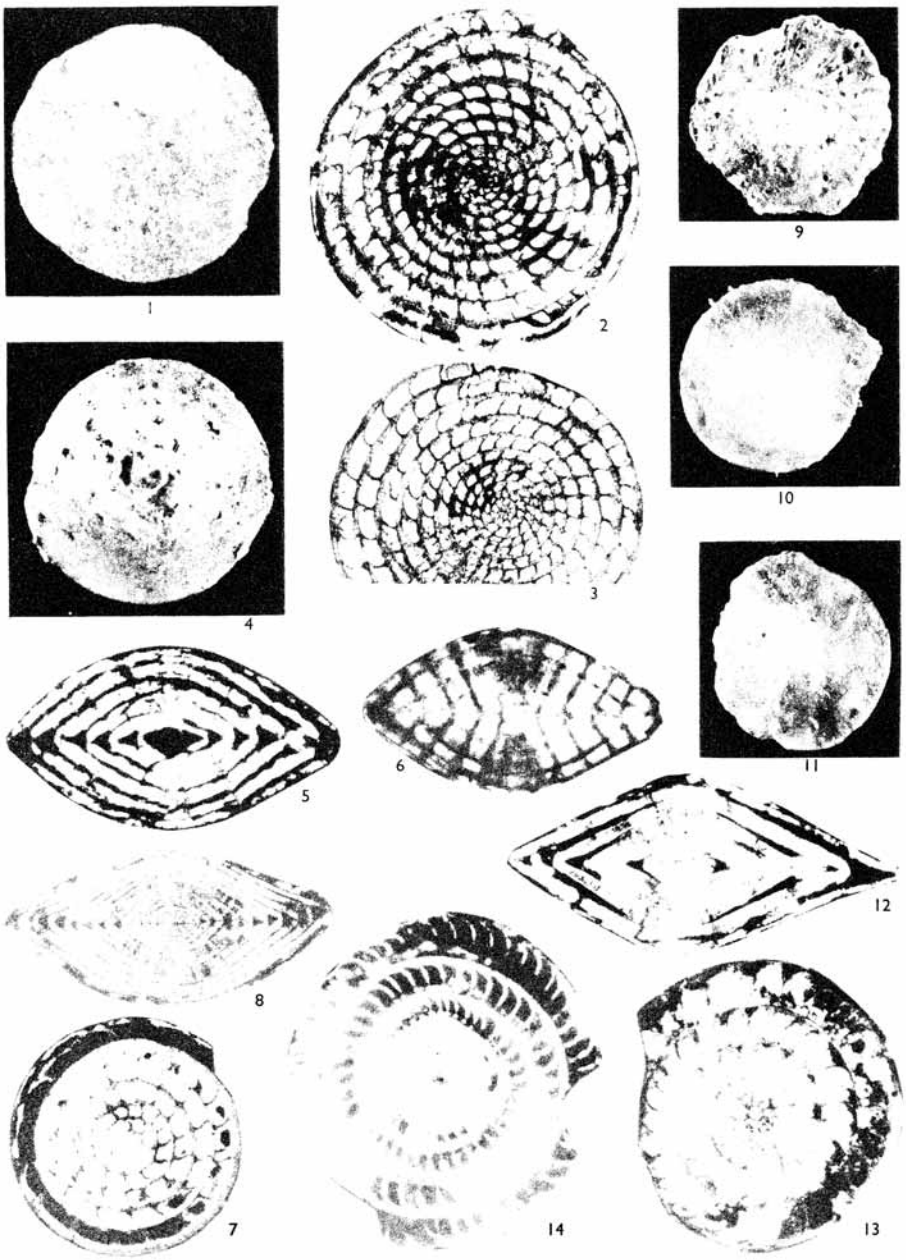
YABE, H. 1921. Note on some Eocene Foraminifera. II. Notes on two Foraminiferal Limestone from E. D. Borneo. *Sci. Rep. Tôhoku Univ.* II Series (Geol.), **5** (4), 100–6, pl. 17, 18.

BIMAL K. SAMANTA
Department of Geology
University College of Wales
Aberystwyth, Wales

Typescript received 3 January 1968



SAMANTA, Upper Eocene *Nummulites*



SAMANTA, Upper Eocene *Nummulites*