CHAPTER VI

SYSTEMATIC PALAEONTOLOGY

(excluding Linderina Schlumberger)
Order Foraminiferida
Family Miliolidae Ehrenberg, 1839
Genus Austrotrillina Parr, 1942

Type species: *Trillina howchini* Schlumberger, 1893

Diagnosis: Test biconvex in side view, subtriangular in polar view; later chambers triloculine in arrangement, each half-a-coil in length, three externally visible; external wall made up of an alveolar inner part and a thin, finely pilled outer skin; aperture pseudocribrate.

Distribution: The type species, *Trillina howchini*, was described by Schlumberger (1893) from Australia. The genus *Austrotrillina*, created by Parr (1942) with *T. howchini* as the type species, has been recognised from numerous localities between southern Europe and central Pacific Islands. It is better known from the Indo-Pacific than from the Tethyan province. There is no illustrated record of the genus from the Caribbean-American region.

Although Schlumberger (1893) dated the original material of the type species of the genus as Eocene, later investigation in the Muddy Creek, Victoria, Australia, the type locality of *A. howchini*, have failed to confirm its occurrence in rocks of Eocene age there. According to reliable published evidences the genus ranges from Early Oligocene to Early Miocene.

Occurrence in Kutch: There are several previous reports of species of *Austrotrillina* from Kutch. In the present area the
genus is poorly represented and was observed only in thin sections of rocks. These random sections are identified here as Austrotrillina sp.

**Austrotrillina sp.**

(Pl. 38, Fig. 8; Pl. 63, Fig. 11)

**Material:** Austrotrillina was observed in three samples represented by one horizontal and three off-centred sections.

**Remarks:** On the basis of the characters observed in the horizontal section the present sections are provisionally identified as Austrotrillina sp. More material including oriented sections is required for a definite identification.

**Distribution:** Austrotrillina sp. is restricted to the Middle Oligocene Bulepidina dilatata Zone of Kapurasi area and Late Oligocene Spiroclypeus ranjanae Zone of Guvar area, Kutch.

**Family Soritidae Ehrenberg, 1839**

**Genus Archaias de Montfort, 1808**

**Type species:** Nautilus angulatus Fichtel & Moll, 1798

**Diagnosis:** Test discoidal, planispiral involute to evolute; chambers becoming flaring to cyclical with irregular inter-septal pillars; apertures multiple, rows of pores on apertural face.
Distribution: The genus is cosmopolitan and has been reported from numerous localities of the three marine provinces including the Indian region. *Archaias* ranges from Middle Eocene to Recent.

Occurrence in Kutch: In the present area only one species, *Archaias* sp. is provisionally identified on the basis of the few sections observed in random thin sections of rocks.

*Archaias* sp.

(Pl. 17, Figs. 1-2)

Material: It is very rare in the present collection and has been examined only in random thin sections of rocks. One vertical and part of two horizontal sections of megalospheric generation were studied.

Remarks: The present specimens are provisionally identified as *Archaias* sp. More material is needed for definite identification of Kutch specimens.

Distribution: The species occurs very rarely in the upper part of the Coral Limestone Member of the Maniyara Fort Formation exposed in Kapurasi and Gugar areas. Here, it is restricted to Middle Oligocene *Eulepidina dilatata* Zone.

Genus *Orbitolites* Lamarck, 1801

Type species: *Orbitolites complanata* Lamarck, 1801

Diagnosis: Test discoidal, evolute; megalospheric nucleoconch
multilocular, chambers in successive alternate annular series; without stolons between chambers of the same series; apertures in vertical rows on the peripheral face.

**Distribution**: The genus has previously been reported from Europe, Asia and Africa. It is best known from the Tethyan region where *Orbitolites* attained its maximum development in number of species and individuals. A publication reporting *Orbitolites* from the America is lacking.

It has been reported to range from Late Palaeocene to early Late Eocene. However, good authorities like Eames (1971) and Hottinger (1973) hold that the stratigraphic range of the genus extends from the base of the Eocene to the top of the Middle Eocene.

**Occurrence in Kutch**: There is no previous published record of *Orbitolites* in Kutch. It occurs rarely in present material and examined only in thin sections of rocks. These random sections of *Orbitolites* are referred to the commonly occurring Middle Eocene species, *O. complanatus* Lamarck.

*Orbitolites complanatus* Lamarck, 1801

(Pl. 17, Fig. 4)

1801 *Orbitolites complanatus* Lamarck, p. 376.

**Material**: In the present material, *Orbitolites* was observed only in one sample of the Fulra Limestone from the Kapurasi area. Isolated specimens were not available for study.
Remarks: For a definite identification of the species, better and more materials are needed so that it can be compared with the Orbitolites reported from Europe. The present material is comparable to the widely distributed form, *O. complanatus*.

Distribution: *Orbitolites complanatus* described originally from the Lutetian of Paris Basin, is known from numerous localities spread over the region between southern Europe and eastern India. According to Hottinger et al. (1964) it is essentially restricted to the Lutetian. Here, in the Kapurasi area, it occurs in the Middle Eocene *Alveolina elliptica* Zone of Fulra Limestone.

Family Alveolinidae Ehrenberg, 1839

Genus *Alveolina* d'Orbigny, 1826

Type species: *Oryzaria boscii* Defrance, 1825

Diagnosis: Test spherical to elongated; chambers planispirally arranged, divided into rectangular chambers; septula alternating in adjacent chambers, with pre- and post-septal passages; two rows of apertures alternate in position.

Distribution: *Alveolina* has been reported from the Tethyan and the Indo-Pacific provinces where it constitutes a significant component of the Palaeocene-Eocene larger foraminiferal fauna. Here it occurs as rock-forming element. The genus has been described and illustrated in detail from southern Europe -
Fig. 16
North Africa region. *Alveolina* from the Indian region is rather poorly known. Like *Assilina*, *Alveolina* also is not known from the Caribbean-American region.

The genus ranges from Middle Palaeocene to Middle Eocene. The report of the occurrence of *Alveolina* in rocks of Upper Eocene age (Eames, 1971) has not been substantiated by the illustration of the fauna.

**Occurrence in Kutch:** In the present area, the genus occurs frequently in the upper part of the Fulra Limestone. Only one species, *Alveolina elliptica* is recognised in the present investigation. Fig. 16 shows the external parameters of *Alveolina*.

1. $D_1$ = Axial diameter of the test.
2. $D_2$ = Equatorial diameter of the test.

*Alveolina elliptica* (Sowerby), 1840

(Pl. 18, Figs. 4-11)

1840 Faciolites elliptica Sowerby, pl. 24, fig. 17.
1925b *Alveolina elliptica* (Sowerby); Nuttall, pp. 378-384, pl. 20, figs. 1-5.
1960 *Alveolina elliptica* (Sowerby); Hottinger, p. 146, pl. 12, figs. 1-3.

**Material:** Free specimens and sections belonging to the megaspheric generation were examined. Specimens from the Matiwarewali Nadi section, Godhatad-Kapurasi area are used here for descrip-
Fig. 17 Scatter diagram of $D_1$ vs. $D_2$ for *Alveolina elliptica* (Sowerby) (Form A) from the Fulra Limestone.
tion and illustration of the species. Sixty-nine specimens examined externally, four in axial sections and four in equatorial sections.

**Description**: The test is medium to large, ellipsoidal to sub-globular in shape. In equatorial sections (Pl. 18, Figs. 4-7) the proloculum is small, circular followed by very narrow, much elongated chambers arranged planispirally. Inner whors are coiled loosely while the outer whors are arranged very tightly. Flosculinised individuals are much more commonly than the unflosculinised ones. The degree of flosculinisation varies considerably from only inner few whors flosculinised to almost all except a few last-formed ones. The flosculinised walls are much thicker than the chamber cavity. The septa are short and curved. Pre- and post-septal passages are distinct. In some flosculinised individuals the unflosculinised outer half of the section often exhibits much irregularity.

The axial sections are elliptical to oval in outline (Pl. 17, Figs. 8-11). The embryonic apparatus is small, circular to subcircular. The chambers are typically narrow and are divided into small rectangular chamberlets subequal in shape and size by very fine septula alternating in adjacent chambers. The chamberlets are very minute in size. The size increases slightly in the polar region.

**Measurements**: The axial diameter of the test ranges from 4.7 mm to 10.9 mm and the equatorial diameter from 3.5 mm to 7.1 mm (Fig. 17).
Remarks: The species is characterised by medium to large ellipsoidal test, small subcircular embryonic apparatus, partly flosculinised whorl walls and very minute chamberlets separated by fine septula.

*A. elliptica* was originally described from Kutch by Sowerby (1840). Nuttall (1926) reported the species from different parts of India-Pakistan region. He examined the specimens collected from Godhatad also. According to him, there are three varieties of *Alveolina*, *A. elliptica* type, *A. elliptica* var. a. and *A. elliptica* var. b. which can be distinguished by the absence or presence and degree of flosculinisation.

In Matiwali Nadi section, Godhatad-Kapurasi area all the alveolines examined were shown variations in the degree of flosculinisation. There is conspicuous variation in the shape and size of the test also. All these specimens are assigned here to *A. elliptica*.

Distribution: According to Hottinger (1960) *A. elliptica* is not represented in the southern Europe - Mediterranean region with *Alveolina elliptica nuttalli* treated as specifically distinct from Sowerby's species. There is no reliable record of the species outside the India-Pakistan region. In Kutch, *A. elliptica* is restricted to the Middle Eocene Fulra Limestone and is known to occur commonly only in its upper part. In Kapurasi and Guvar areas it is restricted to *A. elliptica* Zone of late Middle Eocene age.
Genus *Borelis* de Montfort, 1808

1928 *Neoalveolina* Silvestri, p. 35.

Type species: *Nautilus melo* var. B. Fichtel & Moll, 1798

**Diagnosis**: Test small, average axial diameter up to 2 mm.; nautiloid to fusiform; nepionic part irregularly coiled; septula aligned in adjacent chambers; with preseptal passage only and essentially one row of apertures.

**Distribution**: All authentic records of *Borelis* are restricted to sediments of Late Eocene to Recent age. The previous reports of *Borelis* from rocks older than the Late Eocene resulted mainly from incorrect generic identification. There is no reliable record of true *Borelis* from the pre-Recent sediments of the Caribbean-American region (Cole, 1760). Thus, the fossil occurrence of the genus is restricted to the Tethyan and Indo-Pacific provinces while during the Recent it occurs also in the Atlantic.

**Occurrence in Kutch**: A few off-centered sections of *Borelis* was observed in thin sections of samples from Kapurasi area. Only two species, *B. philippinensis* Hanzawa and *B. pygmaeus* Hamzawa have been identified.

*Borelis philippinensis* Hanzawa, 1949

(Pl. 19, Fig. 5)

1949 *Borelis philippinensis* Hanzawa, pp. 155-157, pl. 4, figs. 1-3, 6-7, non figs. 4-5.
**Borelis philippinensis** Hanzawa; Samanta, Lahiri & Bandyopadhyay, pp. 303-304, pl. 1, fig. 3.

**Material**: Two off-centred sections of a megalospheric specimen was examined from random thin section of rocks.

**Remarks**: The figured near-axial section is morphologically identical to *B. philippinensis* recorded by Samanta et al. (1985) from the Lakhpat area of Kutch. More oriented sections are required for a definite identification.

**Distribution**: In the present material this species occurs in two samples collected from the Coral Limestone Member of the Maniyara Fort Formation exposed in the Kapurasi area. Here it is restricted to the *Eulepidina dilatata* Zone of Middle Oligocene age. This is the first report of *B. philippinensis* from the present area of study. Recently, Samanta et al. (1985) reported and illustrated it from northwestern Kutch. This species was originally described from Late Oligocene of Philippines Islands (Hanzawa, 1949) and reported to range from Middle Oligocene to Late Oligocene.

**Borelis pygmaeus** Hanzawa, 1930

(Pl. 19, Fig. 4)

1929 *Borelis* sp. indet. Yabe & Hanzawa, p. 181, pl. 15, figs. 12-13; pl. 23, fig. 7.
1930 *Borelis (Fasciolites) pygmaea* Hanzawa, pp. 94-95, pl. 26, figs. 14-15.

1932 *Neolveolina pygmaea* (Hanzawa), Bakx, pp. 237-238, pl. 3, figs. 14-20.

1937 *Neolveolina pygmaea* (Hanzawa); Reichel, pp. 112, 138.

1938 *Neoalveolina pygmaea* (Hanzawa); Crespin, p. 10, pl. 3, figs. 3, 5.

1947 *Borelis pygmaeus* Hanzawa; Hanzawa, pp. 9-11, pl. 5.

1947 *Neoalveolina pygmaea* (Hanzawa); Bursch, pp. 28-29, figs. 11, 15, 19.

1953 *Borelis pygmaeus* Hanzawa; Cole in Cole & Bridge, p. 27, pl. 12, fig. 16; pl. 13, figs. 4-7.

1957 *Borelis pygmaeus* Hanzawa; Hanzawa, pp. 55-56, pl. 34, figs. 8-9.

1957 *Borelis pygmaeus* Hanzawa; Cole p. 336, pl. 110, figs. 5-7, non. pl. 102, fig. 1.

1959 *Borelis pygmaeus* Hanzawa; Adams, p. 76, pl. XV, fig. d.

1959 *Borelis pygmaeus* Hanzawa; Cole, p. 767; pl. 240; figs. 11-13.

1964 *Neoalveolina pygmaea* (Hanzawa); Adams, p. 159, pl. 47, fig. 7.

1965 *Neoalveolina pygmaea* (Hanzawa); Adams, p. 334, pl. 25, figs. a-c.

1974 *Borelis pygmaeus* Hanzawa; Adams & Belford (Pars), pp. 448-490, pl. 71, figs. 11-14, non. pl. 71, figs. 9-10.

1976 *Borelis pygmaeus* (Hanzawa); Matsumaru, pp. 194, 196, pl. 3, fig. 16; pl. 4, fig. 32.

1985 *Borelis pygmaeus* Hanzawa; Samanta, Lahiri & Bandyopadhyay, pp. 304, 306-307, pl. 1, figs. 4-5; pl. 2, figs. 1-7.
Material: *B. pygmaeus* is a very rare from represented by off-centred sections of megalospheric specimens in random thin section of rocks.

Remarks: The section illustrated here is a near-axial section. Morphologically, the present material is identifiable with that described from Kutch by Samanta et al. (1985).

Distribution: The species was recognised only from Kapurasi area where it is restricted to two samples belonging to the *Eul epidina dilatata* Zone of Middle Oligocene age. There is no previous record of this species from the present area of study. Earlier, Samanta et al. (1985) described and profusely illustrated it from the Middle Oligocene of Lakpat, northwestern Kutch. *B. pygmaeus* was originally described from Philippines. It is widely distributed in the Indo-Pacific province, where it ranges from Early Oligocene to Early Miocene.

*Family Rotaliidae Ehrenberg, 1839*
*Genus Dictyoconoides Nuttall, 1925*

Type species: *Comulites cooki* Carter, 1861

Diagnosis: Test conical; cortical layer of chambers arranged trochospirally, spire multiple; umbilicus very wide with numerous cavities formed by horizontal partitions traversed by vertical pillars running from beneath the cortical chamber layer to the vertical surface of the umbilicus; septa double with basal intercameral foramen and intraseptal and subsutural canal.
Distribution: Dictyoconoides has been represented from numerous localities between eastern India and northeast Africa. In number of species and individuals it is best represented in Pakistan. There is no report of Dictyoconoides from Europe and the America. Again, it is not represented in East and West Indies. Thus, among the closely related conical rotalids Dictyoconoides is characterised by restricted geographic distribution.

Stratigraphically, the genus is reported to range from Upper Palaeocene to the top of the Middle Eocene in the India-Pakistan region. It has not yet been recorded from rocks younger than the Middle Eocene. It attained its maximum distribution during the Middle Eocene.

Occurrence in Kutch: In Kutch, the genus occurs in the Fulra Limestone and is represented by only one species, Dictyoconoides cooki (Carter). The decorticated specimens (pl. 18, fig. 1) show a cortical layer of rectangular chambers arranged spirally with several intercalary whorls introduced during ontogeny. There is no noticeable change in size of the chambers with growth.

Dictyoconoides cooki (Carter) 1861
(Pl. 18, Figs. 1-3)

1861 Conulites cooki Carter, p. 83, pl. 15, figs. 7a-g.
1925 Dictyoconoides cooki (Carter); Nuttall, pp. 384-387, pl. 21, figs. 1-9.
1926 Dictyoconoides cooki (Carter); Douville, p. 23-26, pl. 2.
1954 Dictyoconoides cooki (Carter); Smout, p. 59-60, pl. 9, figs. 1-5.

Material: Both isolated specimens and sections seen in random thin sections of rocks were examined. All materials belong to megalospheric generation. Five isolated specimens and four axial sections were studied.

Description: Test is medium in size, conical, dorsal side convex with pointed apex (Pl. 18, Fig. 1) and ventral side moderately convex. The decorticated specimens (Pl. 18, Fig. 1) show a cortical layer of rectangular chambers arranged trochospirally with several intercalary whorls introduced during ontogeny. There is no noticeable change in size of the chambers with growth. The apical region on the dorsal side closely papillate. The chambers of the last whorl form a very narrow, rather smooth band on the ventral side (Pl. 18, Fig. 2). The umbilical area is ornamented with large closely spaced subequal granules varying little in size and separated by narrow grooves.

The axial section (Pl. 18, Fig. 3), is very distinctive with a narrow dorsal chamber and a very wide umbilicus beneath. The dorsal side is reflexed upwards and the ventral side is distinctly convex. The protoculum is apical and circular. The chambers are semilunar in shape and separated by very thin walls. The most prominent feature in the umbilicus is the vertical to nearly vertical pillars extending from top of the umbilicus to
its base. The pillars are numerous and vary little in thickness with growth. They are well separated from the adjacent ones. The horizontal plates are distinctly thinner than the pillars and vary much in their course from one side of the chamber layer to the other side. The cavities are well-developed and are arranged in irregular rows between the pillars.

**Measurements**: The diameter of test varies from 5.9 mm to 9.0 mm, the height from 3.0 mm to 4.55 mm and the diameter of umbilical granules from 68 μm to 118 μm.

**Remarks**: *D. cooki* the type species of Dictyoconoides Nuttall was originally described by Carter (1861) from Pakistan as the type species of his new genus *Conulites*. As the generic name *Conulites* was preoccupied, Nuttall proposed the new genus *Dictyoconoides* for Carter's species. The structures of *D. cooki* has been described and illustrated in detail by a number of previous workers. Nuttall (1925) figured it from Kutch. It is a distinctive and readily recognisable larger foraminifera in present material.

**Distribution**: Illustrated records of the species are restricted to rocks of Middle Eocene age. Geographically it is reported to occur in the region between Somaliland in the west to Assam in the east. In Kutch, it is restricted to the Fulra Limestone. In the present area it occurs infrequently in the middle to late Middle Eocene *Discocyclina sowerbyi* and *Alveolina elliptica* Zones of the Fulra Limestone.
Genus **Lockhartia** Davies, 1932

Type species: **Dictyoconoides haimei** Davies, 1927.

**Diagnosis**: Test lenticular to conical, the height not exceeding the diameter, composed of a peripheral layer of chambers arranged in a simple trochoid spire; umbilicus well-developed, divided into numerous cavities by pillars passing continuously through horizontal partition; septa double with basal intercameral foramen; umbilical region on the ventral side occupied by granules separated by shallow grooves; wall calcareous of laminated radially fibrous calcite, coarsely perforate; aperture an interiomarginal slit.

**Remarks**: Because of their optically striking shape, complexity of the structure and stratigraphic usefulness, the conical rotaliids have received special attention of previous workers. Originally described as representative of the genus *Dictyoconoides* Nuttall, *D. haimei* was later designated as the type species of the new genus *Lockhartia* by Davies (1932). The description of the genus provided by Davies (1932), although adequate for its distinction from the closely related genus *Dictyoconoides* Nuttall, was not detailed enough. Later, Smout (1954), in course of a detailed investigation on the family Rotaliidae, described and discussed the external and internal structures of *Lockhartia* and the related genera supported by numerous illustrations. The redescriptions of *Lockhartia* presented by Smout (1954) has been followed by later authors (see also Ellis & Messina, Suppl.)
The distinction between the two genera rests solely on the character of the spire - simple in Lockhartia and multiple in Dictyoconoides. They have exactly the same umbilical structure. Thus, in axial section there may be difficulty in satisfactorily distinguishing between the two genera. It needs rethinking whether the occurrence of intercalary whorls merits such taxonomic significance in these conical rotaIiids.

Samanta (1981, p. 816) has earlier pointed out, "Although the generations of intercalary whorls in Nummulites significantly modifies the appearance of the equitorial plane, ....... Yet the same feature in the Rotaliidae has been used as a basis for erecting two genera (Dictyoconoides and Dictyokathina) despite the fact that other important structural modifications found in Nummulites are absent".

Lockhartia differs essentially from Rotalia in the structure of the umbilicus. Externally the two genera are not always readily distinguished. Recently, Muller-Merz (1980) have further analysed the structure of the type species of these genera with the help of serial sectioning and SEM photographs and reaffirmed that the arrangement of the elements in the umbilicus is distinctive for these two genera, Rotalia and Lockhartia. The morphological and stratigraphical evidences support the derivation of the genus from Rotalia Lamarck during the Palaeocene.
Distribution: Originally described from the Indian subcontinent the genus has been reported from numerous localities between Indonesia in the East and Caribbean-American region in the West. Smout (1954) reviewed the distribution of Lockhartia and observed that Rutten's (1948) identification of specimens from Borneo as Lockhartia was not correct while the species described from the American continent up to that time do not belong to Lockhartia. According to him the authentic record of the genus is restricted between India in the east and East Africa in the west. Since Smout’s redescription of the genus it has been reported from the Caribbean-American region by Levin (1957), Pessagno (1960) and Drooger (1960). It occurs also in North Africa (Haynes, 1962) and in Turkey (Bullerlin & Monod, 1969). Both in number of species and in individuals the genus is known to be best represented in the region between Pakistan and Arabian Peninsula.

The genus ranges from Palaeocene to Middle Eocene. There is no authentic record of Lockhartia from rocks older than the Middle Palaeocene Globorotalia angulata Zone (Samanta 1976). The upper limit extends to the late Middle Eocene Truncorotaloides rhobi Zone. A definite record of the genus from younger horizons is lacking.

Occurrence in Kutch: In Kutch, Lockhartia occurs infrequently in all the three Eocene formations, Naredi, Harudi and Fulra Limestone, exposed in all the four traverses (Traverses I-IV;
Figs. 9-12) examined. The number of isolated specimens available were not adequate for precise identification of all the species represented in the present area. The following six species are identified:

1. **Lockhartia garoensis** Samanta
2. **L. hunti** Ovey
3. **L. pustulosa** Smout
4. **L. tipperi** (Davies)
5. **L. sp. aff. L. conditi** (Nuttall)
6. **L. sp. cf. L. sijuensis** Samanta

These are described below:

**Lockhartia garoensis** Samanta, 1961

(Pl. 20, Figs. 1-3; Pl. 21, Figs. 3-4; Pl. 59, Fig. 10).

1961 **Lockhartia hunti** Ovey var. **garoensis** Samants, p. 40, figs. 4-5.

**Material**: Only megalospheric specimens were examined. Six isolated specimens and four axial sections were studied.

**Remarks**: In course of describing it as a new variety of **L. hunti** Samanta (1961) remarked that it differs from Ovey's species in having more conical dorsal side, prominently convex base and narrow umbilical pillars with prominent horizontal plates between them. These differences are considered here to be of specific significance and hence, it is named here as **L. garoensis**. The occurrence of granules in the apical region is a distinctive
feature of this Middle Eocene species.

The specimens from Kutch are identifiable with Samanta's form. The external features are shown here by SEM photographs. The occurrence of well-separated, spirally arranged small granules in the apical region of the dorsal side is shown in Pl. 20, Fig. 1. The specimens illustrated in Pl. 20, Figs. 2-3 show rather narrow peripheral band encircling the wide umbilical region covered with numerous small, slightly elevated granules well-separated from the adjacent ones by grooves. The axial section illustrated in Pl. 21, Fig. 3 shows all the distinctive features of the species, namely, conical dorsal side with few apical pustules, convex base, and narrow umbilical pillars well-separated from each other and diverging from the apex.

**Measurements**: The diameter of the test varies from 1.40 mm to 1.50 mm and the height from 1.00 mm to 1.10 mm. The diameter of granules on ventral side ranges from 0.10 mm to 0.15 mm and those on dorsal side from 0.15 mm to 0.20 mm.

**Distribution**: Samanta (1961) described it from the middle Middle Eocene of Garo Hills, eastern India. In Kutch it occurs rarely to commonly in the Harudi Formation of Guvar area and the Fulra Limestone of both Guvar as well as Godhatad-Kapurasi areas. Here, it is restricted to the middle Middle Eocene *Nummulites obtusus* and *Discocyclina sowerbyi* Zones.
Lockhartia hunti Ovey, 1947

(Pl. 20, Figs. 5-6; Pl. 21, Figs. 8-9)

1947 *Lockhartia hunti* Ovey, pp. 572-573, pl. 10, figs. 1-6; pl. 11, fig. 1.

1954 *Lockhartia hunti* Ovey, Smout, p. 54, pl. 4, fig. 7.

1961 *Lockhartia hunti* Ovey, Samanta, p. 40, figs. 6-10.

1980 *Lockhartia hunti* Ovey, Rahaghi, p. 42, pl. 8, figs. 11-12.

**Material**: Only megalospheric specimens were studied. Five isolated specimens and four axial sections were examined.

**Remarks**: *L. hunti* was described and illustrated in detail by Ovey (1947) who discussed the affinities of his new species to other species of *Lockhartia* described upto that time. According to its author, the species is characterised by its low conical test with gently convex base, usually smooth dorsal side, umbilical region crowded with granules and encircled by moderately wide peripheral band of 10 to 13 large chambers, wide umbilical cavity and fairly thick close-spaced subparallel pillars with horizontal plates discernible between them. Ovey opined that *L. hunti* appears to be intermediate between the *L. haimei-tipperi* and the *L. newboldi-conditi* groups.

The specimen illustrated by Smout (1954) from Qatar shows a low spire, smooth dorsal side, wide umbilical area covered by subequal close-spaced granules and wide peripheral band of chambers marked by depressed septal sutures and is readily identifiable.
with Ovey's species. However, the specimens from Iran identified as *L. hunti* by Rahaghi (1980) do not exhibit all the essential characteristics of the species.

From the Indian subcontinent the species was first reported by Ghosh (1959) who did not describe or illustrate his specimens. Samanta (1961) first provided illustrations of *L. hunti* from this region. The Kutch specimens show the distinctive features of the species. Hence they are identified as *L. hunti*. The SEM photographs show clearly the external features of the species. As pointed by Ovey in the original publication, here also a few granules occur in the axial region of the specimen figures in Pl. 20, Fig. 5. There appears to be a fewer chambers in the last whorl in the present specimens (Pl. 20, Fig. 6).

**Measurements** : The diameter of the test varies from 1.30 mm to 1.45 mm and the height from 0.80 mm to 0.90 mm. The granules on ventral side ranges from 0.05 mm to 0.20 mm in diameter.

**Distribution** : Ovey (1947) described *L. hunti* from Somaliland, Africa, from rocks which were dated as ? Uppermost Lower Eocene. Smout (1954) recorded it from the Lower Eocene of Qatar. In India the only previous documented record of *L. hunti* is that by Samanta (1961) who identified it from middle Middle Eocene beds. The recorded range of the species is therefore Lower to Middle Eocene. In Kutch, the species occurs commonly in the Fulra Limestone of Harudi, Guvard and Godhatad-Kapurasi areas. Here, it is restricted to the *Discocyclina sowerbyi* and *Alveolina*
elliptica Zones of middle to late Middle Eocene age.

**Lockhartia pustulosa** Smout, 1954

(Pl. 21, Fig. 10)

1954 *Lockhartia hunti* Ovey var. *pustulosa* Smout, pp. 54-55, pl. 4, figs. 8-10.

**Material** : Only one axial section of a megalospheric specimen was examined.

**Remarks** : In describing *L. hunti* var. *pustulosa* from Qatar Smout (1954) remarked that it resembles *L. hunti* closely in all respects excepting the dorsal pustules. However, an examination of the original publication reveals that Smout's form differs distinctly from *L. hunti* in its conical dorsal side, distinctly convex base, very prominently pustulate dorsal surface and few relatively narrow, well-separated pillars. It is treated here as specifically distinct from *L. hunti*.

In Kutch the species was recognised only in random thin sections of rocks. The axial section illustrated in Pl. 21, Fig. 10 shows the conical dorsal side with pustulate apical region, convex base, well-developed pillars and deep semilunar chambers. It is considered as identifiable with *L. pustulosa* Smout.

**Measurements** : The diameter of the test is 2.4 mm and the height is 1.55 mm. The diameter of umbilical pillars varies from 0.05 mm to 0.15 mm. The diameter of apical pillars range from 0.10 mm to 0.30 mm.
Distribution: Smout (1954) described it from the Lower Eocene of Qatar. In Kutch, it occurs rarely in the Naredi Formation of Nareda area and is restricted to Assilina laxispira Zone of Early Eocene age.

Lockhartia tipperi (Davies), 1926
(Pl. 20, Fig. 4; Pl. 21, Figs. 6-7)

1926 Conulites tipperi Davies, pp. 247-8, pl. 18, fig. 8.
1931 Dictyoconoides tipperi (Davies); Nuttall & Brighton, pp. 56-7, pl. 3, figs. 14-17.
1932 Lockhartia tipperi (Davies); Davies, p. 407.
1937 Lockhartia tipperi (Davies); Davies in Davies & Pinfold, pp. 48-9, pl. 6, figs. 14-16, pl. 7, fig. 17.
1954 Lockhartia tipperi (Davies); Smout, p. 55, pl. 4, figs. 11-13.
1962 Lockhartia tipperi (Davies); Sander, pp. 24-5, pl. 4, fgs. 25, 26, 33-36.
1980 Lockhartia tipperi (Davies); Muller-Merz, pp. 31-32, 35, pl. 10, figs. 1,3.

Material: Only megalospheric specimens were examined. The present material consists of three isolated specimens and two axial sections.

Remarks: L. tipperi was originally described as Conulites tipperi by Davies (1926) on the basis of an examination of individuals occurring in hand specimens of rock from Sind. There was only one illustration in the original publication which was,
thus, not adequate for its complete understanding. Later, Nuttall & Brighton (1931) referred specimens from Somaliland to Davies' species. Davies (in Davies & Pinfold, 1937) provided a more complete account of the species based on collections from Salt Range where the species was well-represented. Smout (1954) in course of a restudy of the genus provided description and good illustrations of species from Qatar. He remarked that the large size and the external appearance are distinctive of *L. tipperi*.

Externally, with their flat spire, ventrally more convex shape, numerous close-spaced subequal granules covering the wide umbilical area encircled by a smooth band, and internally, with large umbilical cavity with numerous distinctly developed pillars and well-developed umbilical plates the present specimens are identifiable with *Lockhartia tipperi*. The SEM photograph in Plate 20, Fig. 4 shows clearly the character of the granules and the grooves separating them. It is a very distinctive representative of the genus in present collections. Often the pillars are quite thick leaving only a very narrow spaces between them (Plate 21, Fig. 6).

**Measurements**: The diameter of the test varies from 2.35 mm to 2.80 mm and the height from 1.30 mm to 1.55 mm. The granules on the ventral side ranges from 0.08 mm to 0.25 mm and those on dorsal side from 0.07 mm to 0.20 mm.

**Distribution**: The rock containing the type material of the species was originally registered as "Khirthar" in the collec-
tions of the Geological Survey of India, Calcutta. Later Davies (in Davies & Pinfold, 1937) re-examined the associated larger foraminifera of the sample and concluded that the original material came from the Lowest Laki (Lower Eocene) beds of Sind. The recorded range of *L. tipperi* is Palaeocene to Lower Eocene. Outside the Indian subcontinent, the species has been reported from Somaliland, Qatar and Saudi Arabia where it is restricted to the Lower Eocene. In Kutch, the species occurs commonly in the Naredi Formation of Nareda and Guvar areas. Here, it is restricted to the *Assilina laxispirea* Zone of Early Eocene age.

*Lockhartia* sp. aff. *L. conditi* (Nuttall), 1926

(Pl. 2, Fig. 5; Pl. 59, Fig. 12)

aff. 1926 *Dictyoconoides conditi* Nuttall, p. 119, pl. 11, figs. 7-8.

**Material:** Only one axial section of a megalospheric specimen were examined.

**Remarks:** In its conical dorsal side with convex base, apparently unornamented apical region, thick, conical pillars separated by very narrow spaces, the section shows closest affinity to *L. conditi* as discussed and illustrated by Smout (1954) and is thus provisionally identified as *L. aff. conditi* (Nuttall). Lack of adequate material does not permit a precise identification.

**Measurements:** The diameter of the test is 2.0 mm and the height
is 1.35 mm. The surface diameter of pillars on ventral side ranges from 0.1 mm to 0.2 mm and on dorsal side from 0.07 mm to 0.20 mm.

Distribution: In Kutch, the species occurs rarely in the Naredi Formation of Nareda area and is restricted to the Early Eocene Assilina lexispira Zone.

Lockhartia sp. cf. L. sijuensis Samanta, 1961

(cf. 1961 Lockhartia sijuensis Samanta, p. 39, figs. 1-3.

Material: Only three axial sections of megalospheric specimens were studied.

Remarks: Samanta (1961) systematically described his new species, L. sijuensis supported by five photomicrographs showing its external and internal features. It was distinguished from L. hunti Ovey in its much smaller size and the discontinuous and narrower umbilical pillars. Two nearly-axial sections observed in rock sections are here treated as most closely comparable to L. sijuensis Samanta in the size of the test and the character of the umbilical pillars. The Kutch form differs distinctly from Lockhartia alveolata Silvestri (1942), described from the middle Lutetian of Somaliland, in the shape of the test, lack of pustules on the dorsal side, fewer whorls and narrower pillars well-separated from each other. More material is required for a
precise identification of the present form.

**Measurements**: The diameter of test varies from 1.20 mm to 1.35 mm and the height from 0.95 mm to 1.00 mm. The surface diameter of umbilical pillars ranges from 0.05 mm to 0.17 mm and those of apical pillars from 0.10 mm to 0.15 mm.

**Distribution**: Samanta described *L. sijuensis* from rocks of middle Middle Eocene age. In the present area, *L. cf. sijuensis* occurs rarely in the Fulra Limestone of Guvar and Godhatad-Kapurasi areas and is restricted to the middle to late Middle Eocene *Discocyclina sowerbyi* and *Alveolina elliptica* Zones.

**Genus Pararotalia** Le Calvez, 1949

**Type species**: *Rotalia inermis* Terquem, 1882

**Neorotalia** Bermudez, 1952, p. 75

**Woodella** Haque, 1956, p. 124

**Diagnosis**: Test plano-convex to biconvex, low trochospiral, carnate; chambers lobate or produced into spines; umbilicus filled by single plug and apertures ventral, interiomarginal and extraumbilical-umbilical, with lip.

**Distribution**: *Pararotalia* is cosmopolitan and has been reported by from numerous localities from rocks ranging in age from Late Cretaceous to Recent. It attained its maximum development during the Oligocene. The taxonomy and stratigraphy of the genus have
been established through studies on populations from European and American localities. The genus is not known adequate from India and adjacent regions.

**Occurrence in Kutch:** In Kutch *Pararotalia* is a frequently occurring rotalid and has been reported by a number of previous workers. In present material it has been recognised in thin section of rocks from Guvar and Kapurasi area. Only one species, *Pararotalia mecatepecensis* (Nuttall) is recognised.

*Pararotalia mecatepecensis* (Nuttall), 1932
*(Pl. 17, Figs. 5-6)*

1932 *Rotalia mexicana* Nuttall var. *mecatepecensis* Nuttall p. 26, pl. 4, figs. 11-12.

1957 *Rotalia mecatepecensis* Nuttall; Hanzawa, pp. 59-60, pl. 2, figs. 1-11.

1958 *Pararotalia mexicana mecatepecensis* (Nuttall); Reiss & Merling, pl. 2, figs. 18-24.

**Material:** Only sections of random thin section of rocks were examined. Isolated specimens were not available for study.

**Remarks:** Axial sections showing unequally biconvex test, acute periphery, often keeled, a single plug filling up the narrow umbilicus have been identified here as *P. mecatepecensis* (Nuttall). The identification of the Mexican specimens as *Rotalia* was later pointed out by Reiss & Merling (1958) to be
incorrect and on the basis of more detail study of external and internal features they assigned it to Pararotalia Le Calvez. The identification of the present material as based on a comparison with the illustrations provided by Reiss & Merling (1958).

**Distribution**: The species is widely distributed and has been reported from the Americas, Europe, Africa and Asia. It is usually treated as an Oligocene-Miocene form. It occurs both in the upper part of the Coral Limestone Member exposed near Kapurasi village and in the overlying Ber Moti Member exposed near Guvar village. Here, the species ranges from Middle Oligocene *Eulepidina dilatata* Zone to Late Oligocene *Spiroclupeus ranjanae* Zone.

**Family Nummulitidae de Blainville, 1825**

**Diagnosis**: Test small to large; discoidal, compressed lenticular to strongly inflated, globose; planispiral; secondary skeleton forming a marginal cord along the periphery of whorls; wall calcareous, perforate; complex canal system consisting of septal and marginal canals; aperture at the base of the apertural face.

**Range**: Palaeocene - Recent.

**Remarks**: Family Nummulitidae as defined here includes Nummulites, Assilina, Operculina, Operculinoides and Ranikothalia. Genera with chamberlets belong to the family Cycloclypeidae
(see Haynes, 1981). **Sulcoperculina** Thalman, an Upper Cretaceous genus with asymmetric test and a peripheral median sulcus, is excluded from the family Nummulitidae which is Cenozoic in age. The genera **Biplanispira** Umbgrove, **Pellatispira** Boussac and **Miscellanea** Pfender, although included by Cole (1964) in the subfamily Nummulitinae, are considered by majority of the authors to be morphologically and phylogenetically distinct from **Nummulites**, the type genus of the family Nummulitidae (see Samanta, 1983, 1984).

Of the five genera recognised in the family Nummulitidae, four, **Nummulites**, **Assilina**, **Operculina** and **Operculinoides**, are represented in present material. They constitute some of the commonly occurring larger foraminiferal genera in the Lower Tertiary succession of Kutch and the two first mentioned genera occur as rock-forming elements in several horizons. The family is represented here by twenty-four species.

The essential morphology of the type genus **Nummulites** is shown in Fig. 18; a = test, b = equatorial chamber, c = marginal cord, d = septum, e = alar prolongation of equatorial chamber, f = pillar and g = septal filament.

Fig. 19 shows the external and internal parameters of the Family Nummulitidae:

1. **D** = The diameter of a specimen.

2. **T** = The thickness of the specimen at the centre, measured perpendicular to the median layer.
3. \( T_2 \) = The thickness of the specimen at the halfway between the centre and periphery, measured perpendicular to the median layer.

4. \( D_1 \) = The diameter of the protoconch, measured parallel to the separating wall between the embryonic chambers.

5. \( D_2 \) = The diameter of the deuteroconch, measured parallel to the separating wall between the embryonic chambers.

6. \( h \) = The diameter of the protoconch and deuteroconch together, measured perpendicular to the separating wall between the embryonic chambers.

Genus *Nummulites* Lamarck, 1801

Type species: *Camerina laevigata* Bruguiere, 1972

**Diagnosis:** Test small to very large; spire simple or multiple, increasing gradually in height; chambers involute; lateral wall with transverse trabecules; septal filaments radiate to reticulate.

**Distribution:** *Nummulites* is cosmopolitan and has been recorded from the Tethyan, Indo-Pacific and Caribbean-American provinces. It is best represented in the region between Spain-North Africa in the west and India in the east. In the Indo-Pacific province the genus is well represented in different localities but in the Caribbean-American it is rather poorly represented. It occurs as a rock-forming genus in the Tethyan and the Indo-Pacific provinces.
Nummulites ranges from Palaeocene to Oligocene. It attained its maximum development during the Middle Eocene. The lineages described and illustrated by Schaub (1981) serve as a useful tool in the classification and correlation of the Palaeogene shelf-sequences of the Mediterranean region.

The genus is widely distributed in the Indian region and is known to occur in all the Palaeogene marine sequences described from this region.

**Occurrence in Kutch**: The genus occurs frequently to commonly in all the four formations, Naredi, Harudi, Fulra Limestone and Maniyara Fort, exposed in the four traverses (Traverses I-IV; Figs. 9-12) examined. Often, it occurs as a rock-forming element at several horizons. It ranges from Early Eocene to Middle Oligocene (Fig. 13). Here, the genus is represented by fourteen species:

1. *Nummulites crasseornata* Henrici
2. *N. fichteli* Michelotti
3. *N. maculatus* Nuttall
4. *N. obtusus* (Sowerby)
5. *N. pengaronensis* Verbeek
6. *N. pinfoldi* Davies
7. *N. scaber* Lamarck
8. *N. stamineus* Nuttall
9. *N. umbilicata* Cizancourt
10. *N. varicolarius* (Lamarck)
11. *N. vicarvi* d'Archiac & Haime
12. *N. vohrai* Tandon
13. *N. vredenburgi* Prever
14. *N. sp. aff. N. exilis* Douville

They are described below:

**Nummulites crasseornata** Henrici, 1934
(Pl. 22, Figs. 1-10; Pl. 23, Figs. 1-9; Pl. 53, Figs. 1-11; Pl. 56, Figs. 5-11; Text-figs. 20-22)

1934 *Camerina crasseornata* Henrici, pp. 32-33, pl. 2, figs. 2-5, 12; text-fig. 15.

Two groups of specimens designated as the compressed type and the inflated type are recognised. These are treated here as conspecific, but described separately.

**Compressed Type**

**Material**: Both microspheric and megalospheric specimens were examined. Twenty isolated specimens, four split-equatorial sections and three axial sections of microsphere form and nineteen isolated specimens, fifteen equatorial/split-equatorial sections and five axial sections of megalospheric form were studied.

**Description**:

**Microspheric generation**: The test is small, lenticular with depressed poles and subangular margin (Pl. 22, Fig. 6). The
Fig. 20 Scatter diagram of $D - T_i$ for two Types of Nummulites *crasseornata* Henrici (Form $B'$)
central part is coarsely granulated. The granules are subcircular and form pointed projections on the surface. They occur along the spiral sutures often tending to form spiral ridges. The diameter varies from 2.1 mm to 3.15 mm, the thickness at centre from 0.7 mm to 1.1 mm and the diameter of granules from 62 μm to 300 μm (Fig. 20).

In equatorial section the spire is simple, consisting of 6 to 7 whorls increasing regularly in height (Pl. 22, Figs. 7-8, Pl. 53, Fig. 11). There are about six whorls in a radius of 1.65 mm. The marginal cord is moderately developed increases slowly in thickness and fairly regular to irregular in its course. The equatorial chambers are rectangular and much higher than long. There are about twenty-nine to thirty-one chambers in a whorl 0.5 mm from the centre. The size of chambers increases towards periphery. The septa are thin and regularly spaced. They are straight to distinctly curved backward in their distal end and slightly inclined to the marginal cord at base.

Axial sections show the slightly biumbilicate compressed shape of the test (Pl. 22, Figs. 9-10). The equatorial plane is nearly flat. Usually the equatorial chambers are elongate triangular in shape. In the outer whorls they are appreciably higher than wide. The marginal cord is moderately developed. The alar prolongations are wide. The whorl height increases with growth. The depressed central part of the section is with prominent tapering pillars. The surface diameter of pillars ranges from
Fig. 21 Scatter diagram of $D-T_1$ for two Types of *Nummulites crosseornata* Henrici (Form 'A')
Megalouspheric generation: The test is very small, compressed lenticular with gently depressed central part and subangular to angular margin. The difference in ornamentation between the peripheral part and polar region is marked. The surface is ornamented with thin, wavy septal filaments on the outer part and a few coarse granules in the polar region. The peripheral part is usually non-granulate (Pl. 22, Fig. 1). The diameter of test ranges from 1.0 mm to 1.75 mm, thickness at centre from 0.5 mm to 0.65 mm and diameter of granules from 43 m/μ to 137 m/μ (Fig. 21).

In equatorial section the embryonic apparatus is small, bilocular made up of subcircular to subelliptical protoconch followed by semicircular to reniform deutoconch (Pl. 22, Figs. 2-3; Pl. 53, Fig. 10). The separating wall is straight to gently convex outwards. The internal diameters of protoconch range from 43x43 m/μ to 56x62 m/μ and of the deutoconch from 37x50 m/μ to 43x62 m/μ. The distance across both chambers varies from 87 m/μ to 118 m/μ and the thickness of separating wall from 7 m/μ to 18 m/μ.

The spire is simple, regular with about four whorls in a diameter of 1.4 mm. The marginal cord is moderately developed and is regular in its course. It increases gradually in thickness with growth except in the outermost whorl where it is thinner than the early formed part. The chamber increases gra-
Fig. 22 Rates of opening of spire in two types of *Nummulites crosseornata* Henrici (Form 'A') Coverage of 15 specimens for each type.
dually in size and normally higher than long. They are rectangular. There are about eight chambers in the first whorl, fifteen in the second, twenty-three in the third and thirty-three in the fourth. The septa are moderately thick, inclined to the marginal cord at the base. Usually they are straight with slight backward curvature at their distal end. The whorls open regularly and the height of whorl varies from 75 m/μ in the first whorl to 168 m/μ in the last whorl. The rate of opening of spire is shown in Fig. 22.

Axial section shows the compressed biconcave shape with subangular margin (Pl. 22, Figs. 4-5; Pl. 53, Figs. 8, 12). The protoconch is subcircular followed by crescentic deuteroconch (Pl. 53, Fig. 10). The equatorial plane is flat. The equatorial chambers are triangular and higher than wide. The marginal cord is moderately developed. The alar prolongations are very wide. The thickness of spiral laminae is more or less same except in outermost whorl where it is thinner than the early formed part. The gently depressed central part is ornamented with a few prominent tapering pillars. The surface diameter of polar pillars varies from 0.13 mm to 0.27 mm and that of other pillars from 50 m/μ to 162 m/μ.

**Measurements**: Measurements of external and internal features are shown in Tables 1-6.

**Inflated Type**

**Material**: Both microspheric and megalospheric specimens were examined. Eighteen isolated specimens, four split-equatorial
sections and three axial sections of microspheric form and twenty-one isolated specimens, fifteen equatorial/split-equatorial sections and five axial sections of megalospheric generation were studied.

**Description:**

**Microspheric generation:** The test is small, slightly inflated lenticular with subangular margin (Pl. 23, Fig. 1). The surface is ornamented with granules distributed throughout the test. Usually granules are short, stout and subcircular in outline. The test diameter varies from 2.05 mm to 3.45 mm, the thickness at centre from 0.9 mm to 1.25 mm and the diameter of granules from 75 μm to 312 μm (see Fig. 20).

In equatorial sections the spire consists of simple whorls which are regular in the inner part and becoming irregular in the outer part (Pl. 23, Fig. 9). There are about six whorls in a radius of 1.65 mm. The marginal cord is moderately to well-developed and fairly regular in its course. The equatorial chambers are subrectangular in outline and usually higher than long except the last whorl where chambers both equal in height and length as well as longer than high are quite common. The height of chambers increase slowly with growth. There are about twenty-four to twenty-eight chambers in a whorl 0.5 mm from the centre. The septa are moderately thick and irregularly spaced. Normally they are slightly inclined to the marginal cord at base and slightly to strongly curved backward at their distal end.
In axial sections the shape of test is lenticular with subparallel sides and subangular to angular margin (Pl. 23, Figs. 7-8). The equatorial plane is flat. The equatorial chambers are elongate triangular in shape and chambers slightly higher than wide, wider than high and equal in width and height are common. The marginal cord is well-developed. The alar prolongation is moderately wide. The thickness of spiral laminae is irregular. Often they are divided into lateral chambers. The whorl height is irregular in later whorls. The flat central part of the section is ornamented with a large number of tapering pillars. The pillars are moderately thick and distributed throughout the test except the last whorl. The surface diameter of pillars varies from 50 m/μ to 300 m/μ.

Megalospheric generation: The test is very small, slightly inflated lenticular with subangular margin. The surface is ornamented with a large number of coarse granules around the central part. The septal filaments occur on the peripheral part (Pl. 23, Fig. 6). The diameter of test ranges from 1.10 mm to 1.60 mm, thickness at centre from 0.70 mm to 0.90 mm and diameter of granules from 50 m/μ to 175 m/μ (see Fig. 21).

In equatorial section embryonic apparatus is small, bilocular made up of semicircular to subcircular protoconch followed by crescentic to reniform deutoconch (Pl. 23, Figs. 4-5; Pl. 53, Fig. 7). The separating wall is straight to gently convex outwards. The internal diameters of protoconch range from
38×44 m/u to 50×63 m/u and of deuteroconch from 32×56 m/u to
50×75 m/u. The distance across both chambers ranges from 88 m/u
to 113 m/u and the thickness of separating wall from 12 m/u to
18 m/u.

The spire is simple, consisting of three to four whorls
increasing regularly in height. There are about four whorls in
a radius of 0.62 mm. The rate of opening of spire is represented
in Fig. 22. The marginal cord is well developed and is regular
in its course. Its thickness is more or less constant with growth.
The chambers are subtriangular to rectangular in shape. Usually
the chambers are higher than long though chambers equal in height
and length are also common. There are about eight chambers in the
first whorl, thirteen in the second, twenty in the third and
twenty-seven in the fourth. The septa are inclined to the margi­
nal cord at base. Normally they are curved. Straight septa with
curvature at their distal end are also common. The height of
whorl varies from 75 m/u in the first whorl to 150 m/u in the
last whorl.

In axial section the shape of test is slightly inflated
lenticular with angular to subangular margin (Pl. 23, Figs. 2-3;
Pl. 53, Figs. 2, 5). The protoconch is subcircular in outline
followed by subcrescentic deuteroconch. The equatorial plane is
flat to slightly curved. The equatorial chamber is triangular
and usually equal in height and width. The marginal cord is well-
developed. The alar prolongations are distinct, very wide and
continues from periphery to polar region. Its thickness is more or less constant except in the outermost whorl where it is much thinner than the early-formed part. The slightly inflated central part is studded with prominent tapering pillars. The surface diameter of polar plug ranges from 0.12 mm to 0.25 mm and of pillars from 50 μm to 163 μm.

**Measurements**: Measurements of external and internal features are shown in Tables 1-6.

**Remarks**: The two types are distinguished by their shape and ornamentation of the tests and rate of opening of the spire. The specimens with inflated test are more coarsely granulated and spire opens more slowly. This difference is more marked in the megalospheric specimens.

Originally described from Indonesia the species is reported here for the first time from India. In their essential features the Kutch specimens are most closely comparable to Henrici's species. However, a publication providing detailed discussions and illustrations of *N. crasseornata* from Indonesia for complete understanding of its range and variation is lacking.

**Distribution**: In Kutch, the species occurs in the *Assilina* Limestone Member of the Naredi Formation exposed in Harudi, Nareda and Guvar areas. Here it is restricted in the Early Eocene *Assilina laxispira* Zone.
Nummulites fichteli Michelotti, 1841
(Pl. 24, Figs. 1-10; Pl. 57, Figs. 1-10, 19; Text-figs. 23-25, 27)

1841 Nummulites fichteli Michelotti, p. 44, pl. 3, fig. 7
1853 Nummulites intermedia d'Archiac; d'Archiac & Haime, pp. 99-100, pl. 3, figs. 3a-d, 4a-f.
1853 Nummulites fichteli Michelotti; d'Archiac & Haime, pp. 100-101, pl. 3, fig. 5a.
1853 Nummulites garansianus Toly & Leymerie; d'Archiac & Haime, pp. 101-102, pl. 3, fig. 6a, 7a-g.
1960 Camerina fichteli (Michelotti); Cole, p. 1-4, pl. 3, figs. 5, 9-18.
1970 Nummulites fichteli Michelotti; Roveda, pp. 245-249, figs. 1-31, pl. 22, figs. 1-2.
1981 Nummulites fichteli Michelotti; Schaub, pp. 128-130, pl. 50, figs. 5-18.

Material: Thirty-four isolated specimens, three equatorial sections and four axial sections of microspheric form and sixty-seven isolated specimens, eight equatorial sections and seven axial sections of megalospheric forms were studied.

Description:
Microspheric generation: Test large, discoidal with subangular margin (Pl. 24, Fig. 7). Septal filaments are typically reticulate formed of small meshes of irregular shape and size. Very fine papillae are distributed on the surface of the test. The
Fig. 23 Scatter diagram of $D - T_1$ for *Nummulites fichteli* Michelotti.
size of papillae varies from 31 m/u to 150 m/u. Usually the papillae occur over the intersections of the septal filaments. Test diameter ranges from 8.3 mm to 33.0 mm and the thickness at centre from 1.5 mm to 4.0 mm (Fig. 23).

The spire is simple in the early part and consists of closely coiled whorls as shown in equatorial sections (Pl. 25, Fig. 7; Pl. 56, Figs. 7, 19). The equatorial chambers are rectangular, initially higher than long, gradually tending to be longer than high (Pl. 24, Fig. 9). This is followed by an open spire having rectangular, much longer than high chambers separated by thin, inclined septa. The earliest intercalary whorl is introduced in this part. The marginal cord is fairly regular in its course. It is considerably thinner than the later-formed part. The septa are well-developed and regularly spaced. The maximum number of intercalary whorls observed in an individual is three. There are about twenty-two to twenty-seven whorls in a radius range of 6 mm to 6.6 mm. The whorls increase slowly in height through the greater part of the equatorial section. In the peripheral part the whorls become narrower. Usually, the height of the cavity exceeds the thickness of the whorl wall.

Axial sections (Pl. 24, Fig. 10; Pl. 57, Fig. 5) also show the changes with ontogeny. The shape changes from compressed biconvex to discoidal. The equatorial plane, extremely thin in the inner part of the test, becomes thicker with growth. Equatorial chambers markedly narrow in the early whorls gradually
increase in height. The equatorial chamber is acute triangular in inner part and obtuse triangular in outer part. The marginal cord, thin in early whorls, increases gradually in thickness in later part. The alar prolongations are extremely narrow throughout the whorls. Thin discontinuous pillars are distributed throughout the section (Pl. 24, Fig. 10; Pl. 57, Fig. 5). The diameter of the pillars ranges from 37 μm to 162 μm.

**Megalospheric generation**: Test is small to medium, biconvex with subangular margin. The surface is granulate, the umbonal granules being much coarser than the peripheral ones. The granules occur over the intersections of the branching septal filaments which form a typical reticulate mesh work seen clearly on abraded surface (Pl. 24, Fig. 1). The test diameter ranges from 2.7 mm to 6.8 mm, thickness at centre from 0.6 mm to 2.0 mm and the diameter of granules from 50 μm to 250 μm (Fig. 23). The diameter of umbo/polar pustule varies from 0.5 mm to 1.4 mm.

The megalospheric embryonic apparatus is medium to large, bilocular with two chambers differing markedly in shape and size (Pl. 24, Figs. 5-6; Pl. 57, Figs. 1-2, 4, 10). The protoconch is subcircular followed by the deuteroconch which is relatively smaller and is crescentic in shape. The wall separating the embryonic chambers is very thin and gently convex outwards. The wall of the protoconch is characteristically thin. The internal diameters of the protoconch range from 175x187 μm to 562x462 μm and those of the deuteroconch from 75x187 μm to 487x150 μm.
Fig. 24 Histogram of $D_1$, $D_2$ and $h$ for seven species of Nummulites (Form 'A') Coverage of 5 specimens for each species.

1. Nummulites fichteli Nattall
2. N. maculosus Nattall
3. N. obtusus (Sowerby)
4. N. pentagonans Verbeek
5. N. pinfoldi Davies
6. N. staminius Nattall
7. N. vredenburgi Prever

$D_1$, $D_2$, and $h$
Fig. 25 Rates of opening of spire in eight species of *Nummulites* (Form 'A') Coverage of 8 specimens for each species.
The distance across the embryonic apparatus varies from 262 m/μ to 737 m/μ. Fig. 24 shows the average value of $D_1$, $D_2$ and $h$.

The spire is simple and opens slowly in height. The rate of opening of spire is shown in Fig. 25. There are about six whorls in a test diameter of 2.95 mm. The first nepionic chamber is usually arcuate in shape followed by rectangular much longer than high chambers separated by strongly inclined septa. There are about seven chambers in the first whorl, ten in second, thirteen in third and fifteen in both fourth and fifth. The whorl height varies from 87 m/μ to 150 m/μ in the first whorl and 100 m/μ to 162 m/μ in the last whorl.

In axial sections the size of the embryonic apparatus vary considerably. The protoconch is subcircular in outline followed by crescentic to subtriangular deuteroconch (Pl. 24, Figs. 2-4; Pl. 57, Figs. 3, 6, 8-9). The chambers are triangular in shape, mostly higher than wide and increase slowly in size. The alar prolongations are narrower than the spiral laminae enclosing them. The wall of the last whorl is thinner than the earlier ones. Prominently developed polar plugs gradually increasing in diameter occur over the embryonic chambers. Outside the polar region thin rodlike pillars varying little in diameter occur over the whorl junctions. The surface diameter of the pillars ranges from 25 m/μ to 512 m/μ and the polar plug from 0.6 mm to 1.2 mm.
Measurements: Measurements of external and internal features are appended in Tables 7-12.

Remarks: With its large discoidal test, nearly smooth to finely papillate surface, reticulate filaments, the microspheric generation of *N. fichteli* is a distinctive species in the present collection. The megalospheric generation display notable variation in external and internal morphology. No attempt is made here to assess the significance of these sections in the taxonomy of this reticulate species.

*Nummulites clipeus* and *N. subclipeus*, described by Nuttall (1925) has been regarded by Mohan (1965), Roveda (1970) and others to fall within the range of variation of *N. fichteli* and are thus included here in the synonymy.

Distribution: Not only morphologically but stratigraphically as well *N. fichteli* is a distinctive species and its lower and upper age limits have been used to mark the boundaries between the Eocene and Oligocene and Middle and Upper Oligocene respectively. It has been reported from numerous localities from Tethyan and Indo-Pacific provinces where it often occurs as rock-forming species. In Kutch the species occurs as rock-forming element in the Lower Member of the Maniyar Fort Formation while in the overlying Coral Limestone Member it occurs but less frequently. Here, it ranges from Early Oligocene *Nummulites fichteli* Zone to Middle Oligocene *Eulepidina dilatata* Zone.
1926 Nummulites maculatus Nuttall, 1926
(Pl. 25, Figs. 1-9; Pl. 55, Figs. 3,8,10,14; Text-figs. 24-27)
1926a Nummulites maculatus Nuttall, p. 140-141, pl. 4, figs. 2-6.
1954 Nummulites laevigatus Puri, p. 192 (not Nummulites
laevigatus (Bruguiere), 1792).
1962 Nummulites kutchensis Sengupta, 1962, p. 144-148, pl. 16,
figs. 1-9.
1965 Nummulites bagelensis Verbeek; Sengupta, p. 90-91, pl.15,
figs. 4,6,8; pl. 16; figs. 4-5 (not Nummulites
bagelensis Verbeek, 1982, p. 107)
1965 Nummulites beaumonti Sengupta (parts) p. 92, pl. 17,
fig. 1 (not Nummulites beaumonti d'Archiac & Haime,
1853, pp. 133-134, pl. 8, figs. 1-3).
1970 Nummulites sp. cf. N. maculatus Nuttall; Samanta, p. 187,
table 2.
1976 Nummulites bagelensis Tandon, p. 78-79, pl. 1, fig. 4
1976 Nummulites maculatus Nuttall; Tandon, p. 79-80, pl. 2,
figs. 2-9.
1981 Nummulites maculatus Nuttall; Samanta, p. 14-35, pl. 1,
figs. 1-5; pl. 2, figs. 1-5; pl. 3, figs. 1-6;
pl. 4, figs. 1-4.

Material: Forty-six isolated specimens, five equatorial sec-
tions and four axial sections of microspheric form and fifty-
Fig. 26 Scatter diagram of $D-D/T_1$ for *Nummulites maculatus* Nuttall from the Fulra Limestone.
two isolated specimens, eight equatorial sections and eight axial sections of megalospheric form were examined.

Description:

Microspheric generation: The test is medium to very large and compressed lenticular to thin discoidal in shape with angular margin. The discoidal specimens are usually undulating. The decorticated specimens show the very fine meandriform septal filaments with very fine papillae irregularly spaced on them (see Front-piece). The variations of test diameter and thickness at centre are shown in Fig. 26. The diameter of test ranges from 9.0 mm to 36.2 mm, the thickness of centre from 4.1 mm to 10.0 mm and the surface diameter of granules from 50 mm to 225 mm.

The spire is simple in the inner part gradually becoming multiple with ontogeny. There are about nineteen whorls in a diameter of 16 mm. The first intercalary whorl is generated between the seventh and eighth whorls. The whorls increase slowly in height through the greater part of the equatorial section. In the peripheral part they become narrower. The marginal cord is fairly regular in its course and thickens progressively before the introduction of intercalary whorls.

The septa are nearly perpendicular to slightly inclined to the marginal cord at the base and are generally straight for the greater part of their length with sharp backward curvature at the distal end. The chambers are rectangular and mostly
higher than long. They increase slowly in size with growth. There are about eighteen to twenty-four chambers in a whorl 0.5 mm apart from the centre.

In axial section, the shape of the test changes from biconvex to compressed discoidal with ontogeny (Pl. 25, Figs. 8,9; Pl. 56, Figs. 5, 8-10). The chamber cavities are mostly wider than those in the early whorls. The cavities are elongated triangular in outline and higher than wide. In the outer whorls there is a pronounced thinning and the spiral lamina over the lateral parts of the test. The marginal cord well-developed and represents the thickest portion of the spiral laminae.

The alar prolongations are extremely narrow and range from slit-like to open cavities. The development of pillars varies. They are much irregular in shape and distribution. The umbonal region appears to be more densely pillared (Pl. 56, Fig. 5). The surface diameter of the pillars ranges from 50 m/μ to 200 m/μ.

Megalospheric generation: The test is small, inflated with steeply sloping sides (Pl. 25, Figs. 1-2). The polar region is very coarsely granulated, the granules forming subconical protuberances on the surface of well-preserved specimens. Outside the polar region the pillars are sparsely distributed and are usually situated on the thin sinuous filaments or attached to them. The diameter of the test ranges from 3.0 mm to 4.1 mm, thickness at the centre from 1.1 mm to 2.6 mm, the diameter
of the umbonal granules from 128 m\(\mu\) to 613 m\(\mu\) and the diameter of peripheral granules from 75 m\(\mu\) to 325 m\(\mu\). Fig. 26 shows \(D-D/T_{1}\) relationship.

The megalospheric embryonic apparatus is conspicuously large and bilocular, the two chambers differing markedly in shape and size (Pl. 25, Figs. 3-4; Pl. 55, Figs. 3, 14). The protoconch is always larger than the deuteroconch and separated by a thin nearly straight wall (Pl. 55, Fig. 8). Both the embryonic chambers are flatted along the separating wall. The internal diameters of the protoconch range from 275x375 m\(\mu\) to 825x950 m\(\mu\) and those of the deuteroconch from 125x363 m\(\mu\) to 200x875 m\(\mu\). The distance across the both chambers ranges from 438 m\(\mu\) to 1044 m\(\mu\). The average values of \(D_{1}, D_{2}\) and \(h\) are presented in Fig. 24.

The spire is simple and regular in most specimens (Pl. 25, Figs. 3-4). The whorls increase slowly in height with the exception of the last one which is usually narrower than the earlier-formed one. The rate of opening of whorls is shown in Fig. 25. The marginal cord is moderately developed and is fairly regular in its course in most specimens. The first nepionic chamber is usually arcuate in shape and is followed by chambers which are usually subrectangular in outline. They increase slowly in size. The equatorial chambers vary from higher than long to longer than high. The septa are inclined and are moderately straight in the lower part and are gently
curved backward in their upper part. There are about three whorls in a radius of 2.5 mm. The number of chambers varies from seven to nine in first whorl, twelve to fifteen in second and seventeen to twenty-five in third. The whorl height ranges from 200 μm to 338 μm in the first whorl and 200 μm to 325 μm in the last.

The axial sections (Pl. 25, Figs. 5-6; Pl. 55, Fig. 10) are characterised by remarkably large megalospheric embryonic apparatus. The protoconch is usually subcircular in shape while the deuteroconch is crescentic to subtriangular in outline. There is much variation in the size of the embryonic apparatus (Pl. 55, Fig. 8). The chambers are triangular in shape and mostly higher than wide and increase slowly in size. The alar prolongations are narrow but distinct and vary from low slit-like to distinct open cavities (Pl. 55, Fig. 10). The spiral laminae are generally uniform in thickness from the pole to the periphery except at the junctions with the pillars. The umbonal pillars are most prominent, tapering in shape and extend up to the surface forming rounded protuberances. The surface diameter of the pillars ranges from 50 μm to 675 μm.

**Measurements**: Measurements of external and internal features are shown in Tables 13-18.

**Remarks**: There was considerable confusion regarding the identification of *N. maculatus* by later authors so much so that Sengupta (1964, 1965) failed to recognise it in his material from Northwestern Kutch and referred its microspheric and the
megalospheric specimens to two different species. Satisfactory illustrations showing the essential features of both generations clearly was lacking until Samanta (1981) provided a detailed account on the morphology and distribution of *N. maculatus* based on an examination of specimens from the type collections preserved in the Sedgwick Museum, Cambridge and material collected from southwestern and northwestern Kutch. The list of synonymy presented by Samanta is followed here. Thus, *N. laevigatus* of Puri is treated as a synonym of *N. maculatus*. Again, specimens identified by Sen Gupta (1962, 1965) as *N. kutchensis* n. sp. and *N. bagelensis* Verbeek actually belong to Nuttall's species.

*Nummulites maculatus*, according to Nuttall (1926a, p. 140), resembles *Nummulites gizehensis* followed by workers on Indian *Nummulites* varies greatly. Vredenburg (1906, p. 85) considered *Nummulites obtusus* (Sowerby) as a variety of *N. gizehensis*, while Nuttall (1926b, p. 501) observed that "of the pilate *Nummulites* with meandriform septal filaments *N. maculatus*, *N. carteri*, and *N. gizehensis* show characters in common and are doubtless related to one another". Nagappa (1959, p. 173), on the other hand, treated *N. gizehensis* as closely related to *N. laevigatus* (Brugiere). According to Samanta (1981), *Nummulites obtusus* (Sowerby), *N. laevigatus* (Brugiere) and *N. maculatus* Nuttall belong to three different lineages.

Although in size, shape and external ornamentation *N. maculatus* resembles closely *N. carteri* d'Archiac & Haime
described from Sind, the latter differs in having "much reflected" equatorial chambers.

The megalospheric specimens are much more abundant than the microspheric ones though the microspheric specimens occur as a rock-forming element in a band in the upper part of the Fulra Limestone exposed in Godhatad-Kapurasi and Guvar areas. In most of the present samples *N. maculatus* is represented by megalospheric form mainly.

**Distribution:** The type specimens of *N. maculatus* came from the upper part of the "Nummulitic Limestone" near Ber Nana and Lakhmirani redescribed as the Fulra Limestone by Biswas and Raju (1973). It is a commonly occurring species in the Fulra Limestone of the present area, where it ranges from the *Discocyclina sowerbyi* Zone to *Alveolina elliptica* Zone of Middle Eocene age. In the upper part of the Fulra Limestone the species occurs abundantly.

**Nummulites obtusus** (Sowerby), 1820

(Pl. 26, Figs. 1-8; Pl. 27, Figs. 9-12; Pl. 54, Figs. 1-2, 13-15; Text-figs. 24-25, 27)

1840 *Nummularia obtusa* Sowerby, p. 329, pl. 24, fig. 14,
Not fig. 14a.

1853 *Nummulina obtusa* (Sowerby); Carter, p. 170, pl. 7,
figs. 13, 14.

1853 *Nummulites obtusus* (Sowerby); d'Archiac and Haime,
pp. 122, 123, pl. 6, figs. 13 a-c.
1879 *Nummulites perforata* var. *obtusa* (Sowerby); Rupert Jones in Blanford, p. 10.
1879 *Nummulites obtusa* (Sowerby); Medlicot and Blanford, p. 459, pl. 15, fig. 13.
1906 *Nummulites gizehensis* var. *obtusus* (Sowerby); Vredenburg, p. 85.
1940 *Nummulites obtusus* (Sowerby); Davies, p. 212, pl. 11, fig. 14.
1965 *Nummulites perforatus* (de Montfort); Sen Gupta, pp. 93-95, pl. 16, figs. 1, 2, 11; pl. 17, fig. 3, 9, 10, 13; text-fig. 2.
1981 *Nummulites obtusus* (Sowerby); Samanta, pp. 804-817, pl. 113, figs. 3-5; pl. 114, figs. 1-4, pl. 115, figs. 1, 2; text-figs. 2A-G, 3, 4, 5a-d.

**Material:** Ten isolated specimens, ten split-equatorial sections and five axial sections of microspheric forms and ten isolated specimens, eight equatorial/split-equatorial sections and five axial sections of megalospheric forms were examined.

**Description:**

**Microspheric generation:** Test is lenticular to globose (Pl. 26, Fig. 1). In both thick and thin specimens the edge of the test is often flexed producing concavo-convex to reniform transverse outline. Thick specimens show obtuse margin. Test diameter ranges from 3.1 mm to 17.8 mm and thickness at the centre from 2.7 mm to 8.2 mm.
The surface of the test is conspicuously marked by septal filaments. In smaller lenticular specimens the filaments are simple, meandiform. Highly sinuous, complex meandiform septal filaments sometimes resembling finger prints are characteristics of the larger test with obtuse margins. This complex form and arrangement of the septal filaments creates striking surface pattern which has been found very helpful in identifying this species. In early growth stages the surface is ornamented with conspicuously well-developed polar pustules. The surface of adult specimens is non-granulate.

In equatorial sections (Pl. 26, Figs. 5-6; Pl. 54, Fig. 14) the innerpart of the spire consists of closely spaced regular whorls. Marginal cord is well-developed and gradually increases in thickness. Chambers are radially elongate and rectangular, their height usually exceeding three times their length. Septa are regularly spaced and moderately thick. They are nearly perpendicular to the marginal cord and are usually straight with a bend at the distal end.

The middle part of the spire is made up of open, irregular whorls usually with intercalary whorls. In the earlier whorls the spire is fairly regular. Afterwards, the formation of intercalary whorls sets major irregularity in the spire. Here the whorls are more closely spaced than in the earlier part. The spiral lamina thickens gradually from the beginning and but with the initiation of intercalary whorls the wall becomes progre-
ssively thinner. The septa become slightly inclined and weakly curved backward at their distal end. Chambers are normally higher than long.

The outer part of the spire characterises very narrow approximated whorls between extremely thin spiral wall. Whorls are uniform in appearance. The spiral wall is gently to moderately wavy. Septa are short, straight and almost perpendicular to the spiral lamina. Chambers are very low, squarish to long elongated.

The axial section of mature individuals shows the three parts distinguished in equatorial section (Pl. 26, Fig. 8). The inner part is characterised by very small size, equally biconvex to biumbonate outline with angular margin. The equatorial plane is flat, extremely thin and increasing very slowly in thickness. The chambers are low, slit-like to subtriangular in shape. The marginal cord is distinct. The alar prolongations are very narrow. The polar plugs are well-developed. Pillars are present.

The middle part is usually unequally biconvex with subangular margin (Pl. 26, Figs. 7-8). The equatorial plane is curved. The chambers are wider than high and subtriangular in shape. The spiral laminae and the marginal cord attain maximum thickness here. The spiral laminae are generally uniform in thickness. The alar prolongations are narrow but distinct. In the outer whorls lateral splitting of the spiral laminae produces lateral chambers. Well-developed pillars are characteristic.
Fig. 27 Scatter diagram of $D - T_i$ for five species of Nummulites (Form $A'$)
The outer part has conspicuously flattened polar region and prominently obtuse to bluntly rounded margin. The loss of equatorial plane as well as the marginal cord is significant. The height of the alar prolongation exceeds the thickness of the separating laminae. Lateral chambers are produced by later splitting of the spiral laminae.

**Megalospheric generation**

Test small, thick, evenly lenticular to strongly inflated. Margin subangular to obtuse (Pl. 26, Fig. 4). Surface is non-granulate and ornamented with clearly seen polar pustules. Septal filaments are thin, gently wavy, and closely spaced. Test diameter varies from 2.30 mm to 3.80 mm, thickness at the centre from 0.94 mm to 2.4 mm and surface diameter of polar pustules from 0.60 mm to 1.40 mm (see Fig. 27 for D-T<sub>1</sub> relationship).

Equatorial section shows moderately large, bilocular embryonic apparatus made up of subcircular protoconch followed by semicircular deutoconch. The deutoconch is smaller than the protoconch (Pl. 54, Fig. 13). The separating wall is thin, straight to gently convex outwards. The internal diameters of the protoconch range from 181x281 μm to 200x312 μm and of the deutoconch from 112x212 μm to 131x262 μm. The distance across both chambers ranges from 312 μm to 331 μm. The separating wall is about 12 μm thick. The average values of D<sub>1</sub>, D<sub>2</sub> and h are presented in Fig. 24.
Spire simple, usually regular with about five whorls in a radius of 1.35 mm. Marginal cord is well-developed, thick and increases gradually in thickness. The chambers increase gradually in size and are normally higher than long. Chambers equal in height and length as well as longer than high are also present specially in the outermost whorl. There are about twelve chambers in the first whorl, twenty-three in the second, thirty-four in the third and thirty-nine in the fourth. The septa are short and thick and slightly inclined to the marginal cord. Whorls are opened very slowly and the height of whorls varies from 81 μm in first whorl to 187 μm in last whorl. The rate of opening of spire is depicted in Fig. 25.

In axial section the shape of test is inflated biconvex with subangular to obtuse margin (Pl. 26, Fig. 3; Pl. 27, Fig. 11; Pl. 54, Fig. 15). The protoconch is subcircular followed by reniform deuteroconch. The chambers are triangular and distinctly wider than high. The alar prolongations are narrow. The thickening of spiral laminae increases gradually except in the outermost whorl where it is invariably thinner than the early formed part (Pl. 27, Fig. 11). Polar plug extends up to the surface. The surface diameter of polar plug varies from 0.85 mm to 1.25 mm.

Measurements: Measurements of external and internal features are shown in Tables 19-24.

Remarks: Nummulites obtusus (Sowerby) is one of the most distinctive species of the genus and is readily recognized even in
the field. The microspheric specimens are more common than the megalospheric individuals and exhibit variations in both external and internal features. The megalospheric specimen is characterised by much smaller size, distinctly developed polar pustules and simpler septal filaments. The microspheric individual is characterised by typical highly sinuous, complex meandriform pattern of septal filaments, externally and tripartite subdivision of spire internally.

*N. obtusus* was originally described by Sowerby (1840) from Kutch. He did not describe the species properly and his illustrations were too small to show the essential features clearly. D'Archiac and Haime (1853) provided the first well-illustrated systematic account of the species. Both Sowerby (1840) and d'Archiac and Haime (1853) examined only the microspheric generation. Blanford (1879) reported that *N. obtusus* was a common occurring fossil in Sind and a important fauna of the Khirthar Group. Sen Gupta (1965) illustrated both the generations from Kutch, his figures did not show the diagnostic characters clearly.

Samanta (1981) described and profusely illustrated the species from the type area in Kutch. He presented a detailed discussion and clearly distinguished *N. obtusus* from other species identical to it.

In the present study, materials from the type area Lakhpat, were also examined and illustrated. The present materials des-
scribed and illustrated are identical to that of Samanta (1981) and his identification has been followed here.

**Distribution**: So far authentic records are concerned *N. obtusus* appears to be restricted to Indian subcontinent. In Kutch the species is restricted to the upper part of the Harudi Formation. It occurs with the planktonic foraminiferal fauna indicative of *Globorotalia lehneri* zone of Bolli and is dated as middle Middle Eocene (see Samanta, 1981, p. 817). In the present investigation both the Naliya - Narayan Sarovar Rd. traverse, North-West of Harudi as well as in Guvar *N. obtusus* is essentially restricted to the upper part of the Harudi Formation and occurs in the Middle Eocene *N. obtusus* Zone.

**Nummulites pengaronensis** Verbeek, 1871

(Pl. 27, Figs. 1-8; Pl. 55, Figs. 1, 11, 13; Pl. 56, Figs. 12-13; Text-figs. 24-25, 27)

1871 *Nummulites pengaronensis* Verbeek, pp. 4-6, pl. 1, figs. 1a-k.
1892 *Nummulites nanggoelani* Verbeek, pp. 116, 118.
1896 *Nummulites nanggoelani* Verbeek; Verbeek & Fennema, p. 1152, pl. 8, figs. 111-113.
1896 *Nummulites pengaronensis* Verbeek; Verbeek & Fennema, pp. 1152, 1154.
1912 *Nummulites pengaronensis* Verbeek; Douville, 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, 35a,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.

1959 *Camerina pengaronensis* (Verbeek); Cole, pp. 753-754, pl. 231, figs. 1-17.

1959 *Nummulites pengaronensis* Verbeek; Nagappa, pp. 163, 166, pl. 10, figs. 3-5.

1965 *Nummulites cf. saipanensis* (Cole); Adams, p. 313, pl. 23, fig. c.

1968 *Nummulites pengaronensis* Verbeek; Samanta, pp. 676-680, pl. 128, figs. 1-10; text-figs. 5, 6.

1974 *Nummulites pengaronensis* Verbeek; Samanta & Samaddar, pp. 548-549, figs. 1-3.

Material: Both microspheric and megalospheric specimens were studied. In microspheric generation six isolated specimens, four equatorial sections and three axial sections and in megalospheric generation ten isolated specimens, eight equatorial sections and five axial sections were examined.
Description:

Microospheric generation: The test is medium, evenly biconvex with moderately angular margin. The septal filaments are radial. The surface is smooth (Pl. 27, Fig. 6). The diameter of the test ranges from 4.20 mm to 6.10 mm and the thickness at the centre from 1.80 mm to 2.20 mm.

Equatorial section exhibits simple spire. The septa are perpendicular to slightly inclined at their base, straight at first, then curved backward (Pl. 27, Fig. 7). The whorls increased slowly in height. The septa are more or less regularly spaced throughout the section. The chambers are higher than long and increase slowly in size with growth.

The test is evenly biconvex in axial sections (Pl. 27, Fig. 8; Pl. 56, Fig. 12). Equatorial chambers become gradually higher with ontogeny. They are elongated triangular in outline. The spiral lamina, more or less uniform in thickness in the earlier whorls tends to be very thin in the later whorls. The alar prolongations are narrow. Polar plug is well-developed.

Megalospheric generation: The test is small, highly inflated lenticular with sharp angular margin (Pl. 27, Fig. 1). The surface is smooth with fine radial septal filaments. The diameter of the test ranges from 2.70 mm to 5.00 mm and the thickness from 1.30 mm to 2.75 mm (see Fig. 27).

The equatorial section is characterised by circular to subcircular protoconch followed by the smaller and semicircular to
crescentic deuteroconch (Pl. 27, Figs. 2-3; Pl. 55, Figs. 1, 13). The wall separating the embryonic chambers is thin and gently convex outwards. The internal diameters of the protoconch vary from 75x106 μm to 112x137 μm, those of deuteroconch from 37x100 μm to 62x137 μm and the distance across both the embryonic chambers from 150 μm to 187 μm (for average value see Fig. 24).

The whorls increase slowly in height. The rate of opening of spire is presented in Fig. 25. The marginal cord is moderately developed. The equatorial chambers are mostly higher than long (Pl. 27, Figs. 2-3). The septa are straight and highly inclined to the base which is curved backward in the upper part. The septa are thick and double walled. There are about five whorls in a test diameter of 2.8 mm; nine chambers in the first whorl, seventeen in second, twenty-three in third, twenty-six in fourth and thirty in fifth. The whorl height varies from 87 μm to 137 μm in the first whorl and 250 μm to 287 μm in the last.

In axial section the embryonic apparatus is circular in shape (Pl. 27, Fig. 5; Pl. 55, Fig. 11). The chambers are acute triangular in shape and increase slowly in size. The marginal cord is thin. The alar prolongations are narrow. The spiral laminae are uniform in thickness from pole to the periphery and characteristically thinner in the last whorl than those of the earlier ones. The polar plugs are distinct (Pl. 27, Figs. 4-5). The surface diameter of polar plug varies from 0.80 mm to 1.20 mm.
Measurements: Measurements of external and internal features are represented in Tables 25-30.

Remarks: With the external features of thin, radial, gently curved septal filaments, absence of distinctly developed polar pustules and the internal features of thick, curved septa in equatorial sections and very narrow alar prolongations in axial section, the present specimens are comparable with the description and illustrations of the species presented by Nagappa (1959) and Samanta (1968) from eastern India.

In 1965, Sen Gupta regarded *N. pengaronesis* as a junior synonym of *Nummulites beaumonti* d'Archiac and Haime. According to Samanta (1968) this is not acceptable.

Distribution: The species is widely distributed in the Indo-Pacific province. It is more common in the region between Meghalaya, eastern India and East Indies. It ranges from middle Middle Eocene to Middle Oligocene. In Kutch the species was reported to occur in the Fulra Limestone (Samanta & Samaddar, 1974). In the present area it occurs commonly in this formation and is restricted to the *Discocyclina sowerbyi* and *Alveolina elliptica* Zones of middle to late Middle Eocene age.

*Nummulites pinfoldi* Davies, 1940

(Pl. 28, Figs. 1-6; Pl. 55, Figs. 2, 7, 9, 16; Text-figs. 24-25, 27)

1940 *Nummulites pinfoldi* Davies, pp. 209-210, pl. 10, figs. 1-6, 8.
Material: Only the megalospheric specimens were examined. Ten specimens were studied externally, eight in equatorial sections, and four in axial sections.

Description: The test is small, inflated with truncated as well as depressed pole and subrounded margin (Pl. 28, Fig. 1). The surface is smooth with straight and radial septal filaments. The polar pustule is prominent with flattened or depressed end. The diameter of the test ranges from 1.60 mm to 3.10 mm, the thickness at centre from 0.30 mm to 1.45 mm and the diameter of polar pustules from 0.45 mm to 1.00 mm (for D-T₁ relationship see Fig. 27).

In equatorial sections the embryonic apparatus is small, bilocular (Pl. 27, Figs. 4-6; Pl. 55, Fig. 16). The subcircular to subelliptical protoconch is followed by relatively smaller and semicircular deuteroconch. The wall separating the chambers is slightly curved outward. The internal diameters of the protoconch vary from 100x150 m/μ to 162x200 m/μ and those of the deuteroconch from 87x150 m/μ to 100x156 m/μ.

The distance across the both chambers varies from 206 m/μ to 262 m/μ. The average values of D₁, D₂ and h are seen in Fig. 24.

The whorls increase slowly in height. The rate of opening of spire is depicted in Fig. 25. The marginal cord is well-
developed and is fairly regular in its course. The equatorial chambers are higher than long and rhombic in shape. There are about five whorls in a diameter of 2.4 mm, twelve chambers in the first whorl, twenty-two in the second, twenty-seven in the third, thirty in the fourth. The height of the whorl varies from 67 m/u to 175 m/u.

Axial sections show small and subcircular protoconch followed by reniform deutoconch (Pl. 28, Figs. 2-3; Pl. 55, Fig. 3). The equatorial chambers are wider than high and increase slowly in size. The alar prolongation is moderately open. The marginal cord is weakly developed. The polar plug is well-developed, wide and covering the whole polar region. Its surface diameter ranges from 0.80 mm to 1.30 mm.

**Measurements**: Measurements of external and internal features are presented in Tables 31-33.

**Remarks**: With the flattened or excavated prominent polar pustule, closely coiled spire, gently inclined septa and higher than long equatorial chambers the present material is most closely comparable with *N. pinfoldi* Davies.

**Distribution**: The species was originally described from the Middle Eocene Kohat Shales of Pakistan. Samanta (1973) reported this species for the first time from Kutch. It occurs commonly in the upper part of the Harudi Formation and rarely to commonly in the Fulra Limestone exposed in Harudi and Guvar areas. It is restricted here to middle Middle Eocene *Nummulites obtusus* and
Discocyclina sowerbyi Zones.

**Nummulites scaber** Lamarck, 1804

(Pl. 28, Figs. 7-9; Pl. 56, Figs. 3-4)

1804 *Nummulites scabra* Lamarck, p. 241.

1853 *Nummulites scabra* Lamarck; D'Archiac & Haime, pp. 107-109, pl. 4, figs. 9-12.


**Material**: Only microspheric specimens were studied. Five isolated specimens, three equatorial sections and two axial sections were examined.

**Description**: The test is medium, equally biconvex with angular margin. The septal filaments are thin and closely spaced. The surface of the test is coarsely granulated (Pl. 28, Fig. 7). The granules are uniformly distributed all over the surface and are generally situated over the filaments. The diameter of test ranges from 4.90 mm to 11.30 mm and the thickness from 1.70 mm to 3.55 mm. The diameter of the granules range from 37 μm to 425 μm.

The equatorial section shows simple spire which opens slowly with growth (Pl. 28, Fig. 8). The septa are well-developed and regularly spaced. They are slightly inclined to the marginal cord and are curved backward. The equatorial chambers are higher than long in the earlier whorls and longer than high.
in the later whorls. The number of whorls varies from eleven to fifteen. The total number of chambers in a whorl 0.5 mm from the centre varies from twenty-five to twenty-eight.

The equatorial chambers are triangular in outline and increase slowly in height with ontogeny as shown in the axial section (Pl. 28, Fig. 9; Pl. 56, Fig. 4). The marginal cord is thin in inner whorls which increases in thickness towards the periphery. The alar prolongations are narrow. The pillars are prominent in the axial section and distributed throughout the section. The surface diameter of pillars varies from 87 μm to 450 μm.

Measurements: Measurements of external and internal features are shown in Tables 34-36.

Remarks: The species is characterised by its inflated lenticular shape, coarsely granulated surface and slowly opening spire and referred here as *N. scaber* Lamarck. This is the first report of this species from the area of study. The species is represented by very rare and ill-preserved specimens, so detailed morphological observation was not done.

Distribution: The species was originally described from the Lower Lutetian of Paris Basin, France. *N. scaber* occurs very rarely in the lower and middle parts of the Fulra Limestone exposes in Guvar and Harudi areas. Here, it is restricted to the middle Middle Eocene Discocyclina sowerbyi Zone.
Nummulites stamineus Nuttall, 1926
(Pl. 29, Figs. 1-6; Pl. 55, Figs. 4-6, 15; Text-figs. 24-25, 27)

1926 Nummulites stamineus Nuttall, pp. 131-133, pl. 1, figs. 1-3.

Material: Both microspheric and megalospheric specimens are present. Due to scarcity of material, the microspheric generation is not described here but illustrated only. In megalospheric generation ten isolated specimens, eight equatorial sections and four axial sections were examined.

Description: The test is small, inflated lenticular to subglobular with obtuse margin (Pl. 29, Fig. 6). The surface is smooth and ornamented with thin, radial septal filaments. The diameter of the tests ranges from 3.80 mm to 4.70 mm and the thickness from 2.00 mm to 2.30 mm (see Fig. 27).

In the equatorial section the embryonic apparatus is moderately large and bilocular (Pl. 29, Figs. 2-3; Pl. 55, Figs. 4-6). The protoconch is subcircular to subelliptical in outline while the deuteroconch is smaller and crescentic. The separating wall between the chambers is moderately thick and gently convex outwards to straight in nature. The internal diameters of the protoconch vary from 250x325 μm to 268x375 μm, those of the deuteroconch from 162x362 μm to 175x462 μm and the distance across the embryonic chambers from 425 μm to 450 μm (see Fig. 24 for average values of D₁, D₂ and h).
The whorls increase slowly in height (Pl. 29, Figs. 2-3; Pl. 55, Figs. 3, 15). The rate of opening of spire is shown in Fig. 25. The marginal cord is moderately developed and is fairly regular in its course. The equatorial chambers are rectangular, higher than long and increase slowly with ontogeny. The septa are slightly inclined to the marginal cord at base, straight and evenly spaced. There are about seven whorls in a test diameter of 4.10 mm; thirteen chambers in the first whorl and fifty-six chambers in the last. The height of whorls varies from 125 m/μ in the first whorl to 212 m/μ in the last whorl.

Axial section shows circular to subcircular protoconch followed by semicircular to crescentic deutoconch. The chambers triangular in shape (Pl. 29, Fig. 5, Pl. 55, Fig. 15). The alar prolongations are distinct. The spiral lamina is thick in the polar region. The polar pustules are well developed and extend from the first whorl to the surface of the test (Pl. 29, Fig. 5). The surface diameter of polar plug varies from 0.50 mm to 1.00 mm.

Measurements: Measurements of external and internal features are represented in Tables 37-39.

Remarks: Nuttall (1926) described the species originally from Kutch and Baluchistan.

Smout (1954) included *N. stamineus* in synonymy of *N. discorbinus* and mentioned that *N. stamineus* Nuttall was not
fully described and did not differ significantly from *N. discorbinius*.

In the present study, *N. stamineus* is retained as a valid species following majority of the Indian workers.

**Distribution**: In Kutch, *N. stamineus* Nuttall occurs rarely in the middle and upper parts of the Fulra Limestone. Its occurrence is more common in the Godhatad-Kapurasi area than that in the Guvar area. Here, it is restricted to the middle to late Middle Eocene *Discocyclina sowerbyi* and *Alveolina elliptica* Zones.

*Nummulites umbilicata* Cizancourt, 1946
*(Pl. 30, Figs. 1-3)*

1946 *Nummulites umbilicata* Cizancourt, pp. 644-645, pl. 10, fgs. 6-8; text-fig. 1.

**Material**: Only megalospheric specimens were examined in random thin sections of rocks. Three equatorial sections and three near-axial sections were examined.

**Description**: In equatorial section (Pl. 30, Fig. 1) the test diameter varies from 1.6 mm to 1.8 mm, the embryonic apparatus is small, bilocular and is made up of subcircular protoconch followed by a smaller, reniform deutoconch. The separating wall is very thin, gently convex outwards. The internal diameters of the protoconch range from 62x87 m/μ to 67x93 m/μ and
of the deuteroconch from 43 x 56 m/μ to 46 x 62 m/μ. The distance across both chambers range from 118 m/μ to 137 m/μ. The separating wall is about 12 m/μ thick.

Spire is simple and regular. Marginal cord is well-developed, moderately thick and gradually increases in thickness. The first nepionic chamber is elongated in shape and rests on both the embryonic chambers. The chambers increase gradually in size and are normally higher than long. There are about seven chambers in the first whorl, fourteen in the second and seventeen in the third (Pl. 30, Fig. 1). The septa are moderately thick and double walled. They are slightly inclined at base and curved backward in the upper part. The whorl height varies from 87 m/μ to 200 m/μ.

In near-axial sections (Pl. 30, Figs. 2-3) the test is small, evenly biumbilicate in outline with very acute angular margin. The equatorial chambers are sharp triangular in shape, increase slowly in size and distinctly higher than wide. The spiral laminae increases gradually except in the outermost whorl where it is extremely thin. The alar prolongations are considerably narrower than the spiral laminae. In outermost whorl the spiral laminae as well as alar prolongation of equatorial chambers do not extend up to the poles. The pillars are well-developed and vary in shape and size. Generally they extend up to the surface and appears to form external protuberances. The umbilicate part of the section is more conspicuously pillared.

Remarks: The present specimens are characterised by very small,
biumbilicate shape, small embryonic apparatus, tight spire, thick curved septa and distinct pillars extending up to the surface forming external protuberances. They are treated as identifiable with *N. umbilicata* Cizancourt.

**Distribution:** Cizancourt (1946) described this new species from the Lower Eocene of Aquitaine, France. In the present area it occurs in the Middle Eocene Fulra Limestone; *N. umbilicata* is more frequent in the upper part of the formation. It ranges from middle Middle Eocene *Discocyclina sowerbyi* Zone to the overlying *Alveolina elliptica* Zone of late Middle Eocene age.

**Nummulites variolaria** (Lamarck), 1804

(Pl. 30, figs. 9-10; Pl. 61, Figs. 4, 13, 19, 23, 27)

1804 *Lenticulites variolaria* Lamarck, pp. 187-188.
1853 *Nummulites variolaria* Sowerby; d'Archiac & Haimé, pp. 146-147, pl. 9, figs. 13a-g.
1966 *Nummulites variolaria* (Lamarck); Biondeau, pp. 912-915, pl. 28, figs. 2, 5-8, 11-12, 16-21, 25.

**Material:** Only megalospheric specimens were studied. Five isolated specimens, four equatorial sections and four axial sections were examined.

**Description:** The test is very small and inflated lenticular with angular margin. The surface is typically nongranulate with large, not well-marked polar pustules. The septal filaments are very thin and radial. The diameter of the test ranges from 1.0 mm to
1.35 mm, the thickness at the centre from 0.32 mm to 0.50 mm, and the diameter of polar pustule from 0.15 mm to 0.32 mm.

In equatorial section the embryonic apparatus is small, bilocular with subcircular protoconch and reniform deutoconch subequal in size. The spire opens rapidly and is made up of about three to four whorls. The marginal cord is thin and is regular in its courses. The equatorial chambers are much higher than long. The septa is regular, slightly inclined to the marginal cord of the preceding whorl. They are straight in the lower part and are slightly curved backward in the upper part. The internal diameters of the protoconch range from 43 x 56 μm to 50 x 62 μm and of the deutoconch from 37 x 62 μm to 50 x 62 μm. The distance across both the chambers ranges from 92 μm to 112 μm. There are about eight chambers in the first whorl, thirteen in the second and eighteen in the third. The whorl heights vary from 75 μm to 212 μm.

In axial section the embryonic apparatus is small. The protoconch is subcircular in outline while the deutoconch is crescentic. The equatorial chambers are elongated triangular in shape, increase slowly in size and higher than wide. The spiral lamina is more or less uniform in thickness. The marginal cord is usually thin. The alar prolongations are well-developed and wide. Distinct polar plugs are present. The surface diameter of polar plug varies from 0.2 mm to 0.32 mm.

**Measurements**: Measurements of the external and internal features are represented in Tables 40-42.
Remarks: The Kutch specimens characterised by their small, inflated test with radiate filaments and indistinct polar pustule and rapidly opening spire with higher than long rectangular chambers are identified here *N. variolarius* (Lamarck). They are comparable to those figured by Blondeau (1966) from the European localities.

Distribution: This is a widely radiate *Nummulites* reported from Anglo-Franco Belgian Basin on the northwest to North Africa-Mozambique to New Caledonia in the east from rocks ranging in age from Middle to Late Eocene. In the present area *N. variolarius* occurs commonly to frequently in the Harudi Formation and rarely to commonly in the Fulra Limestone. Here it is restricted to the *Nummulites obtusus*, *Discocyclina sowerbyi* and *Alveolina elliptica* Zones of Middle Eocene age.

*Nummulites vicaryi* d'Archiac & Haime, 1853

(Pl. 29, Figs. 7-9)

1853 *Nummulites vicaryi* d'Archiac & Haime, pp. 139-140, pl. 9, figs. 1a-c.
1981 *Nummulites vicaryi* d'Archiac & Haime; Schaub, pp. 136-137, pl. 54, figs. 6-15.

Material: Only microspheric specimens were studied. Six isolated specimens, five equatorial section and five axial section are examined.

Description: Test is medium to large, lenticular with subrounded
periphery. Surface covered with close-spaced septal filaments sigmoidal to meandriform pattern. The diameter of test varies from 12.1 mm to 22.4 mm and the thickness at centre from 4.8 mm to 7.2 mm.

In equatorial section the spire in the early part is tight, extremely regular in course and made up of narrow, higher than long, close spaced chambers. The septa are nearly perpendicular at the base and straight. Then, the rate of opening of the spire increases appreciably and septa become inclined at the base and gently curved in the distal part. The chamber continue to be higher than long. Marginal cord is very thin. The last few whorls are characterised by narrower cavity and thinner marginal cord. Here the chambers may be longer than high. There are about eighteen whorls in a test diameter of 19.0 mm and twenty-seven to thirty-five chambers in a whorl 0.5 mm apart from centre.

The axial sections show an early inflated biconvex part with well-developed polar plugs and extremely narrow alar prolongations not readily discernible. In the middle part the shape becomes biconvex with rounded margin. The polar plugs become less distinct and the chamber cavity wider than high. In the outer part the walls become much thinner over the poles producing a compressed shape, the filaments become meandriform and chambers much wider than high. The polar plugs are typically lacking in this part. The maximum diameter of polar plug varies from 1.3 mm to 1.75 mm.
Measurements: Measurements of external and internal features are shown in Tables 43-45.

Remarks: The species is distinguished in the present material by its medium to large, biconvex test with close-spaced sigmoidal to meandriform filaments, slowly opening spire and higher than long chambers between inclined slightly curved septa. It is identified here as *N. vicaryi* d'Archiac & Haime as described and discussed in detail by the original authors as well as recently by Schaub (1981). It shows characters of the *N. beaumonti* group and on the basis of its morphology and stratigraphic range, it has been considered as the most developed member of *N. beaumonti* phylum (Schaub, 1981).

Distribution: D'Archiac & Haime (1853) described this new species from Sind, Pakistan. The stratigraphic horizon from which the original material was derived was not precisely known. In a recent study, Schaub (1981) dated the horizon as late Middle Eocene. In Kutch, the species occurs rarely in the Fulra Limestone of Harudi, Guvar and Godhated-Kapurasi areas. Here it is restricted to the middle to late Middle Eocene *Discocyclina sowerbyi* and *Alveolina elliptica* Zones.
Material: Only one equatorial section of megalospheric generation from random thin section of rocks was studied.

Description: The equatorial section is characterised by conspicuously large embryonic apparatus. The two embryonic chambers differ markedly in shape and size. The protoconch is notably large and subcircular in outline while the deutoconch is very small, narrow, arcuate in outline. The separating wall between the two embryonic chambers is very thin and markedly convex outwards. The wall of the protoconch is characteristically thin. The internal diameters of the protoconch is $900 \times 1025$ $\mu$m and those of the deutoconch $125 \times 875$ $\mu$m. The distance across the embryonic chambers is $1037$ $\mu$m.

There are five whorls in a diameter of $7.0$ mm. The spire is simple. The first whorl increases slowly in height. The second and third whorl-heights are more or less same. The last two whorls are narrower than the earlier formed one. The height of whorls varies from $275$ $\mu$m to $700$ $\mu$m. The marginal cord is moderately thick and is fairly regular in its course.

The first nepionic chamber is arcuate in shape. Subsequently, the chambers are narrow, generally curved rectangular to subarcuate in outline and increase regularly in size. They are several times
higher than long. In the last two whorls chambers are rectangular to subrectangular in outline, usually longer than height. The septa are strongly curved, inclined to the marginal cord of the preceding whorl. In inner whorls the septa are moderately straight in the lower part and are moderately to strongly curved backward in upper part. In outer whorls they are virtually straight in greater part of their length from the base and then strongly curved backward in upper part. The septa are regularly spaced and moderately thin and often undulating in course.

Remarks: Tandon (1976) described his new species on the basis of only eight microspheric specimens. The megalospheric generation of the species was not represented in his material. It is thus described here for the first time which is characterised by conspicuously large, subcircular protoconch and very narrow arcuate deuteroconch, narrow equatorial chambers separated by highly curved often undulating septa. It is extremely rare in present material.

Distribution: Originally described from the Middle Eocene of southwestern Kutch, *N. vohrai* occurs very rarely in the Fulra Limestone of the Guvar area. Here the species is restricted to the *Alveolina elliptica* Zone of late Middle Eocene age.

**Nummulites vredenburgi** Prever, 1908

(Pl. 31, Figs. 1-11; Pl. 54, Figs. 3-6, 16-18, Text-figs. 24-25, 27)
1906 *Nummulites douvillei* Vredenburg, pp. 79-85, pl. 8, figs. 1-13 (Non *Lenticuline* (Gumbelia) *douvillei* Prever, 1902).

1908 *Nummulites vredenburgi* Prever (in litt.); Vredenburg, p. 239.

1965 *Nummulites acutus* Sen Gupta, pp. 87-89, pl. 15, figs. 3, 7, 9; pl. 16, figs. 6, 8; pl. 17, figs. 2, 4, 8, 11. (Non *Nummularia acuta* Sowerby, 1840).

1982 *Nummulites vredenburgi* Prever; Samanta, pp. 32-44, figs. 6-10.

**Material**: Both microspheric and megalospheric specimens were studied. Five isolated specimens, six split-equatorial sections and four axial sections of microspheric generation and twelve isolated specimens, eight equatorial sections and six axial sections of megalospheric generation were examined.

**Description**:

**Microspheric generation**: Test medium to large, thin compressed lenticular to nearly discoidal with corded margin (Pl. 31, Figs. 7-8). The gently convex inner part is surrounded by flat peripheral region with subparallel sides forming a flange-like structure. The transverse view resembles to unequally biconvex to plano-convex outline. The conspicuously developed marginal cord of the outermost whorl produces a gently raised rim surrounding the periphery. Surface is ornamented with fine to coarse granules, sub-circular to elongated in outline. The mode of arrangement and
spacing of the granules exhibit considerable variation. Usually, the granules are either situated on the septal filaments or are attached to them. The septal filaments are fine and wavy. On some parts of the surface they produce distinct meshes of varying shape and size thus forming a subreticulate pattern. Test diameter ranges from 6.7 mm to 17.3 mm and thickness at centre from 1.8 mm to 3.35 mm. Surface diameter of granules ranges from 100 mm to 300 mm.

In equatorial section the spire is simple and loosely coiled. There are about ten whorls in a radius of 9.0 mm. In the early whorls the spire is more regular and opens relatively slowly. Afterwards the spire becomes remarkably loose and the whorls open rapidly in height. Usually the rate of opening of the spire is arrested in the outer part of the test. Sometimes the height of the spire exhibits noticeable variation even along the same whorl, is most pronounced in the outer whorls. The marginal cord is well-developed and increases remarkably in thickness with growth. In early whorls it is regular to wavy in course, while in later whorls it often becomes distinctly irregular. Generally, the marginal cord is much thinner than the height of the whorl cavity.

The septa are prominently developed and long. They are generally normal to the marginal cord at the base and straight for the major part of their length with noticeably sharp backward curvature near the top. In the outer whorls the septa become extremely long and tend to exhibit broad flexure in their middle part. Often in the irregular parts of the spire the septa abut
against the earlier formed one instead of extending up to the marginal cord at the top. The septa is double-walled in nature and its thickness remains same throughout the length. The chambers are radially elongated and rectangular in outline. They are typically much higher than long. In the early whorls they are about twice as high as long whereas in the highest part of the spire they become nearly three times as high as long. There are about twenty-two to twenty-seven chambers in a whorl 0.5 m apart from centre.

In axial section the outline of the test appears to be compressed unequally biconvex with rounded periphery. In the inner part the equatorial plane is flat and very narrow while it is gently wavy and wide in the outer part. The equatorial chambers are highly elongated triangular to tapering and much higher than wide in shape. The alar prolongations are narrow but distinct. Their width varies irregularly from periphery to the polar region. The alar prolongations are divided into small, low, elongated cavities by pillars as well as transverse partitions formed of sections of the septal filaments. The well-developed marginal cord is a distinctive feature in axial sections. It represents the thickest portion of the spiral lamina. The spiral laminae are gradually decreasing their thickness from periphery to polar regions. Sometimes the individual spiral lamina splits up into more layers producing later chambers. The lateral splitting is more common in the laminae of later whorls near the marginal cord.
The pillars are distributed from pole to the periphery. They are of varying shape and size. They are irregularly crowded over the inflated inner part of the test. The majority of the pillars do not extend up to the surface. The surface diameter of pillars varies from 62 μm to 300 μm.

Megalospheric generation: Test small, compressed lenticular to almost discoidal with rounded, cord-like margin (Pl. 31, Figs. 1-2). In totally preserved specimens a thin, wide peripheral flange surrounds the gently inflated inner part of test. This flattened peripheral part constitutes nearly one-half of the radius of the test. The thick marginal cord of the outermost whorl forms a swollen rim round the margin. The surface is ornamented with granules of varying shape, size and arrangement. The difference in ornamentation between the peripheral part and umbonal elevation is marked. The umbonal area is covered with coarse, closely spaced granules while over the last whorl the granules are arranged radially marking the course of septal suture. On the last whorl the chamber spaces are usually ornamented with a few, fine, scattered granules. The granules are usually situated on the septal filaments which are fine and irregular in course. The diameter of the test ranges from 1.5 mm to 5.3 mm, thickness at centre from 0.65 mm to 1.4 mm and the diameter of granules varies from 50 μm to 300 μm (see Fig. 27 for D-T relationship).

In the equatorial section the embryonic apparatus is medium in size and bilocular (Pl. 31, Figs. 3-4). The protoconch is sub-
circular in outline with slight flattening along the separating wall. It is followed by reniform deuteroconch. The separating wall between the embryonic chambers is thin and nearly straight to convex outwards. The internal diameters of the protoconch varies from 250x281 m/μ to 437x437 m/μ, those of deuteroconch from 143x343 m/μ to 200x462 m/μ, the distance across both the chambers from 412 m/μ to 637 m/μ and the thickness of the separating wall from 12 m/μ to 18 m/μ (for average values of D1, D2 and h, see Fig. 24).

The spire is simple and loosely coiled. There are about three whorls in a radius of 4.15 mm. The whorls increase rapidly in height. The rate of opening of spire is represented in Fig. 25. Sometimes the height of whorl cavity is irregular in course. The marginal cord is prominently developed, increases in thickness with growth. The marginal cord is fairly regular in course and always much thinner than the heights of whorl cavity. The shape and size of first nepionic chamber vary to some extent. It is followed by subrectangular equatorial chambers larger than the embryonic chambers. There are about five to nine chambers in the first whorl, sixteen to twenty-one in the second whorl and twenty-two to thirty-one in the third whorl. The chambers are higher than long and increase rapidly in size with growth. In the later whorls the chambers are often more than twice as high as long. The septa are long, thin and are nearly normal to the marginal cord at the base. They are straight for the major part of their
length with sharp backward curvature near the top. The spacing of septa is fairly regular. The whorl height varies from 325 m/u to 462 m/u in the first whorl and 537 m/u to 812 m/u in the last whorl.

In the axial section the shape of the test appears to be flat, compressed. The low, wide umbonal elevation is surrounded by thin, broad peripheral flange (Pl. 31, Figs. 5-6). The thickness at the poles is about four times greater than that near the periphery. The equatorial plane is nearly flat. The protoconch is subcircular and the deutoconch is reniform. The equatorial chambers are noticeably elongated triangular and are higher than wide. The alar prolongations are open and vary in width in different parts of the section. The well-developed marginal cord constitutes the thickest part of the spiral lamina. It increases in thickness with growth. The alar prolongations over the marginal cord are much narrower. The pillars are more crowded and prominent over the umbonal elevation than on the peripheral flange. They are relatively thicker on the marginal cords. The pillars in the umbonal part increases in thickness towards the surface. The majority of the pillars extend upto the surface forming granules. The surface diameter of pillars ranges from 75 m/u to 287 m/u.

Measurements: Measurements of external and internal features are presented in Tables 46-51.

Remarks: Both microspheric and megalospheric generations were described and illustrated by Vredenberg (1906) indicating clearly
the distinctive features of the species. According to him *N. vredenburgi* belongs to the *Nummulites laevigatus* group. The specimens of *N. manfredi* Schaub figured by Rahaghi and Schaub (1976, pi. 1, figs. 1-7) from Iran are closely comparable to the types of *N. vredenburgi* in external as well as internal features. *N. vredenburgi* is considered by Samanta (1982) to have been derived from *N. manfredi* Schaub during the Middle Eocene.

Sen Gupta (1965) hold the view that Vredenburg's *Nummulites douvillei* included microspheric and megalospheric generations of *N. acutus* from Kutch. Sen Gupta's figured material of *N. acutus* belong to *N. vredenburgi* as discussed by Samanta (1982). Samanta (1982) described and illustrated the syntypes of *N. vredenburgi* Prever preserved in Geological Survey of India, Calcutta and its topotypes from Lakhpat, Kutch and discussed in detail its differences with *N. acutus* (Sowerby) as well as *N. djokidjokartae* (Martin).

In the present investigation materials from the type area, Lakhpat, were examined and illustrated.

**Distribution**: Vredenberg (1906) described the present species as *N. douvillei* on the basis of specimens collected by Geological Survey of India field party from Kutch. He considered it as restricted to the lower part of his Middle Kirthar (=Middle Lutetian of Paris Basin) According to Samanta (1982) in the type area in Kutch *N. vredenburgi* occurs with the planktonic foraminiferal fauna indicative of *Globorotalia lehneri* Zone of Bolli and
N. vredenburgi - bearing horizon is middle Middle Eocene in age (see Samanta, 1982, p. 44). In Kutch, the species is restricted to the upper part of Harudi Formation. In Naliya - Narayan Sarovar Rd. traverse, north-west of Harudi as well as in Guvar Stream section, N. vredenburgi is virtually restricted to N. obtusus Zone of Middle Eocene age. It is one of the conspicuous larger foraminifera of that zone.

**Nummulites sp. aff. N. exilis Douville, 1919**

(Pl. 30, Figs. 4-7; Pl. 61, Figs. 1, 11, 28, 32-33, 35-36; Text-fig. 25)

aff. 1919 **Nummulites exilis** Douville, p. 62, pl. 1, fig. 42; text-figs. 10-12.

aff. 1919 **Nummulites subexilis** Douville, p. 65, pl. 1, figs. 43-45; text-fig. 13.

**Material**: Only megalospheric specimens were studied. Five isolated specimens, eight equatorial sections and five axial sections were examined during the present investigation.

**Description**: The test is small and compressed biconvex with sharp angular margin. The surface is non-granulate and ornamented with distinct polar pustules. The septal filaments are very prominent, thin, gently wavy, and closely spaced. Test diameter varies from 1.1 mm to 1.6 mm, thickness at the centre from 0.3 mm to 0.5 mm and diameter of polar pustules from 0.1 mm to 0.2 mm.

In equatorial section embryonic apparatus is very small,
bilocular, made up of subcircular protoconch followed by crescentic deuteroconch. The separating wall is extremely thin, gently convex outwards. The internal diameters of the protoconch range from 31x37 m/μ to 43x56 m/μ and of the deuteroconch from 18x31 m/μ to 25x62 m/μ. The distance across both chambers ranges from 56 m/μ to 81 m/μ.

The spire is simple, usually regular with about four to five whorls in a radius of 1.3 mm. Marginal cord is well-developed. Whorls open rapidly. The rate of opening of spire is presented in Fig. The height of whorls varies from 62 m/μ in first whorl to 200 m/μ in last whorl. The chambers increase gradually in size and are much higher than long. The septa are slightly inclined to the marginal cord of the preceding whorl, virtually straight in the greater part at base and are moderately to highly curved backward in their upper part.

In axial section the outline of test is compressed biconvex with sharp angular margin. The equatorial chambers are elongated triangular and distinctly higher than wide. The spiral lamina is more or less uniform in thickness except in the outermost whorl where it is conspicuously thinner than the early formed part. The alar prolongation is narrower than the spiral laminae. The alar prolongations do not reach the poles in the outermost whorl. Polar plugs are prominent and extends upto the surface. The surface diameter of polar plug ranges from 0.12 mm to 0.21 mm.

Measurements: Measurements of external and internal features are presented in Tables 52-54.
Remarks: The present specimens are characterised by its whorl. In external and internal features the present species shows affinity to *N. exilis* Douville known from southern Europe. More detail study based on comparative material is required for its precise identification. There is no previous record of a comparable form from the present area of study.

Distribution: The present species occurs rarely to commonly both in the Harudi Formation as well as the Fulra Limestone. In the present area of study it is restricted to the Middle Eocene *Nummulites obtusus*, *Discocyclina sowerbyi* and *Alveolina elliptica* Zones.

**Genus Assilina d' Orbigny, 1839**

Type species: *Nummulites spira* de Roissy, 1805

*(designated by d'Archiac & Haime, 1853)*

**Diagnosis:** Test small to very large; spire simple or multiple; increasing regularly in height; chambers evolute; whorl walls semi-involute to involute; transverse trabeculae and septal filaments lacking.

**Distribution:** *Assilina* is distinct from the other three genera included here in the family *Nummulitidae* in its restricted geographic and stratigraphic ranges. It is not represented in the Caribbean-American region and is not known to occur east of Indonesia in the Tethyan-Indo-Pacific provinces. The genus is best developed in the region between Spain and western India.
where it occurs as rock-forming genus at several horizons.

All authentic records of Assilina are restricted to the Palaeocene-Middle Eocene interval. In well-dated successions it does not range up to the latest Middle Eocene (Samanta, 1978; Schaub, 1981). It is a well-represented larger foraminifera in the Indian region and has been described and illustrated from the different Palaeocene-Middle Eocene successions of Pakistan (Gill, 1953; Schaub, 1981) and India (Samanta, 1962).

Occurrence in Kutch: In Kutch, Assilina occurs only in the Naredi Formation and the Fulra Limestone exposed in Traverses I-IV (Figs. 9-12). It is not represented in the Harudi Formation, the third rock unit constituting the Lower-Middle Eocene part of the succession. Again, in both the Naredi Formation and the Fulra Limestone the genus is stratigraphically restricted to only part of the formation. Thus, in the Lower Eocene Naredi Formation it is restricted to the Assilina Limestone Member which is characterised by the occurrence of a number of thin bands rich in Assilina. In Fulra Limestone also the genus does not range from the base to the top and occurs as a rock-forming element only in its lower part. The genus is represented in Kutch by the following four species:

1. *Assilina daviesi* Cizancourt
2. *A. exponens* (Sowerby)
3. *A. laxispira* de la Harpe
4. *A. spinosa* Davies

They are described as follows:
Assilina daviesi Cizancourt.

A. laxispira de la Harpe.

A. spinosa Davies.

Fig. 28 Scatter diagram of $T_1 - T_2$ for three species of Assilina (Form 'B') from the Naredi Formation.
Assilina daviesi Cizancourt, 1938
(Pl. 34, Figs. 1-7, 10; Pl. 58, Figs. 12-14; Pl. 59, Figs. 5-9; Text-figs. 28-31)

1937 Assilina sp. cf. A. pustulosa Doncieux; Davies in Davies & Pinfold, pp. 34-35, pl. 4, figs. 13-15, 18, 22.
1938 Assilina daviesi Cizancourt, p. 23, pl. 3, figs. 18, 25-26, text-fig. 2b.
1953 Assilina daviesi Cizancourt; Gill, p. 81, pl. 13, figs. 6-13.

Material: Both microspheric and megalospheric specimens were examined. Seven isolated specimens, three equatorial and split-equatorial sections and three axial sections of microspheric form and fifteen isolated specimens, twelve equatorial sections and five axial sections of megalospheric form were studied.

Description:
Microspheric generation: The test is small, compressed, deeply bumbilicate with angular margin (Pl. 34, Fig. 6). The surface is ornamented with subcircular, coarse granules arranged along spiral sutures. They are most prominent near the centre; peripheral whorls are smoother in appearance. The test diameter varies from 4 mm to 6.8 mm, the thickness of centre from 0.3 mm to 0.4 mm and the diameter of granules from 75 μm to 387 μm (see Fig. 28 for T₁-T₂ relationship).

In equatorial section the spire is simple and usually regular in course (Pl. 34, Fig. 7; Pl. 59, Fig. 6). In a test diameter
Fig. 29 Scatter diagram of $T_1$—$T_2$ for three species of *Assilina* (Form 'A') from the Naredi Formation.
of 6.8 mm there are about nine whorls. The marginal cord is well-developed, regular to slightly wavy in its course and much thinner than the height of the whorl cavity. The equatorial chambers are rectangular, radially elongate and higher than long. There are about twenty-six chambers in a whorl 0.5 mm apart from the centre. The size of chambers increases with growth. The septa are thin and regularly spaced. They are straight to curved backward and mostly inclined to the marginal cord at the base.

Axial sections show the compressed test with deep umbilicus (Pl. 34, Fig. 10; Pl. 59, Fig. 5). The equatorial plane is flat. The equatorial chambers are triangular in shape and are higher than wide. The whorl height increases regularly with growth. The marginal cord is distinct and varies little with growth. The spiral laminae are semi-involute. The pillars are situated at the junction of whorls. The surface diameter of pillars ranges from 37 μm to 362 μm.

Megalospheric generation: The test is very small, compressed, evenly biumbilicate with subangular margin. The surface is ornamented with granules usually distributed along spiral as well as septal sutures (Pl. 34, Figs. 1-2). They are most conspicuous in the depressed central part. The diameter of the test ranges from 1.8 mm to 3.75 mm, thickness at the centre from 0.22 mm to 0.35 mm and diameter of granules from 50 μm to 375 μm. T1-T2 relationship is presented in Fig. 29.

In equatorial sections embryonic apparatus is very small,
Fig. 30 Rates of opening of spire in four species of Assilina (Form 'A')
Coverage of 12 specimens for each species.

- Assilina daviesi Cizancourt
- A. exponens (Sowerby)
- A. laxispira de la Harpe
- A. spinosa Davies
1. *Assilina daviesi* Cizancourt
2. *A. exponens* (Sowerby)
3. *A. laxispira* de la Harpe
4. *A. spinosa* Davies

Fig. 31 Histogram of $D_1$, $D_2$ and $h$ for four species of *Assilina* (Form 'A') - average of 5 specimens for each species.
bilocular, made up of subcircular protoconch followed by semilunar deuteroconch (Pl. 34, Fig. 3; Pl. 58, Fig. 14; Pl. 59, Figs. 7, 9) subequal in size to the protoconch. The separating wall is thin, straight to gently convex outwards (Pl. 58, Fig. 12). The internal diameters of protoconch range from 75x100 m/μ to 93x106 m/μ, those of deuteroconch from 56x100 m/μ to 75x100 m/μ and the distance across both chambers ranges from 150 m/μ to 181 m/μ. The average values of D₁, D₂ and h are shown in Fig. 31.

The spire is simple, fairly regular with about five whorls in a diameter of 3.5 mm. The whorls increase slowly in height. The marginal cord is moderately developed and is fairly regular in its course. They are much thinner than the whorl cavity and increase very slowly in thickness with growth.

The first neioniç chamber is usually subtriangular in shape (Pl. 59, Figs. 7, 9). It is larger in size than the deuteroconch. The equatorial chambers increase gradually in size and are normally rectangular in outline. Generally they are slightly higher than long. There are about seven chambers in the first whorl, thirteen in the second, seventeen in the third and twenty-two in the fourth. The septa are thin, gently inclined to the marginal cord at base. They are virtually straight in the greater part of their length. Some of them are slightly curved backward in their distal end. The whorls open very slowly (see Fig. 30) and the height of whorls varies from 125 m/μ in the first whorl to 343 m/μ in the last whorl.
Axial sections show the stout, equally biumbilicate shape (Pl. 34, Figs. 4-5; Pl. 58, Fig. 13; Pl. 59, Fig. 8). The protoconch is subcircular in outline followed by crescentic deuteroconch. The equatorial plane is flat. The equatorial chambers are evolute, elongate triangular in outline and higher than wide (Pl. 58, Fig. 13). The spiral laminae are very distinct and semi-involute. The pillars occur at the junction of whorls. The surface diameter of pillars varies from 75 m/μ to 400 m/μ.

**Measurements**: Measurements of external and internal features are appended in Tables 55-60.

**Remarks**: Cizancourt (1938) created the new species *A. daviesi* for specimens of *Assilina* from Afghanistan characterised by medium, biumbilicate, coarsely granulate test with regularly opening spire and straight to gently curved septa. She remarked that assilines from Salt Range identified by Davies (in Davies & Pinfold, 1937) as *A. cf. pustulose* Doncieux belong to the new species. Later, Gill (1953) provided detail discussions on the variations displayed by populations of *A. daviesi* from Kohat-Potwar Basin, Pakistan. In their compressed, umbilicate, coarsely granulate test and regularly enlarging spire with straightly to gently curved septa the Kutch specimens are identifiable with *A. daviesi* Cizancourt.

**Distribution**: Originally described from the Lower Eocene of Afghanistan, the species has been reported from the Lower Eocene of different localities in Pakistan. It has also been reported
from the Lower Eocene of western India. In Kutch, the species occurs rarely to commonly in the Assilina Limestone Member of the Naredi Formation exposed in Guvar and Nareda areas. Here, it is restricted to Early Eocene Assilina laxispira Zone.

**Assilina exponens** (Sowerby) 1840

(Pl. 32, Figs. 1-8; Pl. 60, Figs. 1-17; Text-figs. 30-32)

1840 *Nummularia exponens* Sowerby, p. 719, pl. 41, figs. 14a-e.

1853 *Nummulites exponens* (Sowerby); d'Archiac and Haime, pp. 148-150, pl. 10, figs. 1-10.

1853 *Nummulites mamillata* d'Archiac; d'Archiac & Haime, pp. 154-155, pl. 11, figs. 6-8.

1908 *Assilina exponens* (Sowerby); Heim, pp. 242-243, fig. 20A; pl. 7, figs. 1-4, 13-18; pl. 8, fig. 20.

1908 *Assilina mamillata* (d'Archiac); Heim, p. 244, pl. 7, figs. 5-12, 23-37.

1926 *Assilina exponens* (Sowerby); Nuttall, pp. 142-148, pl. 5, figs. 5-6, pl. 6, fig. 1.

1926 *Assilina mamillata* (d'Archiac); Nuttall, p. 143, pl. 6, fig. 4.

1960 *Assilina exponens* (Sowerby); Ziegler, pp. 227-228, fig. 10, pl. 4, figs. 6-8.

1960 *Assilina mamillata* (d'Archiac); Ziegler, pp. 229-230, figs. 11-12; pl. 4, figs. 1-2.

1972 *Assilina exponens* (Sowerby); Blondeau, p. 171, pl. 38, figs. 8-10.

1981 *Assilina exponens* (Sowerby); Schaub, pp. 213-215, pl. 92, figs. 1-20; pl. 93, figs. 1-15; pl. 94, figs. 1-34.
Fig. 32 Scatter diagram of $D - T_1$ for *Assilina exponens* (Sowerby) from the Fulra Limestone.

- **Form A**
- **Form 'B'**
Material: Both microspheric and megalospheric specimens were studied. Twenty-eight isolated specimens, four equatorial sections and four axial sections of microspheric generation and fifty-one isolated specimens, twelve equatorial sections and seven axial sections of megalospheric generation were examined.

Description:

Microspheric generation: The test is medium to large in size and compressed lenticular to discoidal with small polar depression and angular margin (Pl. 32, Fig. 6). The thin peripheral part of large specimens is often wavy and undulating in shape. The surface is ornamented with fine minute papillae arranged along septal sutures often close-spaced to forming shallow ridges. The diameter of the test varies from 14.0 mm to 27.3 mm and the thickness at centre from 2.2 mm to 3.35 mm (Fig. 32).

The spire is simple to multiple and open regularly in height. The outer whorls often increasing more rapidly in height than the inner ones (Pl. 32, Fig. 8). The marginal cord is thin, regular in inner whorls but slightly wavy in outer part. The septa are straight and nearly perpendicular to the marginal cord at the base (Pl. 32, Fig. 8). The equatorial chambers are radially much elongate rectangular and increase noticeably in size with ontogeny. There are about seventeen whorls in a test diameter of 22.3 mm. Number of chambers in a whorl 0.5 m apart from the centre varies from twenty-four to twenty-seven.

Axial sections show the compressed biconvex with gently
flattened polar region to discoidal shape of the test. The equatorial chambers are subtriangular in shape and evolute (Pl. 32, Fig. 7; Pl. 60, Figs. 10, 17). The whorl height increases appreciably towards periphery. The spiral laminae are semi-involute. Fine pillars of varying diameter occur throughout the section. The surface diameter of the pillars ranges from 50 mμ to 900 mμ.

Megalospheric generation: The test is small to medium in size, often umbonate, biconvex to thin discoidal in shape (Pl. 32, Fig. 1) with angular margin. The surface is ornamented with granules and the polar region is more coarsely granulated than the peripheral part. The granules are distributed throughout the test and generally occur along the spiral sutures, septal sutures and over the chamber spaces. Often they occur close-spaced forming spiral as well as septal ridges. The diameter of the test ranges from 3.6 mm to 10.5 mm and the thickness at centre from 1.6 mm to 3.35 mm (Fig. 32). The diameter of the polar granules ranges from 250 mμ to 1000 mμ and that on peripheral part from 100 mμ to 450 mμ.

Equatorial section shows large, bilocular embryonic appara- ratus (Pl. 32, Figs. 2-3; Pl. 60, Figs. 1-4, 11). The two embryonic chambers differ significantly both in shape and size. The subcircular protoconch is followed by much smaller and crescentic deuteroconch. Sometimes the size of the protoconch is more than two times larger than that of the deuteroconch. The separating wall between the embryonic chambers is extremely thin and gently
convex outwards (Pl. 60, Figs. 12-16). The internal diameters of the protoconch range from 312x387 m/μ to 612x687 m/μ and those of the deuteroconch from 137x362 m/μ to 512x525 m/μ. The distance across the embryonic chambers ranges from 12 m/μ to 37 m/μ. Fig. 31 shows the average values of D₁, D₂ and h.

The spire is simple and regular. The whorls slowly increase in height with growth. The rate of opening of spire is depicted in Fig. 30. The marginal cord is moderately developed and fairly regular in its course. The number of whorls varies from three to seven when test diameter ranges from 4.5 mm to 9.4 mm.

The first nepionic chamber is usually arcuate in shape. The thickening of marginal cord usually starts from the third nepionic chamber (Pl. 60, Fig. 1). The equatorial chambers are radially elongate rectangular and increase slowly in size with ontogeny. The equatorial chambers are higher than long. The septa are very thin, straight, almost normal to the marginal cord at base and slightly inclined near the top. The spacing of the septa varies to some extent. The height of the whorls varies from 312 m/μ to 525 m/μ in the first whorl and 437 m/μ to 762 m/μ in the sixth whorl.

Axial section (Pl. 32, Figs. 4-5; Pl. 60, Figs. 5-6, 9) shows subcircular protoconch followed by crescentic deuteroconch. The chambers are triangular in shape and evolute (Pl. 60, Figs. 5-6, 9) while the spiral laminae are distinct and semi-involute. The pillars are numerous and occur throughout the
section specially at the whorl junctions and the polar region. The surface diameter of pillars ranges from 50 m/u to 975 m/u.

**Measurements**: Measurements of external and internal features are presented in Tables 61-66.

**Remarks**: In the original publication Sowerby (1840) provided sketches showing the essential features of the species described as *Nummularia exponens*. Later, d'Archiac & Haime (1853) described and illustrated in detail permitting its ready recognition by later workers. Nuttall (1926) reexamined material from the type locality and discussed its external and internal features supported by photomicrographs. There are good illustrations of the species from numerous localities of the southern Europe - Mediterranean region. According to Schaub (1981) *A. exponens* developed from *A. tenuimarginata* Heim during the Middle Eocene.

The present study shows there are considerable variations in the shape of the test. The megalospheric embryonic apparatus is typically large and thin-walled.

**Distribution**: *A. exponens* is an age diagnostic species of the genus restricted to rocks of middle Middle Eocene age. In Kutch, it is ranges through the *Orbulinoides beckmanni* Zone (Samanta, 1970). In European localities it is considered to range from Middle Lutetian to Basal Biarritzian (Schaub, 1981). In the present area of study *A. exponens* is restricted to the middle part of the Fulra Limestone. Stratigraphically the species is restricted here to the *Discocyclina sowerbyi* Zone which is middle Middle Eocene in age.
Assilina laxispira de la Harpe, 1926
(Pl. 33, Figs. 1-10; Pl. 34, Figs. 11-12; Pl. 58, Figs. 6-10; Pl. 59, Figs. 1, 4; Text-figs. 28-31)

1853 Nummulites granulosa d'Archiac; d'Archiac & Haime, p. 151, pl. 10, figs. 11, 15-18.

1853 Nummulites mamillata d'Archiac var. a. d'Archiac & Haime (Parts), pl. 11, figs. 8a-e.

1926 Assilina placentula vel granulosa, form A, var. laxispira n. var. de la Harpe, édite par Rozlozsmik, p. 92.

1955 Assilina laxispira de la Harpe; Schaub, fig. 1c.

1981 Assilina laxispira de la Harpe; Schaub, pp. 192-200, pl. 73, figs. 56-73; pl. 74, figs. 1-50, 53-54; text-figs. 113-114.

Material: Both microspheric and megalospheric specimens were examined. Ten isolated specimens, four equatorial and split-equatorial sections and four axial sections of microspheric generation and fourteen isolated specimens, twelve equatorial sections and five axial sections of megalospheric generation were studied.

Description:

Microspheric generation: The test is medium to large and thin discoidal in shape with subrounded margin (Pl. 33, Figs. 6-7; Pl. 34, Fig. 11). Usually there is a small depression at the centre. Forms with a broad gentle depression on the central part are also common (Pl. 33, Fig. 7). Generally spirally arranged coarse granules are present on central part. They are subcircular
in outline and occur along the spiral sutures forming spiral ridges. The peripheral part is non-granulate and marked by distinct spiral sutures. Sometimes a few granules may be present on the peripheral part. The test diameter varies from 6.0 mm to 9.0 mm, the thickness at centre from 0.30 mm to 0.45 mm and the diameter of granules from 72 μm to 250 μm (see Fig. 28 for T₁-T₂ relationship).

In equatorial section the spire consists of simple, loosely coiled regular to irregular whorls (Pl. 33, Figs. 8-9; Pl. 34, Fig. 12; Pl. 59, Fig. 4). In a test diameter of 7.4 mm there are about nine whorls. The marginal cord is well-developed and is fairly regular to undulating in its course. The equatorial chambers are radially elongate, rectangular and higher than long. There are about twenty-one to twenty-four chambers in a whorl 0.5 mm from the centre. The size of chambers increases towards periphery. The septa are thin and regularly spaced. They are straight and slightly inclined to the marginal cord at the base.

In axial section the test is thin, flat with subparallel sides, often compressed in the central part with subrounded margin (Pl. 33, Fig. 10). The equatorial plane is flat. The equatorial chambers are elongate triangular to subtriangular in shape. The chambers are evolute (Pl. 33, Fig. 10). The whorl height increases towards periphery. The marginal cord is more prominent in later whorls than in the earlier ones. The spiral laminae are semi-involute and well-developed. The pillars are
moderately thin and situated on the whorl junctions. The surface diameter of pillars ranges from 62 m/μ to 362 m/μ.

**Megalospheric generation**: The test is small, flat, thin discoidal in shape with subangular margin (Pl. 33, Fig. 1). The surface is ornamented with a few coarse granules occurring along the septal sutures. The granules appear concentrated on the polar region. The diameter of the test ranges from 2.85 mm to 4.5 mm, thickness at the centre from 0.30 mm to 0.43 mm and diameter of granules from 62 m/μ to 250 m/μ. T₁-T₂ relationship is presented in Fig. 29.

In equatorial section embryonic apparatus is moderately large, bilocular, made up of circular to subcircular protoconch followed by semilunar deutoconch (Pl. 33, Figs. 2-3; Pl. 58, Figs. 7, 9-10; Pl. 59, Fig. 1). The separating wall is extremely thin, gently convex outwards. The internal diameters of protoconch range from 137x181 m/μ to 187x237 m/μ and of deutoconch from 93x162 m/μ to 200x218 m/μ. The distance across both chambers ranges from 262 m/μ to 412 m/μ. The separating wall is about 12 m/μ thick. The average values of D₁, D₂ as well as h are shown in Fig. 31.

The spire is simple, fairly regular with about five whorls in a diameter of 3.9 mm. The whorls are loosely coiled. The marginal cord is moderately thick and is fairly regular in its course in most specimens. It is thinner than the height of whorl cavity and increases very slowly in thickness towards periphery.

The first nepionic chamber is usually arcuate in shape. It is smaller in size than the deutoconch. The chambers increase
gradually in size and are normally higher than long. They are radially elongate, more or less rectangular in outline. Chambers equal in height and length as well as longer than high are also present specially in the outermost whorl. There are about eight chambers in the first whorl, sixteen in the second, twenty-three in the third and twenty-nine in the fourth. The septa are very thin, inclined to the marginal cord at base. They are straight to slightly curved backward at their distal end. The whorls open regularly in height (Fig. 30) and the height of whorls varies from 175 m/μ in the first whorl to 350 m/μ in the last whorl.

In axial section the test is thin, flat with subparallel sides (Pl. 32, Figs. 4-5; Pl. 58, Figs. 6, 8). The protoconch is circular to subcircular in outline followed by crescentic deuteroconch. The equatorial plane is flat to wavy. The equatorial chambers are evolute, triangular in shape and higher than wide (Pl. 58, Fig. 6). Pillars occur in the polar region at the junction of whorls. The surface diameter of pillars ranges from 50 m/μ to 200 m/μ.

**Measurements**: Measurements of external and internal features are shown in Tables 67-72.

**Remarks**: D'Archiac & Haime (1853) identified some assilines as *Nummulites granulosa* d'Archiac and *Nummulites mamillata* d'Archiac var. a which were treated as distinct of *Nummulites granulosa* d'Archiac (d'Archiac, 1847, 1850. Schaub (1981) in course of his detail monographic study on *Assilina* discussed that those specimens
figured by d'Archiac & Haime (1853) were identifiable with Assilina placenta vel granulosa form A, var. laxispira de la Harpe which was earlier treated as a specifically distinct from A. placenta (Schaub, 1955). This has been accepted by the majority of workers.

The present specimens with their thin, discoidal large test with laxispire are identified here as A. laxispira to which they most closely resemble. The surface ornamentation is somewhat different in Kutch material from that in the lectotype figured by Schaub (1981). The microspheric form in Harpe's collection shows spirally arranged coarse granules and depression at the poles as in present material. The species belongs to the Assilina spira group and is considered to be transitional between A. plana and A. major.

Distribution: A. laxispira was described from rocks of Lower Eocene age. It is regarded as restricted to the upper part of the Lower Eocene. It is a widely distributed species of Assilina and has been reported from different localities spread over the region between southern Europe and Pakistan. In Kutch, the species occurs commonly to frequently in the Assilina Limestone Member of the Naredi Formation exposed in Guvar, Nareda and Harudi - Baranda areas. Here, it is restricted to the Assilina laxispira Zone of Early Eocene age.
Assilina spinosa Davies, 1937
(Pl. 34, Figs. 8-9; Pl. 35, Figs. 1-11; Pl. 58, Figs. 1-5, 11; Pl. 59, Figs. 2,9; Text-figs. 28-31)

1937 Assilina spinosa Davies in Davies & Pinfold, pp. 31-33, pl. 4, figs. 11-12, 16-17.
1937 Assilina subspinosa Davies in Davies & Pinfold, pp. 33-34, pl. 4, figs. 19-20, 23-26.
1981 Assilina spinosa Davies; Schaub, p. 196, pl. 71, figs. 53-55.

Material: Both microspheric and megalospheric specimens were examined. Thirteen isolated specimens, six equatorial/split-equatorial sections and six axial sections of microspheric generation and fourteen isolated specimens, twelve equatorial sections and five axial sections of megalospheric generation were studied.

Description:

Microspheric generation: The test is moderately large to medium in size, thin discoidal in shape with subangular to subrounded margin (Pl. 35, Figs. 1-3). Generally there is a depression in the polar region. The surface of the test is conspicuously ornamented with coarse granules of varying shape and size arranged along spiral and septal sutures, the spiral arrangement being more prominent. Generally they increase in diameter from centre towards periphery, granules near centre are subcircular in outline and those on the peripheral part are somewhat radially
elongate. The test diameter varies from 5.2 mm to 7.5 mm, the
thickness at centre from 0.38 mm to 0.6 mm and the diameter of
granules from 87 m/μ to 375 m/μ (for T₁-T₂ relationship see
Fig. 28).

In equatorial section the spire is simple and mostly regu­
lar in its course (Pl. 34, Figs. 8-9; Pl. 35, Fig. 4; Pl. 59,
Fig. 3). In a test diameter of 8.2 mm there is about ten whorls.
The marginal cord is well-developed and fairly regular in its
course. Often the thickening of marginal cords varies signifi­
cantly. They are much thinner than the height of the whorl cavity.
In the first whorl, chambers are not clearly visible. The equa­
torial chambers are radially elongate, rectangular and distinctly
higher than long, sometimes their height exceeding twice their
length. There are about twenty-one to twenty-five chambers in a
whorl 0.5 mm apart from centre. The septa are thin and regularly
spaced. In the early whorls they are mostly straight and nearly
perpendicular to the marginal cord at base. The septa in the later
whorls are generally inclined to the marginal cord and straight
in the lower part with a slight bend at their distal end.

In axial section (Pl. 35, Figs. 5-6; Pl. 59, Fig. 2) the
test appears flat with slightly compressed sides. The margin is
subrounded. The equatorial plane is flat. The equatorial chambers
are evolute and triangular to subtriangular in shape. Chambers
are generally higher than wide. The whorl height increases slowly
towards periphery. The marginal cord is well-developed. The spiral
Laminae are semi-involute and well-developed. Moderately thick, conical pillars are distributed along whorl junctions (Pl. 59, Fig. 2). They vary slightly in shape and size. The surface diameter of pillars ranges from 62 m/μ to 362 m/μ.

Megalospheric generation: The test is small, flat, compressed, thin discoidal in shape with subrounded to subangular margin (Pl. 35, Fig. 7). The surface is ornamented with coarse granules occurring along the spiral sutures. Finer granules are arranged along septal sutures. They are subcircular to subelliptical in outline. The diameter of the test ranges from 2.5 mm to 4.8 mm, thickness at centre from 0.3 mm to 0.46 mm and diameter of granules from 62 m/μ to 300 m/μ (Fig. 29 presents the T1-T2 relationship).

In equatorial section embryonic apparatus is small, bilocular and made up of subcircular protoconch followed by reniform deutoconch (Pl. 35, Figs. 8-9; Pl. 58, Figs. 1, 3-4, 11). The separating wall is extremely thin, gently convex outwards (Pl. 58, Fig. 11). The internal diameters of protoconch vary from 112x150 m/μ to 162x200 m/μ, those of deutoconch from 100x162 m/μ to 112x187 m/μ, the distance across both chambers ranges from 225 m/μ to 306 m/μ and the thickness of separating wall from 12 m/μ to 37 m/μ. The average values of D1, D2 and h are shown in Fig. 31.

The spire is simple, regular (Pl. 35, Figs. 8-9) with about five whorls in a diameter of 4 mm. The marginal cord is well-developed and is fairly regular in its course. They are much
thinner than the whorl cavity and increase very slowly in thickness towards periphery.

The equatorial chambers increase gradually in size and are normally higher than long. They are radially elongate, rectangular in outline. There are about seven chambers in the first whorl, fifteen in the second, nineteen in the third, twenty-three in the fourth. The septa are very thin, gently inclined to the marginal cord at base. They are straight or gently curved backward. The whorls open slowly (see Fig. 30) and the height of whorls varies from 162 m/μ in the first whorl to 375 m/μ in the last whorl.

In axial section the outline of test is thin, flat with subparallel sides (Pl. 35, Figs. 10-11; Pl. 58, Figs. 2,5). The protoconch is subcircular in outline followed by crescentic deutoconch. The equatorial plane is usually flat. The equatorial chambers are evolute, triangular in shape and higher than wide to equal in height and width (Pl. 35, Figs. 10-11). The marginal cord is well-developed and increases in thickness with growth. The pillars are conical and occur at the junction of whorls. The surface diameter of pillars range from 100 m/μ to 275 m/μ.

Measurements: Measurements of external and internal features are appended in Tables 73-78.

Remarks: In course of describing his new species, *A. spinosa*, Davies (in Davies & Pinfold, 1937) distinguished it from specimens identified by previous Indian workers as *A. granulosa* by its smaller, stouter, more coarsely granulate and distinctly umbilicate
test and more sloping and more widely septa. He considered it as related to *A. granulosa*. In their coarsely granulate, stouter and distinctly umbilicate tests the Kutch specimens are most closely comparable to Davies' species to which they are assigned. The microspheric specimens of the present collection differs somewhat from the figured material of Davies in having thinner test with depressions along the spiral suture wavy marginal cord and more inclined, widely spaced septa.

**Distribution**: Davies described it as ranging from Upper Palaeocene to Lower Eocene in Salt Range, Pakistan, the type area of the species. It has been described and illustrated from other localities in Pakistan and western India by later workers. It is considered by some authors as diagnostic of the Lower Eocene. In Kutch the species occurs as rock-forming abundance at several horizons in the Assilina Limestone Member of the Naredi Formation exposed at Guvar, Nareda and Harudi-Baranda areas. It is restricted here in the *Assilina laxispira* Zone of Early Eocene age.

**Genus Operculina** d'Orbigny, 1826

*Type species*: *Nautilus ammonoides* Gronovius, 1781  
*(designated by Cushman, 1914, see Hottinger, 1977)*

**Diagnosis**: Test small; spire simple; whorls few, increasing rapidly in height; chambers evolute; later whorl walls typically evolute; transverse trabeculae and septal filaments lacking.
Distribution: Operculina is the most widely distributed of the four genera of the family Nummulitidae. It is well-represented in all the three Tertiary provinces and some of its species are reported to be distributed from central Pacific to southern Europe. Again, stratigraphically it has a longer range, from Palaeocene to Recent.

In contrast to Nummulites and Assilina, Operculina from the Indian region is poorly known. There was no attempt to describe and illustrate even the commonly occurring forms from different horizons although it is long known to range here from Palaeocene to Recent.

Occurrence in Kutch: In Kutch, Operculina occurs commonly to rarely only in the Maniyara Fort Formation exposed in Traverses III-IV (Figs. 11-12). It ranges from Early to Late Oligocene. Here, the genus is represented by the following two species:

1. **Operculina roselli** Hottinger
2. **O. sp. aff. O. schwageri** Silvestri

They are described below:

**Operculina roselli** Hottinger, 1977

(Pl. 36, Fig. 3; Pl. 57, Figs. 11, 14)

1977 **Operculina roselli** Hottinger, pp. 97-98, text-figs. 4B, 37A-C.

Material: Only one equatorial section of a megaspheric specimen was examined.
Description: The equatorial section (Pl. 36, Fig. 3; Pl. 57, Figs. 11, 14) shows a suboval outline; moderately rapidly opening spire consisting of 3½ whorls in a diameter of 3.0 mm; very narrow chambers, much higher than long, close-spaced between curved septa, often undulating and characterised by fine but distinct low transverse projections and a well-developed marginal cord. There are about eight chamber in the first whorl, twenty-one in the second and twenty-four in the third.

Remarks: With its close-spaced, undulating septa with low projections and thick marginal cord the present specimens are considered here as identifiable with Operculina roselli Hottinger.

Distribution: Hottinger (1977) described Operculina roselli from the Bianitizian of Spain. In Kutch, the species occurs very rarely in the samples collected from the Lower Member of the Maniyara Fort Formation exposed in Guvar area. It is restricted here in the Nummulites fichteli Zone of Early Oligocene age.

Operculina sp. aff. Operculina schwageri Silvestri, 1928
(Pl. 36, Figs. 1-2; Pl. 57, Figs. 12-13,15-18)

aff. 1928 Operculina schwageri Silvestri, p. 112.
aff. 1977 Operculina schwageri Silvestri; Hottinger, pp. 82-84,
pl. 38, figs. 1-3; Text-figs. 4A, 31A, 32.

Material: Only megalospheric specimens were studied. Five isolated specimens, four equatorial sections and four axial sections were examined.
Description: The test is small, thin and discoidal. A prominent polar pustule is surrounded by thin peripheral flange. The flange is ornamented by septal sutures formed of fine papillae. The diameter of test ranges from 2.5 mm to 3.95 mm and the thickness at centre from 0.50 mm to 0.70 mm. The diameter of polar pustule varies from 0.30 mm to 0.40 mm and that of papillae from 31 mμ to 137 mμ.

In equatorial section (Pl. 36, Fig. 1; Pl. 57, Figs. 12-13, 15) the embryonic apparatus is very small and bilocular (Pl. 57, Figs. 12-13, 15). The protoconch is subcircular and the deutoconch is crescentic in outline (Pl. 57, Fig. 16). The internal diameters of protoconch range from 37x37 mμ to 62x75 mμ, those of deuteroconch from 25x50 mμ to 68x87 mμ and the distance across both the chambers from 75 mμ to 137 mμ.

The whorls increase rapidly in height (Pl. 57, Figs. 12-13, 15). The height of the last whorl is greater than that of the early formed part of the test. The equatorial chambers are typically narrow elongated much higher than long. The marginal cord is narrow and weakly developed. The septa are slightly inclined to the whorl wall, straight in the lower half and then curved strongly backward in the upper part (Pl. 36, Fig. 1; Pl. 57, Fig. 13). The spacing of the septa is regular. There are about three whorls in a diameter of 3.0 mm, eight chambers in the first whorl, twelve in the second and eighteen in the third. The height of the whorls varies from 100 mμ to 150 mμ in the first whorl and 775 mμ to 1050 mμ in the third whorl.
Axial section shows (Pl. 36, Fig. 2; Pl. 57, Figs. 17-18) the compressed, discoidal shape. The embryonic apparatus is very small. The equatorial plane is straight. The whorl height increases rapidly with ontogeny. The equatorial chambers are evolute, typically elongated and much higher than wide (Pl. 36, Fig. 2; Pl. 57, Figs. 17-18). The marginal cord is weakly developed. The polar plug is well-developed, fine pillars often occur at the junction of whorls. The surface diameter of polar plug varies from 0.3 mm to 0.4 mm and that of pillars from 25 μm to 137 μm.

Measurements: Measurements of external and internal features are appended in Tables 79-81.

Remarks: In the shape and size of the test and the character of the spire as well as the septa the present form shows affinity to *Onerculina schwageri* Silvestri figured and discussed in detail by Hottinger (1977) and is thus identified here as *Onerculina* sp. aff. *O. schwageri*. The material available was not adequate for a more detailed investigation.

Distribution: According to Hottinger (1977) *O. schwageri* occurs in late Middle Eocene. In Kutch, the species occurs commonly to abundantly in all the three members namely, Lower, Coral Limestone and Ber Moti belonging to the Maniyara Fort Formation. Here it ranges from Early Oligocene *Nummulites fichteli* Zone to Late Oligocene *Spiroclypeus ranjanae* Zone.
Genus **Operculinoides** Hanzawa, 1935

Type species: *Nummulites willcoxi* Heilprim, 1883

**Diagnosis**: Test small, spire simple, whorls few, increasing rapidly in height; chambers involute; lateral wall with transverse trabeculae; septal filaments typically radiate to falciform.

**Distribution**: Originally described from the Caribbean-American province the genus has later been recognised in the Tethyan and the Indo-Pacific provinces also. In the region between southern Europe and India the genus is less frequent than the other three genera of the family. *Operculinoides* is known to range from Palaeocene to Miocene.

**Occurrence in Kutch**: In Kutch the genus occurs commonly to frequently in the samples of two formations, Harudi and Fulra Limestone collected from the Traverses I, III-IV (Figs, 9, 11-12). In the upper part of the Harudi Formation often it occurs as a rock-forming element. Here, *Operculinoides* ranges from middle to late Middle Eocene. The genus is represented in Kutch by the following four species:

1. **Operculinoides ocalanus** (Cushman)
2. **O. saipanensis** Cole
3. **O. vaughani** (Cushman)
4. **O. sp. aff. O. aspensis** (Colom)

They are described below:
Fig. 33 Scatter diagram of D — Tj for four species of *Opeculinoïdes* (Form 'A')

- *Opeculinoïdes ocalanus* (Cushman)
- O. saipanensis Cole
- O. vaughani (Cushman)
- O. sp. aff. O. aspensis (Colom)
Operculinoides ocalanus (Cushman) 1921
(Pl. 36, Figs. 9-10; Pl. 61, Figs. 6, 15, 18, 21, 25; Text-figs. 33-35)

1921 Operculina ocalana Cushman, p. 129, pl. 19, figs. 4-5.
1941 Operculinoides ocalanus (Cushman). Cole, pp. 31-32, pl. 10, figs. 4-7.

Material: Eight isolated specimens, five equatorial sections and four axial sections of megalospheric form were studied.

Description: The test is small with the well-defined umbonal elevation surrounded by wide thin flange. The polar region is coarsely papillate while the peripheral part is sparsely papillate. The polar papillae are larger and much more elevated on the surface than those on the periphery and form subconical protuberances on well-preserved specimens. The diameter of the test ranges from 1.0 mm to 1.8 mm and the thickness at centre from 0.3 mm to 0.38 mm (see Fig. 33). The diameter of the papillae ranges from 18 m/μ to 125 m/μ.

The equatorial section shows small bilocular embryonic apparatus (Pl. 36, Fig. 9; Pl. 61, Figs. 6, 15). The protoconch is small, subcircular, while the deuteroconch is slightly larger in size and is usually crescentic in outline (Pl. 61, Fig. 18). The internal diameters of the protoconch range from 37x43 m/μ to 50x50 m/μ, those of deuteroconch from 31x68 m/μ to 37x87 m/μ.
Fig. 34. Histogram of $D_1$, $D_2$ and $h$ for four species of \textit{Operculinoides} (Form 'A')

- Average of 5 specimens for each species
Fig. 35 Rates of opening of spire in four species of *Operculinoides* (Form 'A') [Coverage of 5 specimens for each species]
and the distance across the embryonic chambers from 81 m/μ to 100 m/μ. The average values of D₁, D₂ and h are shown in Fig. 34.

The whorls increase moderately rapidly in height (Fig. 35). The marginal cord is well-developed. There are about two and a half whorls in a test diameter of 1.3 mm. The postembryonic chambers are narrow and elongate (Pl. 61, Figs. 6, 15). The chambers are usually higher than long. The septa are prominently curved and thick. There are about seven chambers in the first whorl and thirteen in the second. The whorl height varies from 75 m/μ to 125 m/μ in the first whorl and 212 m/μ to 287 m/μ in the second whorl.

In axial section (Pl. 36, Figs. 10; Pl. 61, Figs. 21, 25) the embryonic apparatus is small and bilocular with circular protoconch and crescentic deutoconch (Pl. 36, Fig. 10). The chambers are narrow, and much higher than wide. The alar prolongations are distinct (Pl. 61, Fig. 25). The spiral laminae gradually increase in thickness from periphery towards polar region. Prominently developed polar plug occurs over the initial chamber forming marked protuberances on the surface. Smaller pillars occur over the whorl junctions. The surface diameter of polar plug ranges from 0.2 to 0.25 mm and the pillars from 18 m/μ to 87 m/μ.

Measurements: Measurements of external and internal features are appended in Tables 82–84.
Remarks: In the present material the species is distinguished by its subcircular test having prominently developed umbo surrounded by thin peripheral flange and is provisionally identified as *O. ocalanus* to which it is most closely comparable.

Distribution: *O. ocalanus* has been reported from a number of localities in the Caribbean-American region where it occurs in the rocks of Eocene age. In Kutch *O. ocalanus* occurs commonly in the Fulra Limestone and ranges from middle Middle Eocene *Discocyclina sowerbyi* Zone to late Middle Eocene *Alveolina elliptica* Zone.

**Operculinoides saipanensis** Cole, 1957  
(Pl. 36, Figs. 11-15; Pl. 61, Figs. 3,10,14,17,20,22, 26,29; Text-figs. 33-35)

1957 *Operculinoides saipanensis* Cole, p. 331, pl. 102, figs. 15-16.

Material: Ten isolated specimens, six equatorial sections and four axial sections of megalospheric generation were examined.

Description: Test is small, with inflated umbo surrounded by narrow thin rim. Polar pustule encircled by smaller papillae occur over the umbonal region. The flange appears smoother. The diameter of the test ranges from 1.15 mm to 2.0 mm and thickness at centre from 0.45 mm to 0.67 mm (Fig. 33). The diameter of papillae varies from 50 μm to 200 μm and that of polar pustule from 0.15 mm to 0.25 mm.
In equatorial sections, the embryonic apparatus is small, bilocular (Pl. 36, Fig. 12; Pl. 61, Figs. 3, 14, 17). The protoconch is small, circular in outline while the deuteroconch is larger and crescentic in outline (Pl. 61, Figs. 26, 29). The internal diameter of the protoconch ranges from $31 \times 37 \, \mu m$ to $50 \times 56 \, \mu m$, those of the deuteroconch from $25 \times 50 \, \mu m$ to $37 \times 87 \, \mu m$ and the distance across both the embryonic chambers from $62 \, \mu m$ to $100 \, \mu m$. The average values of $D_1$, $D_2$ and $h$ are shown in Fig. 34.

The whorls increase rapidly in height (Fig. 35). The equatorial chambers are mostly narrow elongated, usually much higher than long. The marginal cord is narrow and moderately developed. The septa are highly curved and inclined (Pl. 36, Figs. 11, 13; Pl. 61, Figs. 3, 14, 17). There are about three whorls in test diameter of $1.6 \, mm$; six chambers in the first whorl, twelve in the second and nineteen in the third. The height of whorls varies from $100 \, \mu m$ to $150 \, \mu m$ in the first whorl and $300 \, \mu m$ to $512 \, \mu m$ in the third whorl.

In axial section the embryonic apparatus is small, bilocular with circular protoconch and crescentic deuteroconch (Pl. 36, Figs. 14-15). The equatorial chambers are typically narrow, elongated in outline and much higher than wide. The marginal cord is moderately developed. The alar prolongations are distinct (Pl. 36, Figs. 14-15; Pl. 61, Figs. 10, 20, 22). The spiral laminae increase in thickness from periphery towards polar region.
The polar plug forms elevation on the surface. Pillars smaller in diameter occur outside the polar region. Often fine pillars occur over the marginal cord. The surface diameter of polar plug varies from 0.20 mm to 0.22 mm and that of pillars from 37 μm to 150 μm.

**Measurements**: Measurement of external and internal features is presented in Tables 85-87.

**Remarks**: With their subcircular outline, inflated umbonal elevation ornamented with granules and strongly curved septa the present specimens are comparable to *Q. saipanensis* to which they are assigned here.

**Distribution**: In 1957, Cole described and illustrated *Q. saipanensis* from the Tertiary rocks of Saipan. In Kutch, it occurs frequently both in the Harudi Formation and the Fulra Limestone exposed in Godhatad-Kapurasi, Guvar and Harudi areas. Here, the species is restricted to the *Nummulites obtusus*, *Discoyclina sowerbyi* and *Alveolina elliptica* Zones of Middle Eocene age.

**Operculinoides vaughani** (Cushman), 1921

(Pl. 36, Figs. 7-8; Pl. 61; Figs. 7, 9, 31; Text-figs. 33-35).

1921 *Operculina vaughani* Cushman, p. 128, pl. 19, figs. 6-7.
1935 *Operculina vaughani* Cushman. Gravell & Hanna, p. 334, pl 29, figs. 6, 9, 12, 16-21.
Material: Only the megalospheric generation was studied. Ten specimens examined externally; five in equatorial sections and five in axial sections.

Description: The test is small and subtriangular in outline. A subcentral umbo is surrounded by thin wide peripheral flange. Over the thin flange the septal suture are marked by thin lines formed of fine papillae. Otherwise the flange is smooth. The diameter of the test ranges from 1.2 mm to 1.75 mm and the thickness at centre from 0.25 mm to 0.45 mm (see Fig. 33). The diameter of papillae ranges from 12 m/μ to 112 m/μ.

In equatorial section the embryonic apparatus is small and bilocular (Pl. 36, Fig. 7; Pl. 61, Fig. 7). The protoconch is small, circular in outline and the deuteroconch is relatively larger and crescentic and partly embraces the protoconch (Pl. 61, Fig. 31). The internal diameters of the protoconch range from 37x43 m/μ to 50x56 m/μ, those of the deuteroconch from 31x62 m/μ to 50x87 m/μ and the distance across both the embryonic chambers from 81 m/μ to 118 m/μ. The average values of D₁, D₂ and h are presented in Fig. 34. The whorls increase very rapidly in height, the last whorl being much higher than the early formed ones. The rate of opening of spire is shown in Fig. 35. The post-embryonic chambers are narrow, elongated in shape. The septa are smoothly curved (Pl. 36, Fig. 7; Pl. 61, Fig. 7). They are thick and double-walled. There are about two and a half whorls in a test diameter of 1.55 mm, six chambers in the first whorl,
and thirteen in the second whorl. The whorl height ranges from 75 m/μ to 125 m/μ in the first whorl and 225 m/μ to 425 m/μ in the second whorl.

In axial section (Fl. 36, Fig. 8; Fl. 61, Fig. 9) the embryonic apparatus is small. The circular protoconch is followed by the crescentic deuteroconch. The marginal cord is weakly developed. The alar prolongations are narrow (Fl. 36, Fig. 8). The chambers are narrow and elongated and much higher than wide. The spiral laminae increase in thickness from periphery towards pole. On either side of the initial chamber a conical moderately developed polar plug occurs. Away from the poles fine pillars occur. The diameter of polar plug varies from 0.15 mm to 0.20 mm and that of pillars from 25 m/μ to 75 m/μ.

**Measurements**: Measurements of external and internal features are presented in Tables 88-90.

**Remarks**: The species was not systematically investigated from the Middle Eocene of the Indian sub-continent. In the present study the Kutch material has been compared with the Eocene species of the genus which are well-described and illustrated. The species described here resembles closely with *O. vaughani*. In the present material, the semicircular outline, the last whorl opening out very rapidly, coarsely granulated and distinct umbo distinguish the species markedly.

**Distribution**: The species was originally described from the Eocene rocks of Caribbean-American region. In Kutch, it occurs
commonly in the Harudi Formation and the Fulra Limestone. Here it is restricted in the *Nummulites obtusus*, *Discocyclina sowerbyi* and *Alveolina elliptica* Zones of Middle Eocene age in the present area.

**Operculinoides** sp. aff. *O. aspensis* (Colom), 1954

(Pl. 36, Figs. 4-6; Pl. 61, Figs. 2, 8, 30; Text-figs. 33-35)

aff. 1954 *Operculinoides aspensis* Colom, p. 183, pl. 10, figs. 6-8.

aff. 1977 *Operculinoides aspensis* Colom; Hottinger, p. 95, text-fig. 370-V.

**Material**: Only megalospheric specimens were studied. Seven isolated specimens, five equatorial sections and five axial sections were examined.

**Description**: The test is small with well-developed inflated umbo surrounded by very thin wide flange. The polar region is very coarsely granulated. The granules project above the surface. In the peripheral part curved septal sutures are marked by raised lines formed of close-spaced papillae. Here, chamber-spaces are also very sparsely papillated. The diameter of the test ranges from 2.40 mm to 3.0 mm and the thickness at centre from 0.70 mm to 1.00 mm (see Fig. 33). The diameter of the polar pustule varies from mm to mm and that of the granules papillae from 37 m/μ to 200 m/μ.

The equatorial section shows small bilocular embryonic
apparatus (Pl. 36, Fig. 4; Pl. 61, Fig. 2). The protoconch is small, subcircular followed by the deuteroconch which is larger in size and crescentic in outline (Pl. 61, Fig. 30). The internal diameters of the protoconch ranges from 27x25 m/μ to 50x68 m/μ, those of deuteroconch from 25x43 m/μ to 53x87 m/μ and the distance across the embryonic chambers from 62 m/μ to 100 m/μ. The average values of D₁, D₂ and h are shown in Fig. 34.

The whorls increase very rapidly in height (Fig. 35). The outermost whorl is increasing abnormally in height. The spiral wall is becoming irregular in course in the outermost whorl. The marginal cord is weakly developed. There are about three and a half whorls in a test diameter of 2.70 mm. The equatorial chambers are narrow, elongate, close-spaced and much higher than long (Pl. 61, Fig. 2). The septa are thin, slightly inclined to the marginal cord, more or less straight at base and curved throughout their length. There are about six chambers in the first whorl, twelve in the second and seventeen in the third. The whorl height varies from 50 m/μ to 100 m/μ in the first whorl and 450 m/μ to 562 m/μ in the third.

Axial section (Pl. 36, Figs. 5-6; Pl. 62, Fig. 8) shows inflated umbo with a thin wide flange. The embryonic apparatus is small and bilocular with subcircular protoconch and crescentic deuteroconch. The whorl height increases very rapidly in outer whorls (Pl. 36, Fig. 5). The equatorial chambers are narrow and much higher than wide. The alar prolongations are wide (Pl. 61,
Fig. 8). The marginal cord is weakly developed. Pillars forming marked protuberances on the surface occur throughout the section. They are more prominent on the umbo. The surface diameter of polar plug ranges from 0.25 mm to 0.28 mm and the pillars from 37 m\(\mu\) to 175 m\(\mu\).

**Measurements**: Measurements of external and internal features are appended in Tables 91-93.

**Remarks**: With its subconical umbo surrounded by very thin wide flange and coarsely granulated surface, very small embryonic apparatus and very rapidly opening outer whorl, the present specimen show closest affinity to *O. aspensis* as discussed and illustrated by Hottinger (1977) and is thus provisionally identified as *O. aff. aspensis* (Colom).

**Distribution**: *O. aspensis* Colom was originally described from the Lower Eocene of Spain. In Kutch, the species occurs rarely to commonly in the Harudi Formation and Fulra Limestone of Harudi, Guvar’ and Godhatad-Kapurasi areas. Here, it is restricted to the Nummulites obtusus, Discocyclina sowerbyi and Alveolina elliptica Zones of Middle Eocene age.

**Family Cycloclypeidae** Bütschli, 1880

**Diagnosis**: Test large, lenticular to discoidal; chambers planispiral to annular, subdivided into chamberlets; with or without lateral chambers.

**Distribution**: It is cosmopolitan and ranges from Eocene to Recent.
Genus Heterostegina d'Orbigny, 1826

Type species: Heterostegina denressa d'Orbigny, 1826

Diagnosis: Test lenticular to discoidal, planispiral; chambers involute to evolute, high and strongly curved, divided into rectangular chamberlets.

Distribution: The genus is widely spreaded in all the three Tertiary provinces and ranges from Eocene to Recent.

In Kutch, Heterostegina occurs commonly in all the three members of the Maniyara Fort Formation. The genus is represented by two species:

1) H. borneensis Van der Vlerk and
2) H. kohlii Tandon

The internal parameters as measured here are shown in Fig. 36.

1. \( d_1 \) = The diameter of the protoconch, measured along a line perpendicular to the line connecting the midpoints of the protoconch and deuteroconch.

2. \( d_2 \) = The diameter of the deuteroconch, measured along a line perpendicular to the line connecting the midpoints of the protoconch and deuteroconch.

3. \( h_1 \) = Height of the whorl, measured along a line perpendicular to the line connecting the midpoints of the protoconch and deuteroconch.
Heterostegina borneensis Van der Vlerk, 1929
(Pl. 37, Figs. 1-4; Pl. 62, Figs. 7-9; Text-figs. 37-38)

1929 Heterostegina borneensis Van der Vlerk, p. 16, figs. 6a-c, 25a-b.
1930 Heterostegina borneensis Van der Vlerk; Hanzawa, p. 95, pl. 26, figs. 11, 19; pl. 27, figs. 4-8.
1953 Heterostegina borneensis Van der Vlerk; Cole in Cole & Bridge, p. 23, pl. 2, figs. 1-3,5; pl. 4, figs. 16-18.

Material: The species is represented by a few sections in random thin sections of rocks of the present area. Thus, additional material from Waior area, southwestern Kutch, was used. Only megalospheric specimens were examined. Five isolated specimens, eleven equatorial sections and four vertical sections were studied. Due to the thinness the peripheral part of the test is not usually preserved.

Description: The test is small, compressed lenticular to discoidal with low wide umbo and subrounded margin (Pl. 37, Fig. 1). The surface is ornamented with very fine papillae which are distributed marking the course of the primary and secondary septa. The thickness of test at centre ranges from 0.80 mm to 0.92 mm and that at periphery from 0.2 mm to 0.25 mm. The diameter of the papillae ranges from 12 μm to 87 μm.

In equatorial section (Pl. 37, Figs. 3-4; Pl. 62, Figs. 8-9) the embryonic apparatus is moderately large, bilocular made up of circular to subcircular protoconch partly embraced by a semilunar deutoconch. The deutoconch is slightly larger than the protoconch. The separating wall is thin and convex outwards. The internal diameters of the protoconch range from 150x212 μm to 200x212 μm.
Fig. 37 Histogram of $d_1$ and $d_2$ for two species of *Heterostegina* (Form 'A'). Coverage of 10 specimens for each species.

1. *Heterostegina borneensis* Van der Vlerk
2. *H. kohlii* Tandon
Fig. 38 Scatter diagram of $d_l - h_l$ for two species of *Heterostegina* (Form A') from the Maniyara Fort Formation.

- x *Heterostegina borneensis* Von der Vlerk
- • *H. kohlii* Tandon
and of the deuteroconch from 81x231 m/μ to 137x312 m/μ. The average values of d₁ and d₂ is shown in Fig. 37. The distance across both chambers ranges from 256 m/μ to 324 m/μ. The separating wall is about 25 m/μ thick. The d₁-h₁ relationship is represented in Fig. 38.

The spire opens rapidly. In a diameter of 3.2 mm there are about two whorls. The marginal cord is thin. The first nepionic chamber is arcuate in shape. The number of operculine chamber is one (Pl. 37, Fig. 3; Pl. 62, Figs. 8-9). The equatorial chambers are highly curved and divided into chamberlets. The primary septa are strongly curved. The secondary septa are short, straight and usually nearly perpendicular to the primary septa. The chamberlets are rectangular, higher than long. The height of chamberlets increases with growth. There are about ten chambers in the first whorl and twenty-two in the second. The height of the chambers varies from 62 m/μ to 225 m/μ. The height and width of the chamberlets varies from 43 m/μ to 225 m/μ and 68 m/μ to 225 m/μ respectively.

In axial section (Pl. 37, Fig. 2; Pl. 62, Fig. 7) the embryonic apparatus is moderately large. The protoconch is circular in outline followed by crescentic deuteroconch. The equatorial chambers are narrow elongated triangular and involute (Pl. 62, Fig. 7). The marginal cord is weakly developed. The alar prolongation is very narrow and much thinner than the spiral laminae. The polar plug is distinct and extend upto the surface. The pillars vary in shape and size and are most prominent over the septa. The surface diameter of the polar plug varies from 0.3 mm to 0.7 mm and of the pillars from 25 m/μ to 100 m/μ.
Measurements: Measurements of external and internal features are shown in Tables 94-96.

Remarks: The present specimens characterised by their compressed lenticular test moderately large bilocular embryonic apparatus and involute chambers are identified here as *Heterostegina borneensis* Van der Vlerk. The material was not adequate for a detail study of the range of its variations.

Distribution: Van der Vlerk (1929) described the species from Indonesia which later found to be one of the most widely distributed representatives of the genus. Adams (1970) gave its stratigraphic range? Td-Lower Te ? Upper Te. It is widespread during Upper Oligocene-Lower Miocene times. *H. borneensis* is an Indo-Pacific form. Originally described from Indonesia, in the present area the species occurs rarely in the Coral Limestone Member and commonly to frequently in the Ber Moti Member of the Maniyara Fort Formation exposed in Guvar and Kapurasi areas. Here, it is restricted to the *Eulepidina dilatata* and *Spiroclveus ranjanae* Zones of Middle to Late Oligocene age.

*Heterostegina kohlii* Tandon, 1974

(Pl. 37, Figs. 5-10; Pl. 62, Figs. 1-6; Text-figs. 37-38)

1974 *Heterostegina kohlii* Tandon, pp. 199-202, pl. 3, figs. 1-7; pl. 4, figs. 1-6.

Material: Only megalospheric specimens were examined. Seven isolated specimens, eleven equatorial sections and six vertical sections were studied.
Description: The test is small, thin, discoidal with a low, wide umbo subcentral in position (Pl. 37, Fig. 5). The umbonal surface is covered with coarser granules making the septal sutures. The flange is ornamented with fine papillae arranged along the course of the septa and secondary septa. The diameter of the test varies from 1.8 mm to 7.0 mm, the thickness at centre from 0.52 mm to 0.83 mm and that at the periphery from 0.2 mm to 0.3 mm. The diameter of the papillae varies from 37 m/u to 250 m/u.

In equatorial section (Pl. 37, Figs. 8-10; Pl. 62, Figs. 1-3, 5), the embryonic apparatus is small and bilocular. The protoconch is slightly larger than deutoconch (Pl. 37, Fig. 8; Pl. 62, Fig. 3). It is circular to subcircular in outline while the deutoconch is usually crescentic to reniform in shape. The wall separating the embryonic chambers is thin. The diameters of protoconch varies from 106x112 m/u to 225x287 m/u and those of the deutoconch from 62x125 m/u to 100x250 m/u. The average values of d₁ and d₂ is shown in Fig. 37. The distance across both the chambers varies from 193 m/u to 350 m/u. The d₁-h₁ relationship is represented in Fig. 38.

The spire opens rapidly (Pl. 37, Figs. 8-9; Pl. 62, Fig. 1). The marginal cord is thin. The first nepionic chamber is arcuate and rests over both the protoconch and deutoconch. The number of operculine chambers varies from two to four excluding the embryonic chambers. The equatorial chambers are highly curved and divided into chamberlets. The primary septa are smooth, curved, whereas the secondary septa are almost straight and usually perpendicular to the primary septa. There are about two and a half whorls in a test dia-
meter of 4.4 mm, seven chambers in the first whorl and fourteen in the second whorl. The height of the chambers ranges from 62 m/u to 350 m/u. The height and width of the chamberlets varies from 50 m/u to 300 m/u and 37 m/u to 200 m/u respectively.

In axial section (Pl. 37, Figs. 6-7; Pl. 62, Figs. 4, 6), the embryonic apparatus is bilocular, the protoconch is subcircular and the deuteroconch is crescentic in shape. The equatorial chambers are narrow, elongated triangular and evolute (Pl. 37, Fig. 8; Pl. 62, Fig. 4). The whorl wall is involute. The marginal cord is weakly developed. The pillars are distributed over the septa from centre to periphery. They are thicker on the umbonal part. The surface diameter of the pillars varies from 18 m/u to 275 m/u.

**Measurements:** The measurement of external and internal features is appended in Tables 97-99.

**Remarks:** Tandon (1974) adequately described and illustrated the microspheric and the megalospheric specimens of his new species *H. kohlii* from southwestern Kutch. The present specimens from northwestern Kutch come from the same stratigraphic horizon and are identical to those described as *H. kohlii*. Hence they are referred to Tandon's species. The microspheric generation was not represented in present material.

It is distinguished by its very thin test, few rapidly opening spire, 1-2 operculina chambers and evolute chambers which often pinch out in their course, from other species of the genus described from rocks of Lower-Middle Oligocene age.
Distribution: *H. kohlii* is a commonly occurring larger foraminifera in the Lower and Coral Limestone Members of the Maniyara Fort Formation, Kutch. Tandon (1974) described it from the Lower Oligocene of southwestern Kutch. In the present area the species occurs commonly to frequently in the lower two members of the Maniyara Fort Formation of Kapurasi and Guvar areas. Here, it is restricted to the Early to Middle Oligocene *Nummulites fichteli* and *Eulepidina dilatata* Zones. At present it is known to be restricted to western India.

Genus *Spiroclupeus* Douville, 1905

Type species: *Spiroclupeus orbitoideus* Douville, 1905

Diagnosis: Test lenticular to discoidal; chambers planispirally coiled, strongly curved, narrow, divided into rectangular chamberlets, tiers of lateral chambers on either side of the equatorial plane.

Distribution: The genus is cosmopolitan. It ranges from Upper Eocene to Lower Miocene.

*Spiroclupeus ranjanae* Tewari, 1956

(Pl. 38, Figs. 1-5; Pl. 62, Figs. 10-13)

1956 *Spiroclupeus ranjanae* Tewari, pp. 319-320, figs. 1-4.

Material: Only megalospheric specimens were studied. Five isolated specimens, five equatorial/split-equatorial sections and five axial sections were examined. Specimens from Waior area, southwestern Kutch were used for illustrations, as it was not possible to isolate specimens from the present samples. Because of the thinness of the test peripheral part of the specimens were not preserved.
Description: The test is moderately large, biumbonate, with thin flat, often undulating wide flange. The surface of the decorticated specimens is conspicuously ornamented with distinct ridges along the septal sutures forming reticulation on the surface. The granules are most prominent on the umbo (Pl. 38, Fig. 1). The diameter of umbo ranges from 0.87 mm to 1.4 mm, the thickness at centre from 0.8 mm to 1.25 mm and the diameter of granules from 25 m/μ to 225 m/μ.

In equatorial section the embryonic apparatus is moderately large, bilocular and made up of subcircular protoconch partly embraced by a reniform deuteroconch (Pl. 38, Figs. 2-3; Pl. 62, Figs. 10, 12-13). Usually the deuteroconch is larger than the protoconch. The separating wall is moderately thick and moderately convex outwards. The internal diameters of protoconch vary from 225x212 m/μ to 262x312 m/μ and of deuteroconch from 125x275 m/μ to 150x350 m/μ. The distance across both chambers ranges from 343 m/μ to 425 m/μ and the thickness of separating wall from 12 m/μ to 25 m/μ.

The spire opens rapidly. The marginal cord is distinct. In most specimens there is no operculine chamber and, if present, the number is always one (Pl. 62, Fig. 13). The equatorial chambers are highly curved and divided into chamberlets. The shape and size of the chamberlets vary to some extent. In general the chamberlets are rectangular in shape and higher than long. The secondary septa are almost straight and usually perpendicular to the primary septa. The spacing of secondary septa varies to some extent. The height of chambers varies from 45 m/μ to 250 m/μ. The height and width of the chamberlets ranges from 12 m/μ to 243 m/μ and 31 m/μ to 162 m/μ respectively.
In axial section (Pl. 38, Figs. 4-5; Pl. 62, Fig. 11) the embryonic apparatus is medium in size. The protoconch is subcircular in outline followed by the reniform deuteroconch. The equatorial chambers are very narrow, much elongated and involute (Pl. 38, Figs. 4-5; Pl. 62, Fig. 11). They increase in height very rapidly with growth. The marginal cord is weakly developed. Lateral chambers are low elongated cavities separated by thicker walls and arranged in tiers between pillars. There are usually about nine to twelve lateral chambers on each side of the embryonic apparatus. The length of the lateral chambers varies from 150 μm to 166 μm and the height from 15 μm to 18 μm. The thickness of roofs and floors varies from 21 μm to 28 μm. The pillars are distinct and distributed from centre to periphery. They are numerous and vary in shape and size. Usually they are thicker in the central part. The surface diameter of the pillars ranges from 25 μm to 237 μm.

**Measurements** : Measurements of external and internal features are shown in Tables 100-102.

**Remarks** : Tewari (1956) described his new species *S. ranjanae* from the Waior section in southwestern Kutch. The present description is based on free specimens from the same section. They are identical to Tewari's original material. It is the only valid species of *Spiroclypeus* recognised in Kutch.

**Distribution** : The *Spiroclypeus* bed of the Waior Section from which Tewari (1956) described *S. ranjanae* has been dated as Late Oligocene in age. In Kutch the species has been found restricted to rocks of this age. In the present area of study the species occurs
commonly to abundantly in the Ber Moti Member of the Maniyara Fort Formation exposed in Guvar area. Here, it is restricted to the Late Oligocene Spiroclypeus ranjanae Zone.

**Family Miogypsinidae Vaughan, 1928**

*Diagnosis*: Test small, triangular to subcircular in outline; embryonic apparatus subcentral to apical; equatorial chambers arcuate, rhombic to hexagonal arranged on only a segment of the periphery; equatorial chamber layer covered on either side by layers of lateral chambers or by appressed laminae, walls with spiral and intraseptal canal and chambers interconnected by stolons.

*Distribution*: The family is widely distributed in all the three marine Tertiary provinces and ranges from Middle Oligocene to Lower Miocene in age.

**Genus Miogypsinoides Yabe & Hanzawa, 1928**

*Diagnosis*: A genus of the family Miogypsinidae without lateral chambers.

*Distribution*: All the three marine Tertiary provinces from Middle Oligocene to Lower Miocene.

*Miogypsinoides bermudezi* (Drooger), 1951

(Pl. 38, Figs. 6-7; Pl. 63, Figs. 12-13)

1951 *Miogypsina (Miogypsinella) bermudezi* Drooger, pp. 357-359, figs. 1-6.

1974 *Miogypsina (Miogypsinoides) cf. bermudezi* Drooger; Raju, pp. 77-78, pl. 1, figs. 1-5; pl. 3, figs. 1-2; pl. 5, figs. 1-3.
Material: One equatorial section, one vertical section and three off-centre sections of megalospheric generation were examined in random thin section of rocks. The preservation is not satisfactory.

Remarks: In his detail investigation on Indian Miogypsinidae Raja (1974) described and figured specimens from Waior Section, Kutch as M. cf. bermudezi Drooger. The identification of present material is based on his publication. M. bermudezi is a common form in five samples collected from the Ber Moti Member of the Maniyara Fort Formation where it is usually represented by random sections of parts of the test. Morphologically the present material resembles most closely to M. bermudezi Drooger. Free specimens and oriented sections are required for a detail description and illustration of the species, from the present area.

Distribution: M. bermudezi was first described from the subsurface of Cuba by Drooger (1951) from rocks dated as Oligocene. This is usually treated as a Lower Chattian (= early Late Oligocene) marker foraminifera. During the present study the species was recognised only from the Guvar area where it is restricted to the Spiroclypeus ranjanæ Zone of Late Oligocene age. This is the first report of this species from this present area.

Family Amphistegindae Cushman, 1927
Genus Amphistegina d'Orbigny, 1826

Type species: Amphistegina vulgaris d'Orbigny, 1826

Diagnosis: Test asymmetrically lenticular to conical; very low trochoid, involute; numerous chambers and lobed sutures; umbilicus
filled with a plug; wall finely perforate without a canal system; aperture a small opening, often with a lip.

Distribution: Cosmopolitan; Eocene to Recent.

Occurrence in Kutch: The genus occurs in the Fulra Limestone and the Maniyara Fort Formation of Kutch. During the present investigation two species occurring in random thin section of rocks were recognised - *Amphistegina cubensis* Palmer and *A. mamilla* (Fichtel & Moll).

*Amphistegina cubensis* Palmer, 1934

(Pl. 17, Fig. 9)

1978 *Amphistegina cubensis* Palmer; Larsen, p. 223.

Material: A few off-centred sections seen in random thin section of rocks.

Remarks: In Kutch, *A. cubensis* is readily distinguished by its small subtriangular transverse view of the test, low trochoid spire, sharp periphery and very narrow umbilical area. The height tends to be equal to the diameter of the test. It is comparable to Palmer's species.

Distribution: Palmer (1934) described it from the Middle to Upper Eocene of the Caribbean region. Later, Larsen (1978) made observation on the distribution of the species. In Kutch, the species occurs in the *Discocyclina sowerbyi* and *Alveolina elliptica* Zones of Middle Eocene age.
Amphistegina mamilla (Fichtel & Moll), 1798
(Pl. 17, Fig. 7)

1798 Nautilus mamilla Fichtel & Moll, P. 53, figs. 6a-d.
1978 Amphistegina mamilla (Fichtel & Moll); Larsen, p. 224,
l figs. 8–9, 11–12; pl. 6, fig. 3; pl. 7, fig. 4.
1983 Amphistegina mamilla (Fichtel & Moll); Chaproniere, p. 39,
pl. 2, fig. 16; pl. 3, fig. 6.

Material: A few near-axial sections seen in random rock sections.
Remarks: A. mamilla with its large, unequally biconvex shape with
ventral side more strongly convex, umbilical area filled with solid
material and diameter often twice the height of the section is rea-
dily recognised in the present material.

Distribution: The species has previously been reported from the
Middle East, the Indo-Pacific region and Europe. Its reported stra-
tigraphic range is Middle Eocene to Miocene. In the present area
A. mamilla occurs commonly in all the three members of the Maniyara
Fort Formation of Guvar and Kapurasi areas. Here it ranges from
Early Oligocene Nummulites fichteli Zone through Middle Oligocene
Eulepidina dilatata Zone to Late Oligocene Spiroclypeus ranjanae
Zone.

Family Acervulinidae Schultze, 1854
Genus Acervulina Schultze, 1854
Type species: Acervulina inhaerens Schultze, 1854
Diagnosis: Test attached; nepionic stage coiled, ephebic part
uncoiled; later chambers polygonal to irregular in outline in sec-
tion separated by straight to sinuous walls, encrusting; wall calcareous and coarsely perforate.

**Distribution**: Cosmopolitan; Eocene to Recent.

**Occurrence in Kutch**: The genus is restricted to the upper part of the Fulra Limestone in Kutch. In the present investigation only one species, *Acervulina linearis* Hanzawa occurring in random thin section of rocks has been recognised.

*Acervulina linearis* Hanzawa, 1947

(Pl. 17, Fig. 8)

1947 *Acervulina linearis* Hanzawa, pp. 60-61, pl. 16, figs. 2-5.
1957 *Acervulina linearis* Hanzawa. Hanzawa, p. 68, pl. 24, figs. 1a-c; pl. 29.
1967 *Gypsina linearis* (Hanzawa). Hagn and Wellnhofer, pp. 224-227, pl. 5, figs. 1-2; pl. 6, figs. 1-2; pl. 7, figs. 1-3; pl. 8, figs. 1-2.
1983 *Acervulina linearis* Hanzawa. Samanta, p. 188, figs. 2A, 2B, 3C.

**Material**: Only parts of two vertical sections were examined in random thin section of rocks.

**Remarks**: The structures of the Kutch specimens are identified to those of the material from eastern India identified by Samanta (1983) as *A. linearis* Hanzawa. Here it occurs encrusting tests of *Discocyclina* sp.

**Distribution**: *A. linearis* has been recorded from different loca-
lities of the Tethyan, Indo-Pacific and Caribbean provinces. The first illustrated record from India was that by Samanta (1983) from eastern India. Authentic reports of *A. linearis* are restricted to rocks of late Middle to Late Eocene age. In the present investigation the species has been identified from the upper part of the Fulra Limestone exposed in Guvar as well as Godhatad-Kapurasi areas, Kutch. Here, it is restricted to the *Alveolina elliptica* Zone of late Middle Eocene age.

**Genus Gypsina Carter, 1877**

*Type species* : *Polytrema planum* Carter, 1876

**Diagnosis:** Test inflated biconvex to globular; chambers arcuate to rectangular to polygonal in outline, regularly or irregularly arranged; wall coarsely perforate; arched chambers with basal openings.

**Distribution:** Cosmopolitan; Palaeocene to Recent.

**Occurrence in Kutch:** In Kutch, the genus occurs in the Fulra Limestone and in all the three members of the Maniyara Fort Formation. In the present material, it is represented by two species, *Gypsina discuss* Goes and *G. globulus* (Reuss).

**Gypsina discuss** Goes, 1896

*(Pl. 19, Figs. 2-3)*

1896 *Gypsina vesicularis* var. *discuss* Goes, p. 74, pl. 7, figs. 4-6.

1947 *Gypsina discuss* Goes; Bursch, pp. 40-41, pl. 3, figs. 2, 4, 13, 17, 22; pl. 5, figs. 6-7; text-figs. 15, 20.
1983 *Gypsina discuss* Goes; Chaproniere, p. 39, pl. 2, figs. 14-15; pl. 3, fig. 7.

**Material**: Only megalospheric specimens were examined in random thin sections of rocks.

**Remarks**: A few sections characterised by circular outline, central megalospheric embryonic apparatus consisting of a large circular protoconch partly embraced by the deuteroconch, arcuate periembryonic chambers and wide arcuate post-nepionic chambers arranged in concentric rings with two openings at the bases and coarsely perforate wall are identified as *Gypsina discuss* Goes.

**Distribution**: *G. discuss* occurs rarely in the Middle Oligocene *Rulepidina dilatata* Zone of the Coral Limestone Member of the Maniyara Fort Formation exposed in Kapurasi area, northwestern Kutch.

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1878 *Ceriopora globulus* Reuss, p. 33, pl. 5, fig. 7.
1933 *Sphaerogypsina globulus* (Reuss). Galloway, pl. 28, figs. 13, 14.
1957 *Gypsina globulus* (Reuss). Hanzawa, p. 66, pl. 38, figs. 4, 8-9.
1983 *Gypsina globulus* (Reuss). Samanta, p. 189, fig. 3E.

**Material**: Abundant free specimens were available. However, the discussion is essentially based on thin sections of megalospheric specimens occurring in rock sections.

**Remarks**: Test is subglobular with coarse pores in the wall. This often produces a reticulate pattern on the surface. In section the circular initial chamber is followed by a few coiled arcuate chambers. Then the chambers are arranged in concentric rows. The wall of the
chamber are coarsely perforate. It is a readily recognisable species. From India, Samanta (1983) first published illustrations of the internal structure of fossil specimens of this species. Distribution: It is a cosmopolitan larger foraminifera and has been reported from numerous localities from rocks ranging in age from Eocene to Recent. In Kutch, *G. globulus* occurs in the Fulra Limestone and in all the three members of the Maniyara Fort Formation. The localities are Godhatad-Kapurasi, Guvar and Harudi. It occurs in the *Discocyclina sowerbyi*, *Alveolina elliptica*, *Nummulites fichteli*, *Bulepidina dilatata* and *Spiroclypeus ranjanae* Zones of middle Middle Eocene to Late Oligocene age. Here, this is the only larger foraminiferal species which shows such a long stratigraphic range.

Family Cymbaloporidae Cushman, 1927
Genus *Fabiana* Silvestri, 1926

*Tschoppina* Keijzer, 1945, p. 213.

Type species: *Patella (Cymboila) cassis* Oppenheim, 1896

Diagnosis: According to Samanta (1983), the genus is characterised by the regularly or irregularly conical test, composed of a peripheral layer of chambers; umbilicus empty and open or filled up with chamberlets and closed by a plate provided with several large openings; dorsal surface with polygonal meshes; early chambers trocho-spirally arranged, later in cyclical series, partly subdivided into chamberlets by horizontal and vertical partitions; apertures numerous, opening into the umbilicus.
Occurrence in Kutch: In Kutch, section comparable to the species of *Fabiania* was observed in random thin sections of rock which is identified here as *Fabiania* sp. There is no previous record of the genus from the present area of study.

*Fabiania* sp.

(Pl. 17,-Fig. 3)

**Material**: One horizontal section from random thin section of rocks was examined.

**Remarks**: The single horizontal section showing a narrow umbilical layer of chambers encircling the elongated large umbilicus is provisionally referred to the genus *Fabiania*. In the absence of adequate material specific identification has not been attempted.

**Distribution**: *Fabiania* sp. occurs in one sample collected from the basal part of the Fulra Limestone exposed in Guvar area. Here, it is restricted to the *Discocyclina sowerbyi* Zone of middle Middle Eocene age.

**Family Discocyclinidae Galloway, 1928**

**Diagnosis**: Test thin, discoidal to inflated lenticular, circular to stellate in plan; the thin equatorial chamber layer, simple to multiple, covered on both sides by layers of lateral chambers; megalospheric embryonic apparatus bilocular to multilocular; equatorial chambers rectangular to faintly hexagonal in shape and arranged in concentric annuli which vary from circular to stellate in
outline; communication between chambers by stolons; no canals.

**Distribution**: Cosmopolitan; Middle Palaeocene to Uppermost Eocene.

**Occurrence in Kutch**: In the present study two genera of the family Discocyclinidae, *Discocyclina* and *Asterocyclina* are recognised. They occur abundantly to commonly in the Fulra Limestone of Guvar (Traverse III) and Godhatad-Kapurasi (Traverse IV) areas. The type genus *Discocyclina* also occurs in the basal part of the Fulra Limestone exposed in the Harudi area (Traverse I). These two genera occur as rock-forming elements in several horizons. The family is represented here by eleven species.

**Genus Discocyclina** Gumbel, 1868

**Type species**: *Orbitulites pratti* Michelin, 1846

**Diagnosis**: According to Samanta (1967), "the outline of the test circular or quadrate in plan view; the equatorial chambers single-layered throughout the test; the radial chamber walls well-developed, those in adjacent annuli either in alignment or alternate and the annular stolons mostly situated at the proximal side of the chambers".

**Distribution**: *Discocyclina* is the most widely distributed and best represented genus of the family Discocyclinidae. It ranges from Middle Palaeocene to Uppermost Eocene and occurs throughout the tropic and temperate region of the world. In the region between southern Europe and India, the genus is represented by fewer species in the Palaeocene and Lower Eocene but becomes abundant in the Middle and Upper Eocene. In the America: the genus ranges from Palaeocene to Middle Eocene. It occurs in Middle to Upper Eocene beds in the
Indonesian region, while in the Central Pacific Islands it appears to be recorded only in Upper Eocene beds (Samanta, 1967).

Occurrence in Kutch: In the present area the genus occurs abundantly in the middle to late Middle Eocene Fulra Limestone exposed in Harudi, Guvar and Godhatad-Kapurasi areas. At several stratigraphic horizons it occurs as rock-forming element. The following nine species of *Discocyclina* are identified:

1. *Discocyclina adamsi* Samanta & Lahiri
2. *D. assamica* Samanta
3. *D. augustae* Weijden
4. *D. disphaena* (Sowerby)
5. *D. haynesi* Samanta & Lahiri
6. *D. praecomphalos* Samanta & Lahiri
7. *D. sella* (d'Archiac)
8. *D. sowerbyi* Nuttall and

The external and internal parameters of *Discocyclina* used in description and measurements are shown in Fig. 39.

1. D = Diameter of test
2. T = Thickness of test at centre
3. D₁ = Diameter of the protoconch measured normal to the axis of symmetry of the embryonic apparatus.
4. D₂ = Diameter of the deuteroconch measured normal to the axis of symmetry of the embryonic apparatus.
5. H₁ = Height of the protoconch measured along the axis of symmetry and,
Fig. 40 Scatter diagram of $D - T$ for seven species of *Discocyclina* (Form 'A') from the Fulra Limestone
6. $H_2$ = Height of the embryonic apparatus measured along the axis of symmetry.

**Discocyclina adamsi** Samanta & Lahiri, 1985
(Pl. 39, Fig. 11; Pl. 64, Fig. 1; Text-fig. 40)

Discocyclina adamsi Samanta & Lahiri, pp. 229-242, pl. 1, figs. 6-10; pl. 5, fig. 9; text-figs. 5, 8.

**Material**: Only one equatorial section and five vertical sections of megalospheric specimens were studied from random thin sections of rocks. The preservation was not satisfactory.

**Description**: The vertical section (Pl. 39, Fig. 11) shows the compressed, curved test with small flattened umbonal swelling followed by very shallow depressions on either side; large, compressed elliptical embryonic apparatus, extension corresponding that of the umbo; thin equatorial chamber layer and very narrow lateral chambers between thick roofs and floors. The diameter of the test in vertical section varies from 13 mm to 18 mm, the thickness at centre from 0.50 mm to 1.0 mm and those at periphery from 0.60 mm to 1.49 mm (Fig. 40). There are about nine to twenty-one lateral chambers on each side of the embryonic apparatus (Table 112). The length of lateral chambers varies from 25 m$\mu$ to 87 m$\mu$ and the height from 6 m$\mu$ to 8 m$\mu$. The thickness of the roofs and floors varies from 4 m$\mu$ to 10 m$\mu$. The pillars are moderately developed, wedge-shaped and distributed throughout the section.

**Measurements**: Table 112.

**Remarks**: This distinctive species is characterised by the large
and typical shape of the test, large embryonic apparatus, thick equatorial chamber layer and the characters of the lateral chambers and pillars. *D. adamsi* was originally described and illustrated by Samanta and Lahiri (1985) from Babia Hill, Kutch. They assigned the species to the *Discocyclina sowerbyi* group and mentioned that it had some resemblance to *Discocyclina omphalus* in the characters of embryonic apparatus and lateral chambers (see Samanta and Lahiri, 1985, p. 239). The species shows close affinity to *Discocyclina baluchistanensis* (Nuttall) in the characters of the embryonic apparatus.

**Distribution**: In the present area, the species occurs commonly in the Fulra Limestone of Godhatad-Kapurasi and Guvar areas. It ranges from the middle Middle Eocene *D. sowerbyi* Zone to the late Middle Eocene *A. elliptica* Zone. It is more common in the *D. sowerbyi* Zone than in the *A. elliptica* Zone.

**Discocyclina assamica** Samanta, 1963

(Pl. 39, Figs. 8-10; Pl. 64, Fig. 12; Text-figs. 40-42)

1963 *Discocyclina (Discocyclina) assamica* Samanta, p. 658-661, pl. 34, figs. 1-6.
1965 *Discocyclina assamica* Samanta; Samanta, p. 421, pl. 1, figs. 5-8.
1985 *Discocyclina assamica* Samanta; Samanta & Lahiri, pp. 242-249, pl. 1, figs. 1-5; pl. 9, figs. 1-12, text-figs. 5-7.

**Material**: Five isolated specimens, five equatorial and four vertical sections of megalospheric specimens were examined.

**Description**: Test small, distinct umbo surrounded by wide, very thin and wavy flange. The diameter of test varies from 2.0 mm to
Fig. 41 Scatter diagram of $D_1 - D_2$ for six species of *Discocyclina* (Form 'A') from the Fulra Limestone.
Fig. 42 Scatter diagram of $H_1 - H_2$ for six species of *Discocyclina* (Form 'A') from the Fulra Limestone.
10.5 mm and the thickness at centre from 0.55 mm to 1.30 mm (Fig. 40). The diameter of papillae ranges from 25 μm to 62 μm.

The megalospheric embryonic apparatus is moderately large eulepidine (Pl. 39, Figs. 8-9; Pl. 63, Fig. 12). The protoconch is subcircular in equatorial sections and elliptical in vertical sections. The deutoconch is much larger, subcircular to slightly irregular in outline and embraced upto 3/4 of the protoconch. The internal diameters of protoconch varies from 100x112 μm to 150x200 μm and those of deutoconch from 256x287 μm to 382x475 μm. The distance across both chambers varies from 250 μm to 382 μm (Figs. 41-42). The thickness of outer wall of the embryonic apparatus ranges from 9 μm to 12 μm.

The periembryonic chambers are rectangular in equatorial sections (Pl. 39, Fig. 9). They are wider than the later-formed chambers (Pl. 39, Fig. 8). The large size of both embryonic apparatus and the surrounding periembryonic ring make the early chambers prominent and quiet distinct from the later equatorial chambers. There are about thirty-two to forty-one chambers in the periembryonic ring. Their radial diameter ranges from 50 μm to 118 μm and tangential diameter from 18 μm to 50 μm.

Equatorial sections (Pl. 39, Fig. 8) show narrow, radially elongate chambers arranged in concentric annuli which are very irregular in shape. Usually, the annular walls are thicker than the radial ones which are mostly aligned in adjacent annuli. The radial diameter of the equatorial chambers varies from 37 μm to 100 μm.
and the tangential diameter from 12 m/μ to 25 m/μ.

The vertical section (Pl. 39, Fig. 10) shows the thin, wavy test with a small sloping umbo, elliptical embryonic apparatus. This equatorial chamber layer and rectangular lateral chambers arranged in tiers (Pl. 39, Fig. 10).

Measurements: Tables 113-115.

Remarks: D. assamica Samanta is characterised by very thin test, medium eulepidine embryonic apparatus, radially elongated peri-embryonic chambers always wider than the later-formed equatorial chambers, strikingly narrow radially elongate equatorial chambers dominantly aligned radial chamber walls in adjacent rings and very thin equatorial chamber layer. The present material is identifiable with D. assamica Samanta originally described from Garo Hills, eastern India and is also similar to the specimens described from Kutch by Samanta and Lahiri (1985).

Distribution: So far D. assamica is known from India only. The species was originally described from the Late Eocene of Garo Hills, Meghalaya by Samanta (1963). It has recently been recorded from Kutch by Samanta & Lahiri (1985). In the present area, it occurs commonly to rarely in the Fulra Limestone exposed in Guvar and Godhatad-Kapurasi areas and appears to be restricted in the Discocyclina sowerbyi as well as Alveolina elliptica Zones of Middle Eocene age.

Discocyclina augustae Weijden, 1940
(Pl. 39, Figs. 1-4; Pl. 64, Fig. 2; Text-figs. 40-42)

1868 Orbitoides (Discocyclina) papyracea (Boubee); Gumbel, pp. 687, 690-696, pl. 3, figs. 3-12, 19-29.
1903 Orthophragmina pratti (Michelin); Schlumberger, pp. 274-275, pl. 8, figs. 2-3; text-fig. A.

1922 Discocyclina archiaci (Schlumberger) Douville, pp. 57, 65, 67; text-fig. 2.

1940 Discocyclina (Discocyclina) augustae Weijden, pp. 23-26, pl. 1, figs. 4-8; pl. 2, figs. 1-2.

1941 Discocyclina augustae Weijden; Bronnimann, pp. 253-260, pl. 14, figs. 7-12, pl. 15, figs. 1-2, text-figs. 1-5.

1950 Discocyclina augustae Weijden; Ruiz de Gaona, pp. 22-127.

1953 Discocyclina augustae Weijden; Schweighauser, pp. 49-51, pl. 8, figs. 1-3; pl. 13, fig. 4; text-fig. 41.

1958 Discocyclina augustae Weijden; Neumann, pp. 84-86, pl. 12, figs. 1-6; pl. 26, figs. 1-2; pl. 35, fig. 3; text-fig. 21.

1965b Discocyclina augustae Weijden; Samanta, pp. 421-422, pl. 3, figs. 7-13; pl. 4, fig. 12.

1973 Discocyclina augustae Weijden; Brolsma, pp. 417-418, pl. 1, figs. 5-6; pl. 2, figs. 3-5.

1983 Discocyclina augustae Weijden; Setiawan, p. 98, pl. 17, fig. 7.

1985 Discocyclina augustae Weijden; Samanta & Lahiri, pp. 249, 252-253, pl. 2, figs. 1-7; pl. 10, figs. 1-12, text-figs. 5-7, 9-10.

Material: Only megalospheric specimens were examined. Five specimens were studied externally, five specimens in equatorial sections and five specimens in vertical sections.

Description: The test is small, thin with very small umbo slightly elevated and surrounded by thin wide peripheral flange (Pl. 39, Figs. 1-2). The surface is ornamented with coarse granules. The
diameter of the test varies from 3.3 mm to 5.0 mm and the thickness at centre from 0.45 mm to 0.80 mm (Fig. 40). The diameter of umbo ranges from 0.50 mm to 1.00 mm. The diameter of granules varies from 50 μm to 125 μm.

The embryonic apparatus is small, nephrolepidine (Pl. 64, Fig. 2). The protoconch is subcircular to circular in both equatorial and vertical sections. The deuteroconch is large, crescentic in equatorial sections and subelliptical in vertical sections. The internal diameter of the protoconch varies from 37x50 μm to 62x75 μm and that of the deuteroconch from 87x150 μm to 150x187 μm. The distance across both chambers varies from 112 μm to 156 μm (Figs. 41-42). The thickness of the outer wall ranges from 4 μm to 6 μm.

The periembryonic chambers are small, rectangular in equatorial sections (Pl. 64, Fig. 2). They do not differ markedly from later-formed equatorial chambers. There are about twenty to twenty-six chambers in the periembryonic ring. Their radial diameter ranges from 18 μm to 31 μm and tangential diameter from 12 μm to 25 μm.

The equatorial chambers (Pl. 39, Fig. 3) are mostly rectangular, increasing in length towards the periphery. The radial walls are alternate in adjacent annuli. The radial diameter of the chambers ranges from 18 μm to 87 μm, the tangential diameter from 6 μm to 25 μm and the height from 18 μm to 25 μm.

In vertical sections (Pl. 39, Fig. 4) the low lateral chamber cavities lie between thicker roofs and floors. There are about eight to fifteen lateral chambers on each side of the embryonic apparatus. The length of the lateral chambers ranges from 43 μm to 87 μm.
and the height from 9 m/μ to 18 m/μ. The thickness of roofs and floors varies from 9 m/μ to 25 m/μ. Pillars are well developed and extend upto the surface forming conical granules. They are more prominent on the umbo.

**Measurements**: Tables 116-118.

**Remarks**: The present specimens characterised by their small, thin, flat test with small, gently elevated umbo, granulated exterior, very small, nephrolepidine embryonic apparatus and very low, appressed lateral chambers between thick roof and floors are identifiable with *D. augustae* Weijden. Recently Samanta & Lahiri (1985) described and illustrated *D. augustae* from northwestern Kutch.

**Distribution**: This is a widely distributed representative of *Discocyclina* and has been reported from southern Europe in the west to Assam in the east. Samanta (1965b) recognised this species from Late Eocene of Garo Hills, eastern India which is virtually the first record of the species from localities outside Europe. Fermont (1982) recorded it from the Lower Eocene of Israel. Samanta and Lahiri (1985) described and illustrated this species from the Middle Eocene Fulra Limestone of Lakhpat-Babia area of Kutch. It is a commonly occurring and easily recognisable form in the present area. Here it is restricted to the middle to late Middle Eocene *Discocyclina sowerbyi* and *Alveolina elliptica* Zones.

*Discocyclina dispansa* (Sowerby), 1840
(Pl. 40, Figs. 6-7; Text-figs. 40-42)

1840 *Lycophris dispansus* Sowerby, p. 327, pl. 24, figs. 16, 16a-b.

1861 *Orbitoides dispansa* (Sowerby). Carter, pp. 446-450, pl. 16, figs. 1a - 1a-1; pl. 17, figs. 1m-o.

1897 *Orbitoides dispansa* (Sowerby). Medlicott & Blanford, pl. 15, figs. 8, 8a-d.

1926 *Discocyclina dispansa* (Sowerby). Nuttall, pp. 145-147, pl. 7, figs. 1,3,5.

1926 *Discocyclina javana* (Verbeek) var. *indica* Nuttall, pp. 147-148, pl. 7, figs. 4,6,8.

1963a *Discocyclina* (*Discocyclina*) *dispansa* (Sowerby). Sengupta, pp. 38-41, pl. 1, figs. 1-9; pl. 2, figs. 1, 3-9.

1965b *Discocyclina dispansa* (Sowerby). Samanta, p. 422, pl. 1, figs. 9-11.

1985 *Discocyclina dispansa* (Sowerby). Samanta & Lahiri

**Material**: Only megalospheric specimens were examined. Five isolated specimens, five equatorial sections and five vertical sections were studied.

**Description**: The test is medium in size with wide, prominent umbo surrounded by thin peripheral flange. The umbo is often slightly flattened. The surface is ornamented with close-spaced subrounded granules. The diameter of the test varies from 5.8 mm to 10.2 mm and the thickness at centre from 1.6 mm to 2.85 mm (Fig. 40). The diameter of granules varies from 75 μm to 450 μm.

The embryonic apparatus is medium, eulepidine (Pl. 40, Fig. 7) with small, subcircular protoconch embraced by the much larger deutoconch. The maximum diameter of the protoconch varies from
125x137 m/μ to 187x218 m/μ and that of the deuteroconch from 306x425 m/μ to 450x537 m/μ. The distance across both chambers varies from 375 m/μ to 481 m/μ and the height of the embryonic apparatus from 150 m/μ to 225 m/μ (Figs. 41-42). The thickness of the outer wall of the embryonic apparatus varies from 9 m/μ to 18 m/μ.

The periembryonic annulus is made up of forty-one to fifty rectangular radially elongate chambers (Pl. 40, Fig. 7). Their radial diameter varies from 31 m/μ to 75 m/μ and tangential diameter from 18 m/μ to 37 m/μ.

The rectangular equatorial chambers are arranged in concentric annuli which are more or less circular in outline. The radial diameter of the equatorial chambers increases with ontogeny. The annular walls are thin and often wavy in course. In parts of the sections the annuli are incomplete and pinch out irregularly. The radial diameter of the equatorial chambers varies from 21 m/μ to 67 m/μ, the tangential diameter from 18 m/μ to 50 m/μ and the height from 25 m/μ to 50 m/μ.

Vertical sections show an oval embryonic apparatus (Pl. 40, Fig. 6). In the umbonal part over the embryonic apparatus the lateral chamber cavities are open rectangular and lie between thin roofs and floors and are arranged in regular tiers. Pillars are numerous and distributed throughout the section. They increase in diameter towards the surface. There are about nine to twenty-five lateral chambers on each side of the embryonic apparatus. The length of the lateral chambers varies from 75 m/μ to 225 m/μ and the height from 25 m/μ to 50 m/μ. The thickness of the roofs and floors varies from 6 m/μ to 21 m/μ.
Measurements: Tables 116-121.
Remarks: The megalospheric generation of the species is characterised by its medium, prominently umbonate test; coarsely granulated surface; medium eulepidine embryonic apparatus and open, rectangular lateral chambers between thin roofs and floors arranged in tiers in the umbo.

*D. dispansa* was created by Sowerby (1840) on the basis of specimens from Babia Hill and Waghapadhar in Kutch. He described it as *Lycophris dispansus*. Nuttall (1926) described and figured the microspheric generation of the species based on the specimens collected from Waghapadhar, Kutch and described a new variety *D. javana* (Verbeek) var. *indica* from Kutch and Sind. Sengupta (1963a) for the first time described and illustrated in detail both the generations of *D. dispansa* from Kutch.

Samanta (1965b) included *D. javana* (Verbeek) var. *indica* in the synonymy of *D. dispansa*. Samanta and Lahiri (1985) discussed and figured in detail the range of variation of species represented in the type area, Babia Hill in Kutch.

Distribution: So far as reliable records are concerned, *D. dispansa* occurs only in the India-Pakistan region and ranges from Middle to Late Eocene (Samanta, 1965). *D. dispansa* occurs abundantly in the Fulra Limestone of Guvar and Godhatad-Kapurasi areas as revealed in the present study. Here, it is middle to late Middle Eocene in age and occurs in *Discocyclus sowerbyi* and *Alveolina elliptica* Zones.
Discocyclina havnesi Samanta & Lahiri, 1985

(Pl. 39, Figs. 5-7; Pl. 64, Figs. 3-4; Text-figs. 40-42)

1985 Discocyclina havnesi Samanta & Lahiri, pp. 262-272, pi. 4, figs. 1-6; pi. 12, figs. 9-14; text-figs. 5-7.

Material: Five isolated specimens, five equatorial sections and five vertical sections of megalospheric form were examined.

Description: The test is very small umbonate with biconvex sloping umbo surrounded by a narrow, thin peripheral flange (Pl. 39, Fig. 6). The umbo is coarsely and closely granulated. The surface is ornamented with coarse, subcircular granules on the umbonal region which decreases in size towards the periphery. In general, the outermost part of the flange is smoother (Pl. 39, Fig. 6). The diameter of the test varies from 2.25 mm to 3.35 mm and the thickness at centre from 0.95 mm to 1.85 mm (Fig. 40). The diameter of the umbonal granules varies from 87 μm to 250 μm and those at the periphery from 37 μm to 63 μm.

The embryonic apparatus is very small eulepidine. Both the protoconch and deutercoconch are usually circular to subcircular in outline. The deutercoconch is larger than the protoconch (Pl. 39, Fig. 7; Pl. 64, Figs. 3-4). The protoconch is almost completely embraced by the deutercoconch. The internal diameters of the protoconch varies from 50x50 μm to 62x68 μm and that of deutercoconch from 100x125 μm to 137x156 μm. The distance across both the chambers varies from 118 μm to 143 μm and the height of the embryonic
apparatus from 200 m/μ to 225 m/μ (Figs. 41-42). The thickness of the outer wall of the embryonic apparatus is usually 8 m/μ.

The periembryonic chambers are generally rectangular to spatulate in outline (Pl. 64, Figs. 3-4). There are about eighteen to twenty-four chambers in the periembryonic ring. The radial diameter of the periembryonic chambers varies from 18 m/μ to 31 m/μ and the tangential diameter from 12 m/μ to 21 m/μ.

Equatorial section (Pl. 39, Fig. 7) shows rectangular, quadrature and faintly hexagonal equatorial chambers arranged in concentric annuli which are stellate in outline (Pl. 39, Fig. 7). The rays are best developed in the inner part of the section. There are six to eight rays in a specimen. At the rays the chambers are more elongated. The radial walls alternate in adjacent annuli. The radial diameter of the equatorial chambers varies from 18 m/μ to 75 m/μ, the tangential diameter from 12 m/μ to 38 m/μ and the height from 21 m/μ to 43 m/μ.

Vertical sections show thin equatorial chamber layer and moderately open rectangular lateral chamber cavities between thin roofs and floors arranged in regular tiers (Pl. 39, Fig. 5). There are about sixteen lateral chambers on each side of the embryonic apparatus. The length of the lateral chambers varies from 112 m/μ to 225 m/μ and the height from 31 m/μ to 7.5 m/μ. The thickness of the roofs and floors varies from 12 m/μ to 21 m/μ. The pillars are distributed throughout the section. They are prominently developed at the centre forming distinct protuberances on the surface of the test. Usually they are conical in outline.
Measurements: Measurements of external and internal features are appended in Tables 122-124.

Remarks: With their small inflated test, coarsely granulated biconvex umbo, thin flange, small eulepidine embryonic apparatus, stellate arrangement of equatorial chambers and open rectangular lateral chambers arranged in tiers the present specimens are identifiable with *D. haynesi* originally described from Babia Hill, Kutch (Samanta & Lahiri, 1985). It is distinguished from *D. dispansa* by its smaller test, much narrower flange, smaller embryonic apparatus and protruding apical granules.

Distribution: Originally described from Babia Hill and Lakhpat areas of Kutch the species is restricted to the middle part of the Fulra Limestone. In the present area it occurs commonly in the Middle Eocene Discocyclina sowerbyi and Alveolina elliptica Zones of the Fulra Limestone exposed in the Godhatad-Kapurasi and Guvar areas.

*Discocyclina praemphalus* Samanta & Lahiri, 1985
(Pl. 40, Figs. 2-3; Pl. 64, Figs. 6-7; Text-figs. 40-42)

1985 *Discocyclina praemphalus* Samanta & Lahiri, pp. 272-275, pl. 5, figs. 1-6; text-figs. 5-7, 12.

Material: Five isolated specimens, five equatorial sections and five vertical sections of megalospheric forms were studied.

Description: Test is curved, small to medium in size with wide flattened umbo surrounded by a thin flange which is usually not preserved completely. An annular depression encircles the umbo
which is provided with a central depression of varying magnitude. The surface is granulate. The diameter of the test varies from 5.0 mm to 9.6 mm and the thickness at centre from 0.5 mm to 0.75 mm (Fig. 40). The diameter of the granules varies from 37 m/μ to 100 m/μ.

The megalospheric embryonic apparatus is small eulepidine (Pl. 64, Figs. 6-7). In equatorial section the small subcircular protoconch (Pl. 40, Fig. 3) is embraced by the larger deuteroconch. The diameters of the protoconch vary from 56x56 m/μ to 87x93 m/μ and those of the deuteroconch from 175x218 m/μ to 237x250 m/μ. The distance across both chambers varies from 193 m/μ to 246 m/μ (Figs. 41-42). The thickness of the outer wall of the embryonic apparatus varies from 8 m/μ to 12 m/μ.

The periembryonic chambers are radially elongate rectangular. There are about twenty-nine to thirty-four chambers in the peri-embryonic ring. Their radial diameter ranges from 21 m/μ to 50 m/μ and their tangential diameter from 12 m/μ to 25 m/μ. In equatorial sections (Pl. 40, Fig. 3) radially elongate rectangular equatorial chambers are arranged in regularly formed annuli. The radial walls alternate in adjacent annuli. The radial diameter of the equatorial chambers varies from 12 m/μ to 75 m/μ, the tangential diameter from 9 m/μ to 25 m/μ and the height from 21 m/μ to 43 m/μ.

Vertical sections (Pl. 40, Fig. 2) show the omphaloid shape of the test, thin equatorial chamber layer, small oval embryonic apparatus and low, slit-like lateral chamber cavities arranged irregularly between relatively thick roofs and floors. Pillars are dis-
tributed throughout the section. They are more prominent in the umbo-
nal part. There are about eleven to seventeen lateral chambers on
each side of the embryonic apparatus. The length of the lateral cham-
bbers varies from 31 m/u to 87 m/u and the height from 6 m/u to 12 m/u.
The thickness of the roofs and floors varies from 8 m/u to 18 m/u.

**Measurements**: Measurements of external and internal features are
shown in Tables 125-127.

**Remarks**: With its small to medium test; wide flattened umbo, usually
excavated at the centre; small eulepidine embryonic apparatus and
their equatorial chamber layer the present material is identifiable
with *D. praeomphalus* described and illustrated by Samanta and Lahiri
(1985) from Fulrâ-Lakhpat area of Kutch.

*D. praeomphalus* is considered as ancestral to the Late Eocene
Indo-Pacific form *D. omphalus* (Fritsch) from which it differs by
having small size of the test and small eulepidine megalospheric
embryonic apparatus.

**Distribution**: Originally described from Babia Hill, Dehdhapur areas,
Kutch the species is middle to late Middle Eocene in age and is res-
stricted to the Fulra Limestone. In the present area it occurs both
in the *Discocyclina sowerbyi* and *Alveolina elliptica* Zones of Middle
Eocene age.

**Discocyclina sella** (d'Archiac), 1850

(Pl. 39, Fig. 12; Pl. 69, Fig. 11)

1850 *Orbitolites sella* d'Archiac, p. 405, pl. 8, figs. 16-16a.
1903 *Orthophragmina sella* (d'Archiac); Schlumberger, pp. 278-279,
pl. 9, figs. 14-16, 25.
1922 Discocyclina sella (d'Archiac); Douville, pp. 69-70, 89-90, pl. 4, figs. 6-7.
1940 Discocyclina (Trybliodiscodina) sella (d'Archiac); Weijden, pp. 48-50, pl. 7, figs. 3-5.
1953 Discocyclina sella (d'Archiac); Schweighauser, pp. 66-67, pl. 11, figs. 2, 6, 10, 11, 13; text-figs. 22, 49.
1958 Discocyclina sella (d'Archiac); Neumann, pp. 106-109, pl. 22, figs. 1-8; pl. 26, figs. 5-7, pl. 36, figs. 2, 4; text-fig. 33.
1965b Discocyclina sella (d'Archiac); Samanta, p. 426, pl. 2, figs. 1-7; pl. 4, fig. 11.
1978 Discocyclina sella (d'Archiac); Sirotti, p. 59, pl. 2, figs. 3-7.
1983 Discocyclina sella (d'Archiac); Setiawan, pp. 97-98, pl. 17, fig. 8.
1985 Discocyclina sella (d'Archiac); Samanta & Lahiri, pp. 275-279, pl. 6, figs. 1-4; pl.12, figs. 1-8; text-figs. 5-7.

Material: Only two equatorial sections of megalospheric specimens were studied in random thin section of rocks.

Description: In equatorial section (Pl. 39, Fig. 12), the embryonic apparatus is small eulepidine. The protoconch is usually subcircular and almost completely embraced by the large, subcircular deuteroconch (Pl. 64, Fig. 11). The periembyronic chambers are rectangular and radially elongated. There are about thirty chambers in the periembyronic ring.

Measurements: The internal diameters of protoconch ranges from 75x75 m/μ to 100x100 m/μ and those of deuteroconch from 191x208 m/μ to 183x300 m/μ. The distance across the embryonic chambers is 200 m/μ.
Remarks: The present material is identifiable with that from Lakhapat-Fulra area of Kutch described and illustrated in detail as *D. sella* by Samanta and Lahiri (1985).

Distribution: This widely distributed species of *Discocyclina* occurs in numerous localities in Europe and Asia and has earlier been recorded from eastern India (Samanta, 1965) and Kutch (Samanta and Lahiri, 1985). The reported stratigraphic range is Middle to Late Eocene. In the present area of study it occurs in two samples of the Fulra Limestone collected from Guvar and Godhatad-Kapurasi areas. Here it is restricted to the *Discocyclina sowerbyi* Zone of middle Middle Eocene age.

*Discocyclina sowerbyi* Nuttall, 1926

(Pl. 40, Figs. 1, 4; Pl. 64, Fig. 5; Text-figs. 40-42)

1840 *Lycophris ephippium* Sowerby, p. 327; pl. 24, figs. 15, 15a-b.
1926 *Discocyclina sowerbyi* Nuttall, pp. 149-150, pl. 8, figs. 1-3.
1963a *Discocyclina* (*Discocyclina*) *sowerbyi* Nuttall; Sen Gupta, pp. 41-42, pl. 2, fig. 2; pl. 3, figs. 1-10; pl. 4, fgs. 1-8.
1965b *Discocyclina sowerbyi* Nuttall; Samanta, pp. 426, 428, pl. 3, figs. 1-6; pl. 4, fig. 10.
1985 *Discocyclina sowerbyi* Nuttall; Samanta & Lahiri, pp. 279, 283-287, pl. 6, figs. 5-6; pl. 7, figs. 1-6; pl. 8, figs. 3-4; pl. 13, figs. 1-12; text-fig. 5.

Material: Four isolated specimens, five equatorial sections and five vertical sections of megalospheric form were examined.
Description: The test is medium to large in size, plano-convex to weakly inflated biconvex, saddle-shaped with a moderately developed umbo. The surface is ornamented with granules distributed throughout the test. The diameter of the test varies from 8.35 mm to 12.7 mm and the thickness at centre from 1.9 mm to 3.8 mm (Fig. 40). The average diameter of the granules varies from 50 m/μ to 225 m/μ.

The megalospheric embryonic apparatus is large eulepidine (Pl. 40, Fig. 1; Pl. 64, Fig. 5). The protoconch is subelliptical to irregular and the deuteroconch is much larger and subcircular – subrectangular to irregular in outline. The protoconch is almost completely embraced by the deuteroconch (Pl. 40, Fig. 1). The maximum diameter of the protoconch varies from 412x500 m/μ to 650x712 m/μ and that of the deuteroconch from 825x1150 m/μ to 1237x1550 m/μ. The distance across the both chamber varies from 850 m/μ to 1262 m/μ (Figs. 41-42). The thickness of the outer wall of the embryonic apparatus ranges from 6 m/μ to 18 m/μ.

There are about forty-two radially elongated narrow rectangular chambers in the periembryonic ring which is very often quite irregular in width. The radial diameter of the periembryonic chambers varies from 68 m/μ to 150 m/μ and the tangential diameter from 31 m/μ to 68 m/μ. Equatorial chambers are rectangular in shape and radial walls alternate in adjacent annuli. The radial diameter of the equatorial chambers increases slowly with growth. The annular walls are usually thicker than the radial ones. The radial diameter of the equatorial chambers varies from 50 m/μ to 125 m/μ, the tangential diameter from 18 m/μ to 75 m/μ and the height from 25 m/μ to 68 m/μ.
Vertical sections (Pl. 40, Fig. 4) show the large flattened megalospheric embryonic apparatus, equatorial chamber layer increases appreciably in height with growth, curved annular wall and long open rectangular lateral chamber cavities arranged in tiers between thin roofs as well as floors. There are about seventeen to thirty-three lateral chambers on each side of the embryonic apparatus (Table 130). The length of the lateral chambers ranges from 75 m/μ to 200 m/μ and the height from 12 m/μ to 37 m/μ. The thickness of the roofs and floors varies from 6 m/μ to 18 m/μ. The pillars are numerous, distributed throughout the section and irregular in shape.

**Measurements**: Tables 128-130.

**Remarks**: The present species with their large, usually saddle-shaped test; large, eulepidine embryonic apparatus, the deuteroconch often irregular in outline, the tiers of long and low rectangular lateral chambers separated by straight, thin partitions are identifiable with *D. sowerbyi*. The species was described by Sowerby (1840) as *Lycophris ephippium* from Babia Hill and Wagapadhar, Kutch. As the trivial name was preoccupied Nuttall (1916) named it as *Discocyclina sowerbyi*. This species has earlier been described and illustrated from Kutch by Sowerby (1840), Nuttall (1926), Sen Gupta (1963) and Samanta and Lahiri (1985).

**Distribution**: This species was based on material from Babia Hill and Waghapadhar in Kutch. This species is restricted to the India-Pakistan region and is reported to range from middle Middle to Late Eocene. In the present area *D. sowerbyi* occurs abundantly in the Fulra Limestone of Godhatad-Kapurasi, Guvar and Harudi areas.
The species is more abundant in the lower part of the formation where it often occurs as a rock-forming element. *D. sowerbyi* is restricted to the *Discocyclina sowerbyi* and *Alveolina elliptica* Zones of middle to late Middle Eocene age.

**Discocyclina sp. aff. D. sowerbyi** Nuttall, 1926
(Pl. 40, Fig. 5)


**Material** : Only one vertical section of megalospheric form was examined.

**Description** : The vertical section (Pl. 40, Fig. 5) shows a large test with wide, gently flattened umbo occupying the greater part of the section and a very narrow flange; large, gently flattened embryonic apparatus; equatorial chamber layer increasing appreciably in height, rectangular lateral chambers between thin roofs and floors arranged in tiers and thick pillars varying much in diameter distributed throughout the section.

**Measurements** : The diameter of the test is + 8.9 mm and the thickness at centre 2.28 mm. There are about fourteen to eighteen lateral chambers on each side of the embryonic apparatus. The length of the lateral chambers varies from 56 μm to 175 μm and the height from 12 μm to 31 μm. The thickness of the roofs and floors ranges from 9 μm to 18 μm.

**Remarks** : Samanta and Lahiri (1985, p. 219) identified twelve species of *Discocyclina* from the Middle Eocene of Kutch. Of these,
three distinguished only on the basis of examination of vertical sections in thin sections of rocks, were named as Discocyclina sp. A, D. sp. B and D. sp. C. The present form correspond to D. sp. B of Samanta & Lahiri (1985). The material is insufficient for a systematic study. In its large test, characters of embryonic apparatus and lateral chamber the species shows close affinity to D. sowerbyi Nuttall and is this provisionally identified as D. sp. aff. sowerbyi.

**Distribution**: In the present area the species occurs very rarely in the Fulra Limestone of Guvar area and is restricted to the middle Middle Eocene Discocyclina sowerbyi Zone.

**Genus Asterocyclina** Gumbel, 1870

Type species: Calcarina (?) stellata d'Archiac, 1846

**Diagnosis**: In plan view, the test is circular, polygonal or stellate in outline. The rays are either prominent, extending from the centre to beyond the general periphery of the test, or faint to absent on the surface, but always distinct in equatorial sections at least in its inner part. A multiplication of the equatorial chamber layer occurs along the rays. The radial chamber walls are well-developed and alternate in adjacent annuli. The annular stolons are situated at the proximal side of the equatorial chambers (Samanta, 1967).

**Distribution**: According to Samanta (1967) "Asterocyclina ranges from Middle Palaeocene to Upper Eocene. It is poorly represented in Palaeocene to Lower Eocene beds. Its occurrence in an horizon lower than Middle Eocene appears to be restricted to the region..."
between the Mediterranean area and Western Pakistan. It is widely distributed in the Middle and Upper Eocene rocks of Europe, Africa, Middle East, Pakistan, India, East Indies and the Americas. In central Pacific Islands the genus is restricted to Upper Eocene".

**Occurrence in Kutch:** *Asterocyclina* occurs frequently to commonly in parts of the Fulra Limestone of Guvar and Godhatad-Kapurasi areas and ranges from middle to late Middle Eocene age. Here, it is represented by two species:

1. *Asterocyclina alticostata* (Nuttall)
2. *A* sp.

*Asterocyclina alticostata* (Nuttall), 1926

(Pl. 41, Figs. 1-7; Pl. 64, Figs. 8-10)

1926 *Actinocyclina alticostata* Nuttall, p. 157, pl. 8, figs. 6-8.

1963 *Asterocyclina alticostata* (Nuttall). Sengupta, pp. 95-98, pl. 3, figs. 1-8; text-fig. 2.

**Material:** Only megalospheric specimens were studied. Five isolated specimens, five equatorial sections and five vertical sections were examined. Due to extreme thinness of the test it was not possible to separate the complete test from the matrix.

**Description:** The test is small to moderately large, thin, umbonate with a small umbo surrounded by a very thin, wide flange (Pl. 41, Figs. 5-6). Five to seven prominently elevated primary rays radiate from the umbo. In addition to these there are a few secondary rays which start from outside the umbonal region. The surface is covered with papillae which are coarser on the umbo and the rays. The diameter
of the test varies from +2.30 mm to +9.80 mm, the thickness at centre from 0.80 mm to 1.75 mm and the diameter of umbo from 0.85 mm to 2.10 mm. The diameter of the papillae ranges from 25 \( \mu m \) to 125 \( \mu m \).

The megalospheric embryonic apparatus is moderately large, nephrolepidine (Pl. 41, Fig. 1). The protoconch is subcircular to elliptical in outline (Pl. 64, Figs. 8–10) and subcircular in outline in vertical section (Pl. 41, Figs. 2–4). The deuteroconch is reniform in equatorial section and crescentic in vertical section. The protoconch is partially embraced by the larger deuteroconch (Pl. 64, Figs. 8–10). The diameters of the protoconch ranges from 106x143 \( \mu m \) to 175x250 \( \mu m \) and those of deuteroconch from 125x206 \( \mu m \) to 150x350 \( \mu m \). The distance across both the embryonic chambers varies from 243 \( \mu m \) to 337 \( \mu m \).

The periembryonic chambers are spatulate to rectangular either radially or tangentially elongate. The two principal auxiliary chambers are usually larger than other periembryonic chambers. The radial diameter of the periembryonic chambers varies from 12 \( \mu m \) to 75 \( \mu m \) and the tangential diameter from 25 \( \mu m \) to 43 \( \mu m \).

Equatorial section (Pl. 41, Fig. 17) shows the stellate arrangement of the equatorial chambers. Usually five rays start from the periembryonic annulus. The rays are narrow near the centre but broaden out towards the periphery. The secondary rays occur outside the umbonal area and not so well-defined as the primaries. The chambers in the rays are narrow, radially much elongated than the tangential diameter. The radial walls alternate in position in
adjacent annuli. The radial diameter of the chambers in the rays varies from 37 m to 106 m and the tangential diameter from 12 m to 37 m.

In vertical sections the embryonic apparatus is moderately large, bilocular (Pl. 41, Figs. 2-4). The equatorial chamber layer is considerably thicker along the rays. The lateral chambers are open, rectangular separated by the relatively thin roofs and floors arranged in regular tiers. There are about ten to twenty lateral chambers on both sides of the embryonic apparatus. The length of the lateral chambers ranges from 37 m to 100 m and their height from 9 m to 25 m. The thickness of the roofs and floors varies from 6 m to 12 m. The pillars are numerous and usually thin. The strong pillars are usually visible in the umbonal part. The surface diameter of pillars ranges from 18 m to 125 m.

Measurements : Tables 131-133.
Remarks : Probably because of its large size, greater number of rays and large embryonic apparatus Nuttall (1926) originally described it as an Aktinocyclina. Later workers on Kutch foraminifera also identified it as an Aktinocyclina until Sen Gupta (1963) carried out a systematic study on the internal structure of the test and showed that it is an Asterocyclina.

Distribution : In the present area the species occurs commonly to abundantly in the Fulra Limestone. In Guvar area it is concentrated in a band in the middle part of the formation. In Kutch A. alticostata is restricted to the Middle Eocene Discocyclina sowerbyi and Alveolina elliptica Zones.
Asterocyclina sp.
(Pl. 41, Figs. 8-9)

Material: Only two equatorial sections of megalospheric specimens were examined in random thin section of rocks.

Description: In equatorial section the embryonic apparatus is small nephrolepidine (Pl. 41, Fig. 9). Circular to subelliptical protoconch is followed by a slightly larger reniform deuteroconch (Pl. 41, Fig. 8). The separating wall is gently curved. The two principal auxiliaries are arcuate in shape and larger than the other chambers in the periembryonic ring. There are four distinct rays which are narrow near the centre and broaden out with ontogeny. The chambers in the rays are narrow, radially much elongate than the tangential diameter. The radial walls alternate in position in adjacent annuli.

Measurements: In equatorial section the diameters of the protoconch are 50x62.5 μ and those of the deuteroconch are 68x100 μ. The distance across both the chambers ranges from 131 μ. The radial diameter of the periembryonic chambers varies from 25 μ to 31 μ and the tangential diameter from 25 μ to 38 μ. The radial diameter of the chambers in the rays varies from 31 μ to 38 μ and the tangential diameter from 18 μ to 25 μ.

Remarks: The present species is readily distinguished from A. alticostata (Nuttall) by its smaller embryonic apparatus and fewer rays. There are no secondary rays. Lack of adequate material does not permit precise identification. It is here provisionally identified as A. sp.

Distribution: In the present area, the species occurs rarely in
the Fulra Limestone and is restricted to the Middle Eocene Disco-
cyclina sowerbyi and Alveolina elliptica Zones.

Family Lepidocyclinidae Scheffen, 1932

**Diagnosis**: Test circular or radiate, thin, discoidal to inflated lenticular; 3-layered, median layer of arcuate, ogival, rhombic to hexagonal chambers arranged in concentric annuli, covered on either side by lateral chamber layer; megalosphere bilocular; chambers connected by stolons; no canal system.

**Distribution**: Cosmopolitan; Middle Eocene to Middle Miocene.

Genus *Eulepidina* Douville, 1911

**Type species**: *Orbitoides dilatata* Michelotti, 1861

**Diagnosis**: A genus of the family Lepidocyclinidae characterised by a megalospheric embryonic apparatus consisting of a small thin-walled protoconch embraced more than half of its diameter by a large, thick-walled deuteroconch, both subcircular in equatorial section. The periembryonic chambers are typically narrow and very considerably in position.

**Distribution**: Cosmopolitan; Middle Oligocene to Early Miocene.

**Occurrence in Kutch**: The genus occurs commonly to frequently in parts of the Maniyara Fort Formation exposed in Guvar and Kapurasi areas. Here it appears to be restricted to rocks of Middle Oligocene age. Only one species, *E. dilatata* (Michelotti) is recognised which is described below:
Eulepidina dilatata (Michelotti), 1861
(Pl. 42, Figs. 1-3, 7; Pl. 63, Figs. 2-4, 8-10)

1853 Orbitoides sp. Carter, pp. 175-176, pl. 7, figs. 40, 41
1861 Orbitoides dilatata Michelotti, p. 17, pl. 1, figs. 1-2.
1868 Orbitoides (Lepidocyclina) dilatata Michelotti. Gumbel, p. 190, 717-718, pl. 4, figs. 45-47.
1906 Lepidocyclina dilatata (Michelotti). Vredenburg, p. 91.
1907 Lepidocyclina dilatata (Michelotti). Vredenberg, p. 67
1908 Orbitoides (Lepidocyclina) dilatata (Michelotti).
Checchia-Rispoli, pp. 99-100, 130; pl. 5, fig. 7; pl. 7, fig. 15.
1910 Lepidocyclina dilatata (Michelotti). Silvestri, pp. 139-156, text-figs. 25, 90a-e; pl. 1, figs. 2-10.
1924 Eulepidina dilatata (Michelotti). Douville, p. 48, pl. 2, fig. 3.
1925 Eulepidina dilatata (Michelotti). Douville, pp. 71-73, pl. 4, figs. 1-4, pl. v, figs. 1-4.
1926 Lepidocyclina (Eulepidina) dilatata (Michelotti). Nuttall, pp. 378-387, pl. 13, figs. 1-4, text-fig. 1.
1966 Eulepidina dilatata (Michelotti). Butt, p. 98.

Material: Five isolated specimens, six equatorial sections and five vertical sections of megalospheric generation were examined.
Description: Test small to medium, nearly flat to curved with well-developed umbo sloping gradually towards the periphery (Pl. 42, Fig. 1). The granules on the umbo are coarser and close-spaced than those on the flange. The diameter of test varies from 6.10 mm to 13.20 mm and the thickness at centre from 0.90 mm to 3.00 mm. The diameter of the granules ranges from 50 μm to 262 μm.

The embryonic apparatus is large and eulepidine (Pl. 63, Figs. 2-4, 8-10). The protoconch is usually subcircular in outline in equatorial section and elliptical in vertical section. The deuteroconch is much larger, subcircular in outline and embraces more than 2/3 of the protoconch (Pl. 63, Figs. 2-4, 8-10). The outer wall of the embryonic apparatus is conspicuously thick. The diameters of the protoconch ranges from 500x543 μm to 637x687 μm and those of the deuteroconch from 725x775 μm to 1100x1150 μm. The distance across both the embryonic chambers ranges from 731 μm to 1100 μm. The outer wall of the embryonic apparatus is 50 μm to 87 μm thick.

The periembryonic chambers are very small and mostly arcuate in shape. The shape and arrangement are not always quite distinct in sections.

The equatorial chambers are spatulate to hexagonal in shape (Pl. 42, Figs. 2, 7). They are arranged in concentric annuli. The chambers increase in size towards the periphery.

The vertical section shows the biconvex shape of the test, large strongly flattened embryonic apparatus, thick equatorial chamber layer, open lateral chambers arranged in tiers and thick
pseudopillars distributed throughout the umbonal part (Pl. 42, Fig. 3). The length of the embryonic apparatus varies from 875 m/μ to 1250 m/μ and the height from 350 m/μ to 475 m/μ. The thickness of the equatorial chamber layer varies from 100 m/μ to 125 m/μ. The lateral chambers are open rectangular. They lie between relatively thin roofs and floors and are arranged in regular tiers. There are about six to fourteen lateral chambers on each side of the embryonic apparatus. The length of the lateral chambers varies from 56 m/μ to 168 m/μ and the height from 18 m/μ to 75 m/μ. The thickness of the roofs and floors varies from 18 m/μ to 31 m/μ. The pillars are distinct and uniformly distributed (Pl. 42, Fig. 3).

**Measurements**: Tables 134-136.

**Remarks**: The present specimens are characterised by medium sized umbonate test, granulate exterior, large eulepidine embryonic apparatus, spatulate to hexagonal equatorial chambers and open lateral chambers between straight roofs and floors arranged in tiers. They are comparable to the populations from the Oligocene of the India-Pakistan region identified by previous workers as *Eulepidina dilatata*. A review of the previous publications shows that this has been used as a blanket name for the earliest *Eulepidina* of this region. No attempt has yet been made to compare the Indian assemblage with near topotype material of *E. dilatata*. It was probably Vredenburg (1906) who first used the name *L. dilatata* for all eulepidines occurring in the Oligocene of Pakistan. He thus used a wide concept of the species. This has been followed by later workers on Indian assemblage. Nuttall (1925) made an attempt to
compare his material from Pakistan with that described by Douville (1925) from Europe. Recently, Tandon (1970) provided illustrations of the species from Kutch.

**Distribution:** *E. dilatata* was first described from Italy where the type level was considered to be of Lower Miocene age (Adams, 1970). However, more recently Adams et al. (1983) hold the view that *E. dilatata* which is represented in both the Tethyan and the Indo-Pacific provinces ranges from the Middle Oligocene to the Early Miocene.

This is one of the most widely distributed representatives of the genus occurring in both the Indo-Pacific and the southern Europe-Mediterranean regions. It is a commonly recognised species in the India-Pakistan region where it is treated as restricted to the Middle Oligocene. This is the earliest species of *Eulepidina* in India. Its first appearance has been used to mark the boundary between the Early and Middle Oligocene in this region.

In Kutch, it constitutes a commonly occurring and distinctive component of the larger foraminiferal fauna of the Lower Member (upper part) and the Coral Limestone Member of the Maniyara Fort Formation exposed in Guvar and Kapurasi areas. Here, it is restricted to the *Eulepidina dilatata* Zone of Middle Oligocene age.

**Genus Nephrolepidina** Douville, 1911

*Type species:* *Nummulites marginata* Michelotti, 1841

**Diagnosis:** A genus of the family Lepidocyclinidae characterised by a megalospheric embryonic apparatus consisting of a small circular to subcircular protoconch embraced to about half of its diameter by
a larger reniform deuteroconch; two principal auxiliary chambers and one or more adauxiliary chambers and arcuate, rhombic to spatulate equatorial chambers arranged in annuli.

**Distribution**: Cosmopolitan; Late Eocene - Middle Miocene.

**Occurrence in Kutch**: In the present material it has been observed only in random thin sections of rocks of the Ber Moti Member of Maniyara Fort Formation exposed in the Guvar Stream section near Guvar village. Here it is restricted to the Late Oligocene. Only two species have been identified:

1. **Nephrolepidina morgani** (Lemoine & Douville) and
2. *N. sp.*

**Nephrolepidina morgani** (Lemoine & Douville), 1904
(Pl. 42, Figs. 5-6; Pl. 63, Figs. 1, 5-7)

1904 *Lepidocyclina morgani* Lemoine & Douville, p. 17-18, pl. 2, fig. 4; pl. 3, fig. 2.
1924 *Lepidocyclina* (Nephrolepidina) *morgani* (Lemoine & Douville); Vaughan, p. 798.
1925 *Lepidocyclina* (Nephrolepidina) *morgani* (Lemoine & Douville); Douville, p. 80.
1926 *Lepidocyclina* (Nephrolepidina) *morgani* (Lemoine & Douville); Yabe & Hanzawa, p. 45, pl. 1, fig. 6.

**Material**: Only four equatorial sections and four vertical sections of megalospheric form were examined in random thin section of rocks.

**Description**: In equatorial section the embryonic apparatus is typically nephrolepidine and medium in size (Pl. 42, Fig. 6; Pl. 63,
Figs. 1, 5-7). The subcircular protoconch is partly embraced by the
crescentic deuteroconch which is larger than the protoconch. The
separating wall is convex outwards. Feriembryonic chambers are
narrow and very notably in shape. The two primary auxiliaries are
markedly elongated. The protoconchal auxiliaries are arcuate while
those on the deuteroconch are mostly spatulate in shape. The equa­
torial chambers are mostly rhombic in shape (Pl. 63, Figs. 1, 5-7)
and arranged in concentric rings. They alternate in adjacent rings
and increase in size and growth.

In vertical section (Pl. 42, Fig. 5) the embryonic apparatus
is small to medium in size and elliptical in outline. The equatorial
chamber layer is thin near the centre and increases in height with
ontogeny. The lateral chambers are open, rectangular. They are sepa­
rated by relatively thin roofs and floors and are arranged in regular
tiers. The pillars are distinct and uniformly distributed throughout
the section (Pl. 42, Fig. 5).

Measurements: In equatorial section the diameters of the proto­
conch are 125x150 μm and those of deuteroconch are 100x262 μm.
The distance across both the embryonic chambers is 250 μm. The
outer wall of the embryonic apparatus is 25 μm thick. In vertical
sections the thickness of the equatorial chamber layer varies from
12 μm to 24 μm. There are about twelve to fourteen lateral chambers
on each side of the embryonic apparatus. The length of the lateral
chambers varies from 31 μm to 68 μm and the height from 6 μm to
18 μm. The thickness of the roofs and floors varies from 6 μm to
9 μm.
Remarks: *N. morgani* was originally described by Lemoine & Douville (1904) from South Spain as a *Lepidocyclina* characterised internally by a nephrolepidine megalospheric embryonic apparatus and externally by several prominent umbonal pustules. Since then the species has been reported and discussed by workers on Mid-Tertiary larger foraminifera of the Mediterranean region. Among later authors there was a tendency to use the trivial name *morgani* for all *Nephrolepidina* population of the southern Europe - Mediterranean region which are phylogenetically intermediate between *N. praemarginata* (Douville) and *N. tournoueri* (Lemoine & Douville). According to these authors there is only one lineage of European *Nephrolepidina* consisting of three successive species, *N. praemarginata*, *N. morgani* and *N. tournoueri*. A systematic account of these species has recently been provided by de Mulder (1975) supported by illustrations of the specimens of these three species of *Nephrolepidina* from their respective type areas in southern Europe. Morphologically and stratigraphically the present material is very close to the specimens of *N. morgani* from the type area figured by de Mulder (1975).

Distribution: Lemoine & Douville (1904) first described it from Guadalquivir Basin in southern Spain. It is widely distributed in southern Europe - Mediterranean region where it is considered to range from Chattian to Aquitanian. In Kutch, the species occurs in the Ber Moti Member of the Maniyara Fort Formation exposed in the Guvar area. Here, it is restricted to the *Spiroclypeus ranjanae* Zone of Late Oligocene age.
Nephrolepidina sp.  
(Pl. 42, Fig. 4)

Material: Only one vertical section of megalospheric specimen was studied in random thin section of rocks.

Description: The embryonic apparatus is small with subparallel sides (Pl. 42, Fig. 4). The equatorial chamber layer is very thin and varies little in height. The lateral chambers are open, rectangular between very thin straight roofs and floors and are arranged in regular, compact tiers. The pillars are distinct and distributed throughout the section. They are more prominent over the embryonic apparatus (Pl. 42, Fig. 4).

Measurements: The height of the equatorial chamber varies from 35 m μ near centre to 71 m μ at the periphery. There are about eight to nine lateral chambers on each side of the embryonic apparatus. The length of the lateral chambers varies from 35 m μ to 214 m μ and the height from 25 m μ to 71 m μ. The thickness of the roofs and floors ranges from 6 m μ to 9 m μ.

Remarks: The present form differs from the specimens identified here as N. morgani (Lemoine & Douville) by its smaller test; flattened, smaller embryonic apparatus and thinner equatorial chamber layer. It is provisionally separated as N. sp. in the present work. More material is needed for a precise identification.

Distribution: It is a rare form occurring in the Ber Moti Member of the Maniyara Fort Formation exposed in Guvar Stream section near Guvar village. Here, it is restricted to Late Oligocene Spirolypeus ranjanae Zone.