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BIOMETRIC STUDY OF SOME EOCENE *NUMMULITES* AND *ASSILINA* FROM KUTCH AND JAISALMER, INDIA

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ABSTRACT

The sedimentary successions of Eocene age in the western part of India contain two stratigraphically important larger foraminiferal genera, *Nummulites* and *Assilina*. In spite of their biostratigraphic value, the taxonomic status of many species of the two genera is still debated. This is due to a lack of data on intraspecific variations and absence of objective discriminating criteria for closely resembling taxa. The present study documents nineteen species of *Nummulites* and five species of *Assilina* from Kutch and Jaisalmer. Their biometric data are provided and they are illustrated with scanning electron micrographs. The factor analysis of the morphological data has shown that the variables related to test size, namely diameter, thickness and number of whorls are controlled by one factor while the variables related to chamber size, namely height and length of chambers and diameter of proloculus are controlled by the other. It is inferred that the first factor is the influence of environment and the second is palaeobiological, especially in response to endosymbionts.

INTRODUCTION

In the Cenozoic, tropical, shelf carbonates, larger foraminiferal genera *Nummulits* and *Assilina* are dominant in the Palaeogene period and most diverse in the Eocene, often occurring in rock-building quantity, forming the famous "nummulitic limestones". Their abundance, rapid evolution and abrupt extiniction as well as sensitiveness to habitat envrionment have made them useful in biostratigraphy and palaeoenvironmental interpretations. Many species of *Nummlites* and *Assilina* have been used as index fossils and they are proved to be biostratigraphically important, especially where planktic foraminifera and calcareous nannoplankton are poorly developed or ill-preserved. A large number of such species have been reported from Kutch and Rajasthan. However, the description of these species as well as those from other parts of India are largely qualitative in nature, where external and internal characters are qualitatively compared with the holotypes. Lack of precise definitions of species often makes it difficult to distinguish between morphologically less distinct species. This is one of the reasons why some of the species reported from this region are still debatable. A biometric approach with quantification of morphological parameters, emphasising populatoin variability is necessary for understanding biostratigraphic and palaeoecological importance of these groups. The importance of this approach has become more obvious in recent years when palaeontology is increasingly relying on statistical analysis of morphometric data making it more amenable to computer handling. In the present paper, 19 species of *Nummulites* and 5 species of *Assilina* from the Eocene sections of Kutch and Jaisalmer are described with their biometric data. These are the most commonly occurring species from this region for which sufficiently good number of specimens were available for biometric study.

AREA OF STUDY

The study area includes Kutch district of Gujarat and Jaisalmer district of Rajasthan. In Kutch, it falls under the Survey of India toposheet No. 41A/10 and 41A/11. The traverses were taken along Berwali River from Harudi to Bermoti (23° 26'N 68° 41'E-23° 30'N, 68° 37'E) and the scarp section near Naredi (23° 32'N, 68° 38'E). In Jaisalmer district, the field areas are near Khuiala village (27° 11'N, 70° 22'E) which falls under the toposheet No. 40 I/8. The location and geological maps of the study areas are given in fig. 1. Stratigaphically, the Kutch section is referred to the Naredi Formation, Harudi Formation and Fulra Limestone. The Eocene rocks of Jaisalmer are referred to the Khuiala Formation.

* Deceased on 22.08.1997

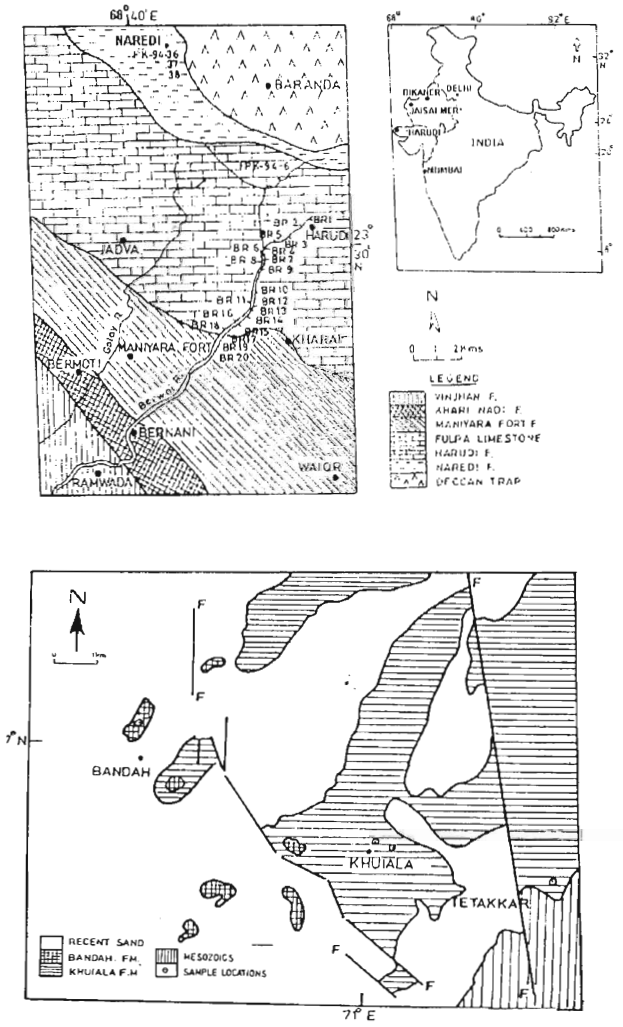

Fig. 1. Location and geological map of the areas of study (after Tandon, 1976; Singh, 1984).

Additional materials were collected from Madh (Bikaner district), where the section is referred to the Kolayat Formation. The stratigraphic columns of the examined sections are given in fig. 2.

METHODOLOGY

The processed samples were examined under a stereozoom binocular microscope to pick the specimens of *Assilina* and *Nummulites*. Later, based on external morphology, the specimens were separated into different morphotypes. Up to 40 good specimens from each morphotype were selected, stored in punch slides and indexed by OTU (Operational Taxonomic Unit) Numbers. Some of the morphotypes were sparsely represented in the sample and in view of this they were not further considered for biometric study. For morphometric measurements about 25 equatorial sections and 5 axial sections of each of the morphotypes were prepared. The diameter and thickness of the test were measured with the help of vernier callipers before preparing sections. The length and height of chambers, diameter of protoconch and thickness of marginal cord were measured in equatorial sections under Wild M8 stereozoom binocular microscope with the attachement of digital length measuring set. Number of whorls and chambers were counted under the microscope. The details about the biometric parameters are discussed later. The minimum, maximum and mean values and standard deviation for each variables were computed for different morphotypes separately. Spiral diagrams of the morphotypes were prepared by plotting the distance of each whorl from the center of the test against the whorl number. Similar plots were made for number

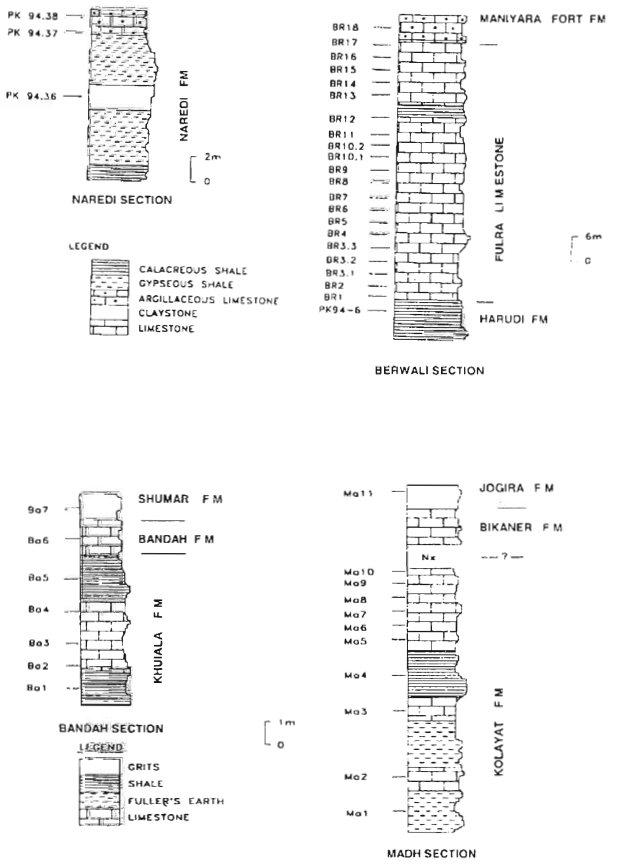

Fig. 2. Stratigraphic column of the examined sections in Kutch and Rajasthan.

of chambers also. Partial correlation and R-mode Factor analyses were done using STATGRAF package to find out the relationship among the variables. The data sets were normalised before analyses.

The external and equatorial views of the described species are photographed in JEOL JSM 840 A scanning electron microscope. For axial sections and equatorial sections of some recrystallised species, thin sections were prepared and photographed under optical miroscope. The species described in this study are illustrated in Plates II-VIII. In addition, it also illustrates some other species which are recorded in this study but whose detailed biometry could not be done due to limited number of specimens. The distribution of species in Berwali section in Kutch is shown in table 1. All the OTUs and assemblage slides (No. IITB/96-1 to IITB/96-560) are stored in the Microbiostratigaphy Laboratory of the Department of Earth Sciences, IIT, Bombay.

MORPHOLOGICAL PARAMETERS

Consistent methods of counting and measuring has been followed for numerical expression of the morphological data. The following eight morphological parameters have been measured for each species. These parameters are shown in Plate-I. The minimum, maximum and mean values of these parameters and their standard deviations (SD) for each species are given in systematics.

D : Maximum diameter of the test.

T : Maxmium thickness of the test at the pole.

LI : Length of the third chamber (initial chamber of first whorl).

HI : Height of the third chamber.

LL : Length of the largest chamber in the last whorl. In most cases the chambers are rectangular and length does not vary from base to top of the chamber. For trapezohedral chambers, the measurements have been taken at the the central part.

HL : Height of the chamber in the last whorl for which length has been measured.

M : Thickness of marginal cord of the last spire. Where the marginal cord is not well developed or preserved, it has been measured at the penultimate whorl. Where the thickness is varying, measurement was taken at the thickest portion of the cord.

Tables 1. Distribution of species of *Nummulites* and *Assilina* in the Fulra Limestone, Berwali section, Kutch.

	BR 1	BR 2	BR 3.1	BR 3.2	BR 3.3	BR 4	BR 5	BR 6	BR 7	BR 8	BR 9	BR 10	BR 11	BR 12	BR 13	BR 14	BR 15	BR 16	BR 17
N. acutus	C	C	C	C	C	C	C	C	C	A	A	C	C	C	C	C	C	C	C
N. beaumonti								R			C	R				R			
N biarritzensis															R	C	R		
N. cuvillieri	C	C	C	A	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
N. discorbinus		R										C					R	C	C
N. maculatus															R	A	A	A	C
N. neglectus																		C	C
N. orbignyi																		R	R
N. pengaronensis	C	C	A	A	A	C	C	C	A	A	C	A	C	C	C	C	C	C	C
N. pinfoldi																		C	C
N. praediscorbinus	C	C	C	A	C	C	C	C	A	C	C	C	A	C	A	C	C	C	C
N semiglobuls																R			
N. stamineus																C	C	C	C
N. variolarius																			R
N. vicaryi															C	R			
N. vohrai	C	R													C	R			
A. exponens	VA	C	C																

C- Common : 10-20 specimens VA-Very abundant : > 50 species
A- Abundant : 20-50 specimens --- Not found

P : Protoconch diameter. The diameter of the proloculus for megalospheric forms is measured along a line at right anlges to the line passing through the centres of the first and second chamber.

W : Number of whorls. The first whorl has been considered from the third chamber till one volution.

The ratio of diameter to thickenss (D/T) and chamber length to chamber height (LI/HI and LL/HL) are computed to describe the shape of the test and chamber respectively. The statistical parameters including minimum, mean and standard deviation values for the measured specimens for each variables are given for all the species. The histograms of the measured variables for some of the species are shown in figs. 3-7 and for the remaining species it may be obtained from one of the authors (PKS). Distance of each successive whorl from the centre (Rn) has been meaured and number of chambers in each whorl (Cn) are counted. The minium and maximum values within the studied individuals have been used to plot the spiral diagrams showing the possible range of variation (figs. 8-12).

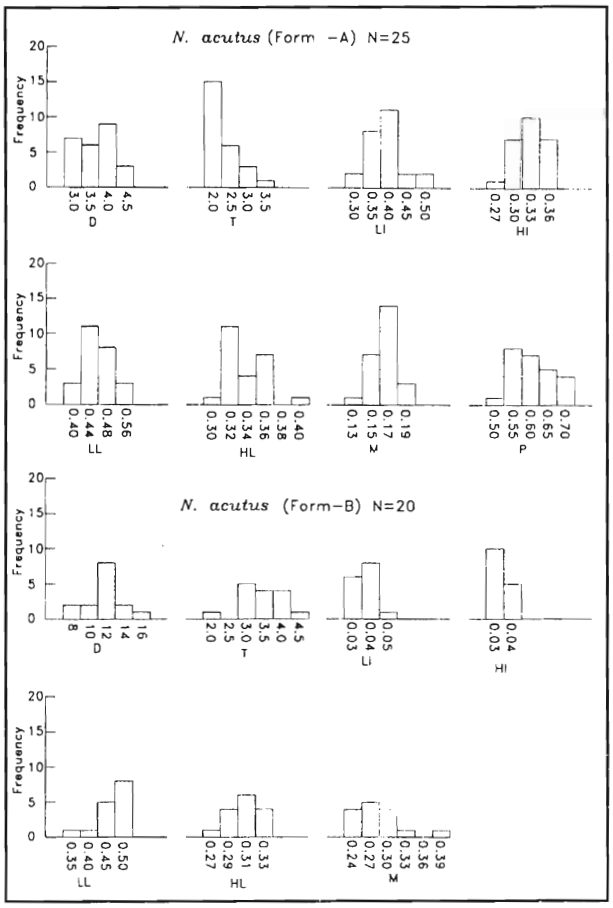

Fig. 3. Histograms of morphological parameters of *N. acutus*.

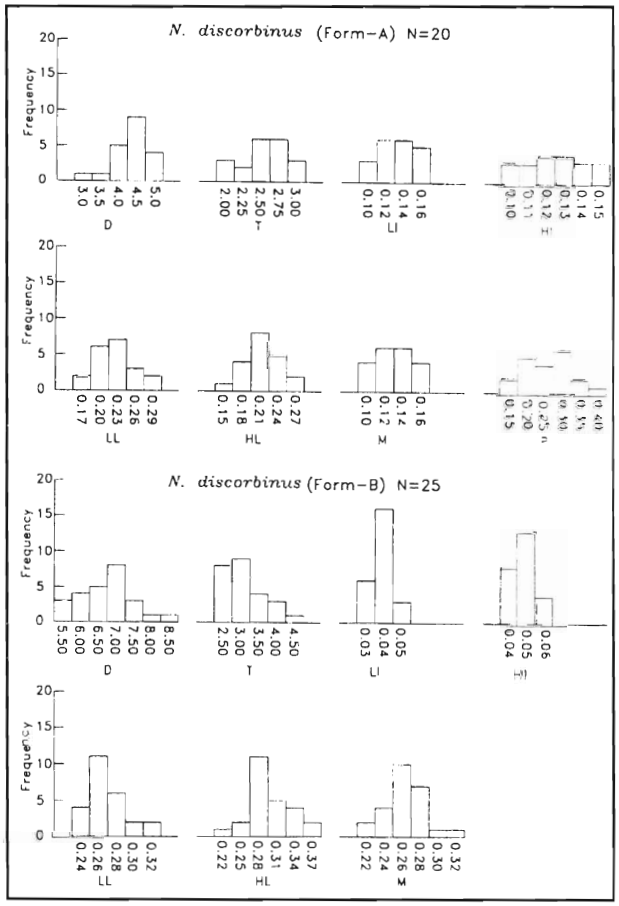

Fig. 4. Histograms of morphological parameters of *N. discorbinus*.

SYSTEMATIC PALAEONTOLOGY

Order **Foraminiferida** Eichwald, 1830

Suborder **Rotaliina** Delage and Herouard, 1896

Superfamily **Rotaliacea** Ehrenberg, 1839

Family **Nummulitidae** de Blainville, 1827

Genus ***Nummulites*** Lamarck, 1801

Type species: *Camerina laevigata* Bruguie're, 1792. p.399; SD ICZN, 1945, Op. 192.

Nummulites Lamarck, 1801, p. 101 (nom. consev.; ICZN, 1945, Op 192, P. 154)

Nummulites includes hundreds of species with varying but gradational morphological characters. Test is flattened discoidal to lenticular and even

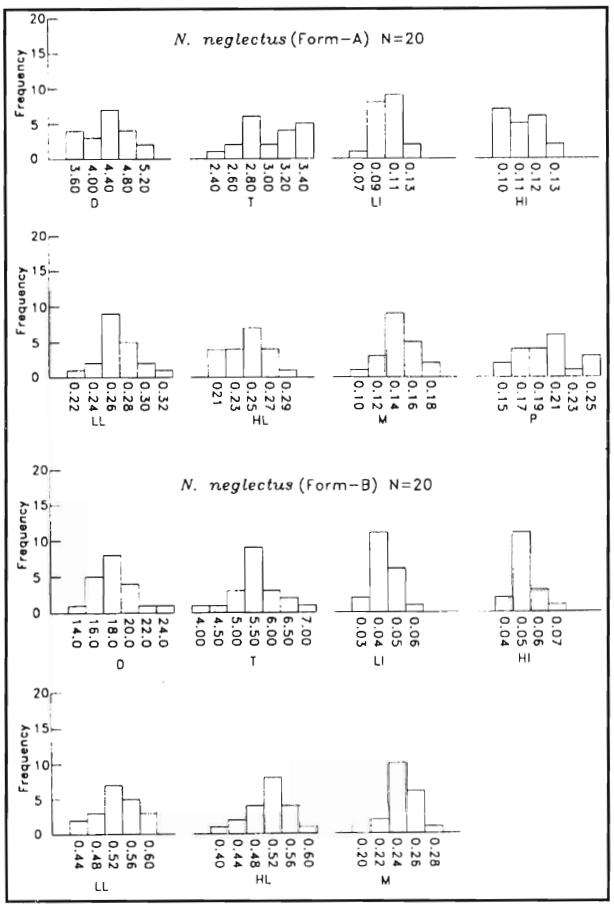

Fig. 5. Histograms of morphological parameters of *N. neglecuts.*

globular. Test size varies from less than 1mm to above 120 mm. Although commonly involute test a few species show evoluteness in later whorls; Dimorphism due to different mode of reprodcution is common. The degree of dimophism is more pronounced in large species, sometimes making it difficult to identify the two generations of the same species. In some species, trimorphism has also been detected (Matsumaru, 1996). The test may be smooth or granulated. The size and nature of arrangement of granules are of specific character. The extensions of septa over the lateral surface, called the septal filaments, vary from straight radial to meandriform and sigmoidal. In the Oligocene species, they become reticulate with branching. Proloculus and second chamber are separated by an imperforate common wall with a single central pore and with a row of pores at the base of the septum. The proloculus and second chamber may be of equal size (isolepidine forms) or the second chamber may be small (anisolepidine form). The second chamber tends to be larger than the third. Later chambers are simple and undivided, numerous chambers per whorl, chamber shape rectangular to isometric; septa straight to curved at the periphery; distinct marginal cord on the periphery; Marginal canal with a network of elongate meshes, ramified sutural canals. Number of whorls vary from 2-3 to as many as 30 in large microspheric forms. In most of the species, the spire is regular, with gradual opening out. Most of the species are tightly coiled with low spire. In some advanced forms, intercalary whorls may be introduced by splitting of marginal cord. Trabeculae are present.

Nummulites acutus (Sowerby)

(Plate II, figs. 1,2,4,5,11, 14; Figs. 3, 8)

Nummularia acuta Sowerby, 1840, p. 329, pl.24, figs. 13-13a.

Nummularia acuta (Sowerby) Sen Gupta, 1965, p.87-89, pl.15, figs.

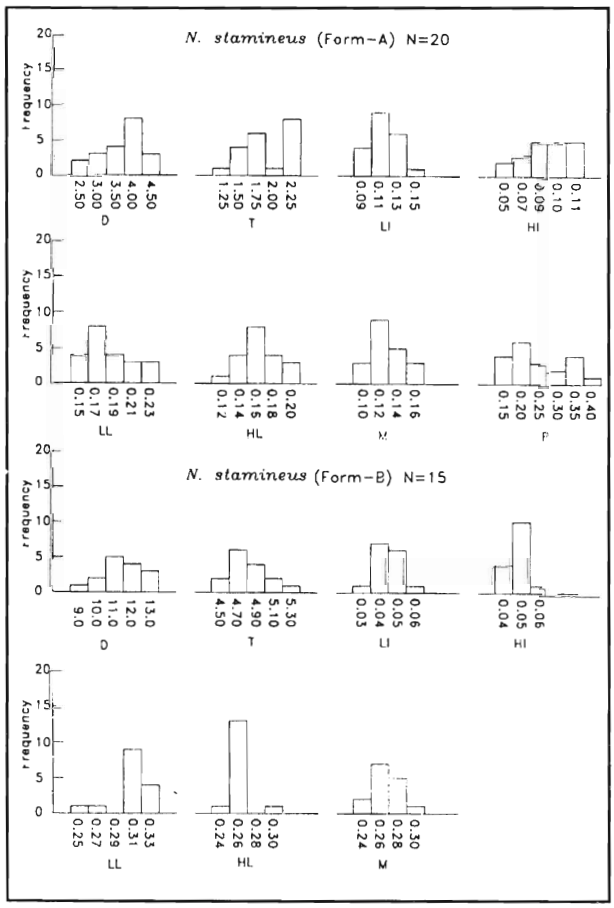

Fig. 6. Histograms of morphological parameters of *N. stamineus.*

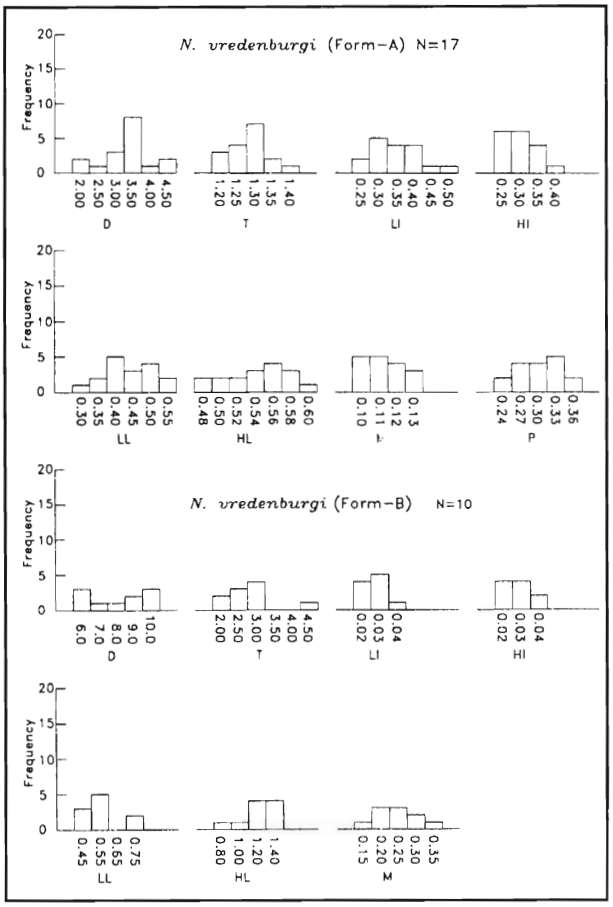

Fig. 7. Histograms of morphological parameters of *N. vredenburgi.*

3,7,9; pl.16, figs. 6,8; pl. 17, figs. 2,4,8,11. Blondeau 1972, p.242; pl. 35, figs. 10,11. Samanta, 1982 p.27-32, figs. 3-5. Samanta *et al.*, 1990, p.47, pl.12, figs. 1-6, pl.13, figs. 1-16. Racey, 1995, P.30, pl. 1, figs. 5-7,9.

The microspheric forms are medium sized (D=6.2-16.0mm), lenticular (D/T=2.5-4); surface granulated, curved to wavy, septal filaments branching and uniting irregularly to produce a subreticulate pattern on parts of the surface; spire regular, opening gradually, with the peripheral whorls in larger individuals narrower; septa slightly inclined, gently curved; chambers usually longer than high. The megalospheric forms are small (D=2.8-4.3 mm), lenticular to inflated lenticular (D/T= 1.2-2.0); a narrow, thin, sometimes undulating flange surrounding the pole; coarsely granulated than the micropsheric forms, granules more closely placed in inflated specimens; proloculus large (0.5 to 0.7mm).

Morphometric parameters in mm (15 specimens, B-Forms)

	D	T	LI	HI	LL	HL	M	D/T	LI/HI	LL/HL	W
Min.	6.20	1.86	0.03	0.03	0.35	0.27	0.23	2.56	0.75	1.25	7
Max.	16.00	4.23	0.05	0.04	0.50	0.33	0.37	3.99	1.67	1.67	15
Mean	10.63	3.18	0.04	0.03	0.45	0.30	0.27	3.35	1.13	1.49	
SD	2.24	0.57	0.01	0.00	0.04	0.02	0.04	0.36	0.27	0.12	

Morphometric parameters in mm (25 specimens, A-Forms)

	D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	2.82	1.72	0.29	0.26	0.39	0.30	0.13	0.50	1.25	1.00	1.08	3
Max.	4.32	3.28	0.48	0.35	0.54	0.40	0.18	0.69	2.08	1.45	1.61	4
Mean	3.46	2.12	0.37	0.32	0.44	0.34	0.16	0.59	1.65	1.16	1.33	
SD.	0.47	0.39	0.05	0.02	0.04	0.02	0.01	0.06	0.20	0.09	0.15	

Remarks: Nuttall (1926) considered *N. acutus* (Sowerby) as a senior synonym of *N. vredenburgi* Prever. Most of the later workers followed this concpet. Sen Gupta (1965) also had a similar view. A detailed examination of the lectotype of *N. acutus* and syntypes and topotypes of *N. vredenburgi* from Kutch led Samanta (1982) to treat them as distinct species. According to him, the two species belong

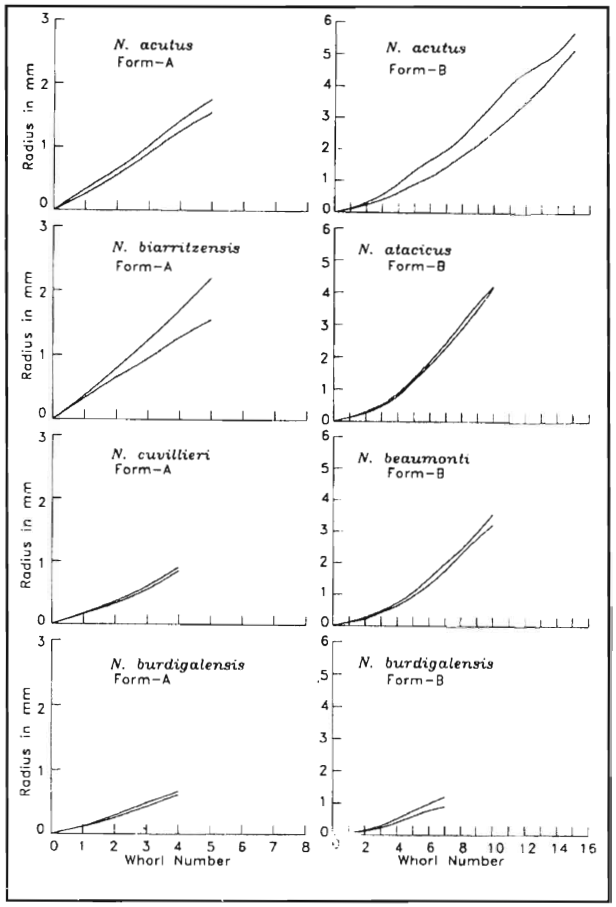

Fig. 8. Spiral diagrams of *N. acutus, N. biartizensis, N. cuvillieri, N. atacicus, N. beaumonti and N. burdigalensis.*

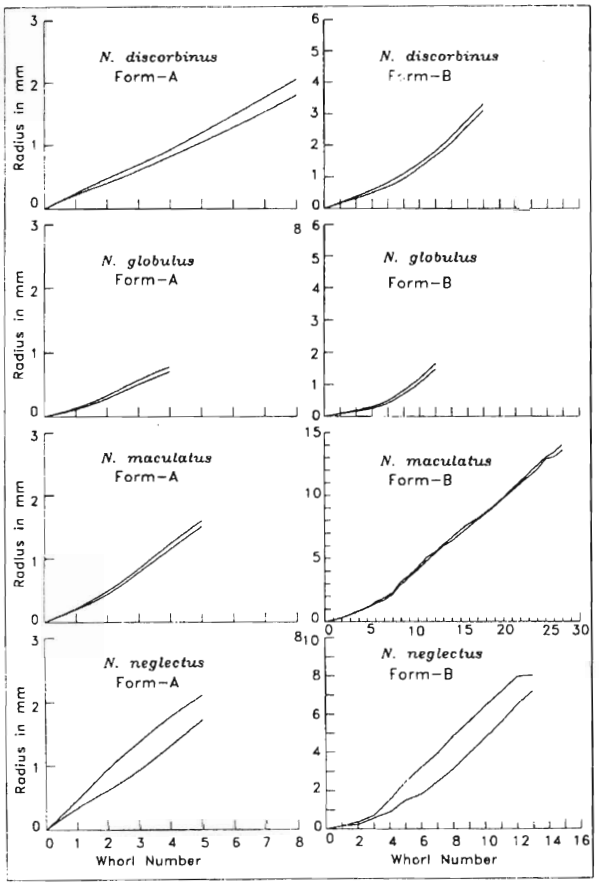

Fig. 9. Spiral diagrams of *N. discorbinus, N. globululs, N. maculatus and N. neglectus.*

to *N. laevigatus* group and have considerable morphological similarity. *N. vredenburgi*, however, is shown to differ from *N. acutus* by being large and thinner, having more sinuous septal filaments, prominent marginal cord, loosely coiled spire and higher than longer chambers. More recently, Racey (1995) considered *N. vredenburgi* as a junior synonym of *N. acutus*. In the present study, the two species are found to be distinct on biometric criteria.

Distribution : Fulra Limestone.

Nummulites atacicus Leymerie
(Pl. II figs. 3, 6; Fig. 8)

Nummulites atacica Leymerie 1846. p. 358. pl. 13. figs. 13a-e.

Nummulites atacicus Leymerie, Nuttal, 1925, p. 444-445, pl. XXV, figs. 1-6.- Schaub, 1981, p.18, table 14. fi. i; pl.25, figs. 1-51. - Racey, 1995, p.32, pl.2, figs. 18-20.

The microspheric forms are large (D=7.3-11.4mm); test lenticular (D/T=2.7-3.3), with thin sharp periphery, septal filaments closely spaced, straight to gently curved, radial; spire regular; chambers, fairly tight, regular and numerous, higher than long; septa thin, slightly inclined, straight, becoming slightly curved towards periphey; marginal cord uniformaly thin.

Morphometric parameters in mm (20 specimens, B-forms).

	D	T	LI	HI	LL	HL	M	D/T	LI/HI	LL/HL	W
Min.	7.31	2.88	0.03	0.03	0.32	0.49	0.14	2.71	0.60	0.75	8
Max.	11.39	3.42	0.06	0.06	0.53	0.62	0.20	3.34	1.00	0.90	15
Mean	9.01	3.23	0.05	0.04	0.46	0.55	0.17	3.02	0.85	0.80	
SD	0.98	0.13	0.01	0.01	0.05	0.04	0.02	0.21	0.14	0.12	

Remarks : It resembles *N. neglectus* and *N. biarritzensis.*

Distribution: Khuiala Formation.

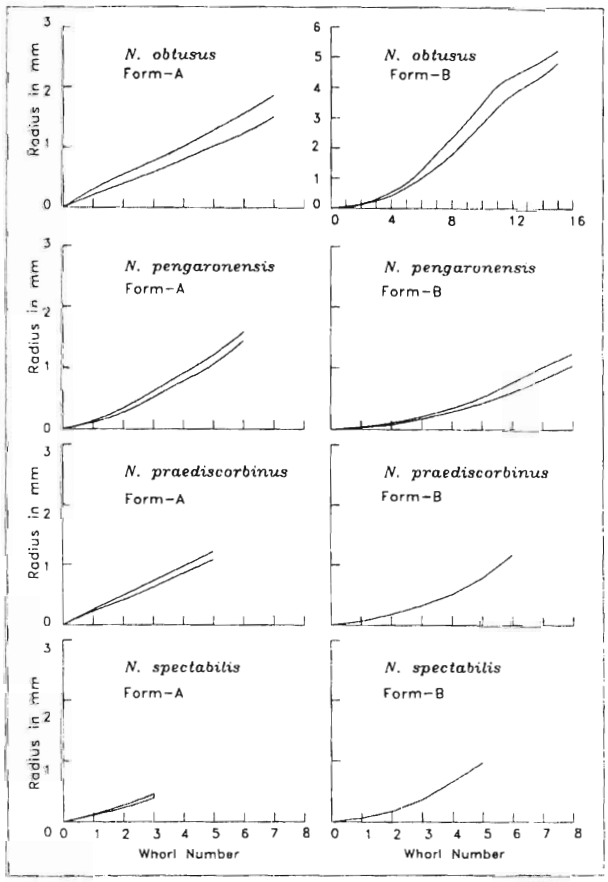

Fig. 10: Spiral diagrams of *N. obtusus, N. pengaronensis, N. praediscorbinus* and *N. spectabilis.*

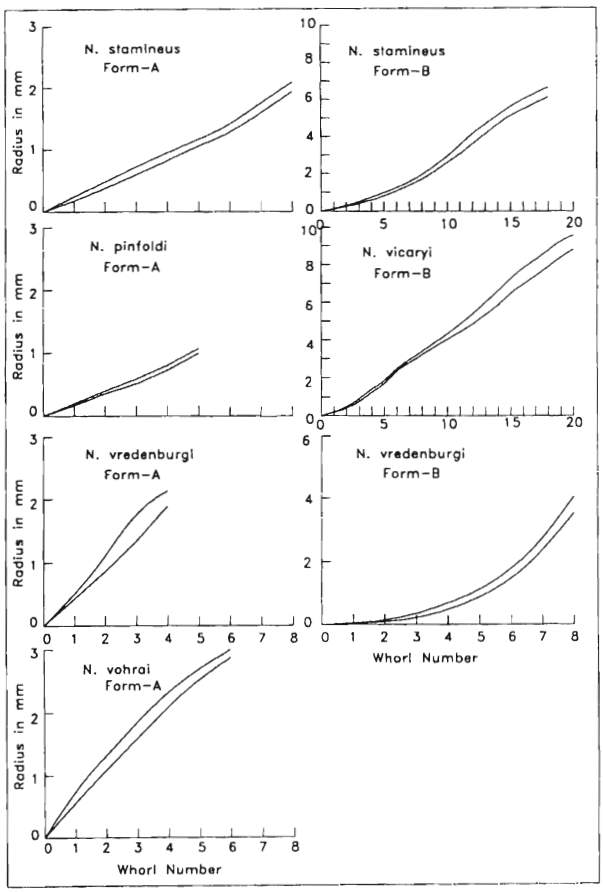

Fig. 11. Spiral diagrams of *N. stamineus, N. pinfoldi, N. vicaryi, N. vredenburgi* and *N. vohrai.*

*Nummulites beaumonti*d' Archiac and Haime (Pl.II, figs.12-13; Fig. 8)

Nummulites beaumonti d' Arachiac and Haime 1853, p. 133, pl.8, figs. 1a-e, 2,3. -Davies, 1940, p.206-209, pl. ix, figs. 1-9.- Schaub, 1981, p. 135, table 14, pl.53, figs. 17-19, 22-25.- Samanta *et al.* 1990, p.21, pl.2, figs. 7-11, pl.5, figs, 10-11.-Racey, 1995, p.34-35, pl.5, figs. 15-17,19

The microspheric forms are small to medium sized (D=3.8-11.8), test lenticular (D/T 1.9-4.2); sharp to genly rounded periphery; septal filaments often show a distinct polar twist; polar pillar sometimes present, though large specimes are evenly convex; spire regular, failry loose; (10 whorls in a radius of 6mm); chambers subrectangular, isometric to longer than high in later whorls; septa straight, perpendicular to slightly inclined; marginal cord of fairly uniform thickness. The megalospheric forms are not found.

Morphometric parameters in mm (20 specimens, B-forms)

	D	T	LI	HI	LL	HL	M	D/T	LI/HI	LL/HL	W
Min.	3.80	1.24	0.03	0.09	0.2 6	0.25	0.13	1.90	0.30	).87	9
Max.	11.80	3.90	0.05	0.11	0.42	0.33	0.24	4.18	0.45	1.45	13
Mean	7.06	2.45	0.03	0.10	0.35	0.29	0.20	2.91	0.36	1.20	
SD	2.14	0.61	0.01	0.01	0.03	0.02	0.02	0.56	0.06	0.13	

Remarks: While describing *N. beaumonti* from Kutch, Sen Gupta (1965) treated it as a synonym of *N. stamineus* and *N. pengaronensis*. However, his figured microspheric specimens resemble more with *N. neglectus* and *N. stamineus* than with *N. beaumonti. N. pengaronensis* is a morphologically distinct species. *N. stamineus* is more inflated and have radial septal filaments, tightly coiled with more number of chambers. *N. beaumonti* can be differentiated from *N. neglectus* by its smaller test size and by shape and size of chambers.

Distribution : Fulra Limestone.

Nummulites biarritzensis d'Archiac and Haime (Pl.III, figs. 1, 2, 12; Fig. 8)

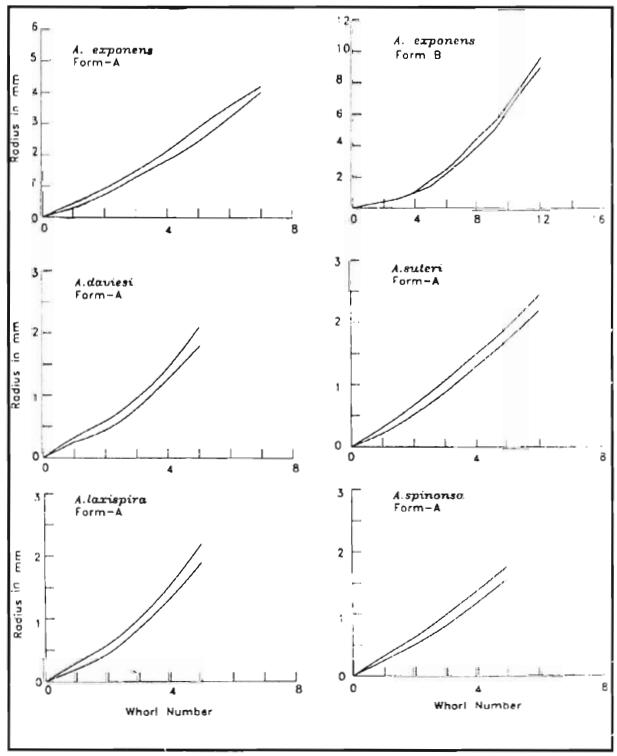

Fig. 12. Spiral diagrams of *A. exponens, A daviesi, A. suteri, A. laxispira* and *A. spinosa.*

Nummulites biarritzensis d'Archiac and Haime, 1853, p.131-133, pl.8, figs. 4b-c,6a.-Schaub, 1981, p.123, table 15, pl. 51, figs. 30-46. Samanta *et al* . 1990, p.30, pl.6, figs. 7-9.-Racey, 1995, p.35-36, pl. 3, fis, 13-14, 18-19.

The megalospheric forms are small (D=2.0-4.2mm), inflated lenticular (D/T=1.3-2.1), septal filaments thick, radiating from well-marked polar pustules; spire regular, increasing in height; marginal cord thick; septa inclined, curved.

Morphometric parameters in mm (15 specimens, A-forms)

	D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	1.98	1.06	0.12	0.16	0.23	0.21	0.11	0.29	1.30	0.65	1.00	3
Max.	4.15	2.01	0.18	0.23	0.41	0.35	0.18	0.41	2.09	0.90	1.50	6
Mean	2.68	1.54	0.16	0.20	0.32	0.27	0.14	0.35	1.77	0.81	1.20	
SD	0.60	0.35	0.01	0.02	0.06	0.04	0.02	0.03	0.24	0.08	0.14	

Remarks : It resembles *N. discorbinus* and *N. beaumonti* externally. However, it can be differentiated from them in equatorial section by its loose coiling and less number of chambers.

Nummulites burdigalensis (de la Harpe)
(Pl.II , figs. 7-10, 15; Fig. 8)

Nummulites burdigalensis (de la Harpe) Schaub, 1951, pp 1-222, pl. 1, fig 13-15, 16a, 17a-b.- Blondeau, 1972 p. 159, pl. XXXII, figs. 11-14.- Schaub, 1981, p.79-80, pl.5, figs. 1-51

The microspheric forms are small (D=1.4-2.5mm); test inflated, lenticular (D/T=1.7-2.3) with central depression; acute margin; large pustules cover the central zone; sharp radiating and branched septal filaments; pustules on septal filaments., septa almost perpendicular in the eariler chambers but curved in the later; chambers radially elongated and rectangular; in axial section, distinct alar prolongation, wavy outline; thin evenly distributed pillars. The megalospheric forms are slightly smaller (D=0.7-1.4mm) and similar to the microspheric forms in all respects; proloculus small (0.06-0.10 mm).

Morphometric parameters in mm (20 specimens, B-forms)

	D	T	LI	HI	LL	HL	M	D/T	LI/HI	LL/HL	W
Min.	1.43	0.76	0.01	0.01	0.09	0.10	0.06	1.70	0.50	0.52	4
Max.	2.54	1.32	0.02	0.02	0.22	0.31	0.10	2.26	2.00	1.00	6
Mean	1.92	0.98	0.01	0.01	0.18	0.22	0.08	1.95	1.08	0.82	
SD	0.33	0.16	0.00	0.00	0.03	0.05	0.01	0.14	0.58	0.13	

Morphometric parameters in mm (20 specimens, A-forms)

	D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	0.71	0.46	0.05	0.05	0.10	0.10	0.04	0.06	1.42	0.75	0.75	2
Max.	1.37	0.78	0.09	0.08	0.19	0.16	0.07	0.10	2.23	1.50	1.21	4
Mean	1.03	0.58	0.07	0.07	0.14	0.14	0.06	0.08	1.77	1.03	1.00	
SD	0.22	0.10	0.01	0.01	0.02	0.02	0.01	0.01	0.21	0.18	0.12	

Remarks : It can be differentiated from *N. globulus* by its granulation.

Distribution : Naredi Formation.

Nummulites cuvillieri Sander
(Pl. III, figs. 4, 5, 7-8; Fig. 8)

Nummulites cuvillieri Sander 1962, p.12, pl.I, figs. 1-13.-Samanta *et al.*, 1990, p.54-55, pl. 16, figs. 1-15.-Racey, 1995, p.40-41, pl. 1, figs. 17,19-21.

The megalospheric forms are very small (D 1.3-1.7mm), inflated lenticular (D/T=1.9-2.5) with a small central depression and a fairly rounded periphery; granules are distributed irregularly over much of the test surface and are generally coarser towards the poles; septal filaments obscured by coarse granules but generally sinuous; spire regular, opening slowly; chambers slighlty curved, becoming more isometric in the outermost whorl; septa fairly thick, inclined, sometimes gently curved; marginal cord approximately1/3 chamber height; proloculus small (0.04-0.08mm), oval; in axial section, the first three whorls are regular, involute and have well-developed alar prolongations; outer whorls often broken, incompletely involute; large granules concentrated towards a polar depression. The microspheric foms are rare and slightly larger and similar in other respects to megalospheric forms.

Morphometric parameters in mm (20 specimens, A-forms)

	D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	1.30	0.68	0.05	0.04	0.15	0.12	0.04	0.04	1.85	1.06	1.00	4
Max.	1.92	0.84	0.06	0.06	0.23	0.19	0.07	0.08	2.51	1.47	1.25	5
Mean	1.69	0.77	0.05	0.05	0.19	0.16	0.06	0.07	2.20	1.21	1.07	
SD	0.18	0.04	0.00	0.01	0.02	0.02	0.06	0.01	0.18	0.10	0.10	

Remark : This species occurs throughout the Fulra Limestone and is easily distinguished by its central depression.

Distibution: Fulra Limestone.

Nummulites discorbinus (Schlotheim)
(Pl. III, figs. 9,13,14,16, 18; Figs. 4, 9)

Lenticulites discorbinnus Scholotheim, 1820, p.89.

Nummulites discorbinus (Schlotheim)- Blondeau, 1972, p.47, pl.18,

figs. 15-20.- Schaub, 1981, p. 134, pl.52, figs 51-68.- Samanta *et al.* 1990, p.15-16, pl. 2, figs. 12-22, pl.5, fig. 1-12.-RACEY, 1995, p. 41-42, pl. 2, figs. 29-31.

The microspheric forms are medium sized (D= 5.2-8.2mm); test inflated lenticular (D/T=1.5-2.0) with a rounded periphery; septal filaments radiating, straight to gently curved; spire is regular, tightly coiled; marginal cord thick, chambers higher than long to longer than high, slightly arcuate; septa slightly inclined; last few whorls sometimes more tightly coiled. The megalospheric forms are medium (D= 2.9-4.8mm); inflated, lenticular (D/T= 1.5/1.9); proloculus small (0.14-0.38mm). Other characters same as that of microspheric forms.

Morphometric parameters in mm (25 specimens, B-forms)

	D	T	LI	HI	LL	HL	M	D/T	LI/HI	LL/HL	W
Min.	5.21	3.33	0.03	0.04	0.23	0.22	0.22	1.54	0.50	0.78	10
Max.	8.22	4.32	0.05	0.06	0.31	0.36	0.31	1.98	1.25	1.18	13
Mean	6.46	3.66	0.04	0.05	0.26	0.29	0.26	1.76	0.82	0.93	
SD	0.72	0.25	0.01	0.01	0.02	0.03	0.02	0.11	0.17	0.09	

Morphometric parameters in mm (20 specimens, A-forms)

	D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	2.89	1.90	0.09	0.10	0.16	0.14	0.09	0.14	1.50	0.77	0.83	5
Max.	4.81	2.82	0.16	0.15	0.27	0.26	0.16	0.38	1.96	1.27	1.21	9
Mean	4.12	2.43	0.13	0.12	0.21	0.24	0.12	0.25	1.70	1.02	1.04	
SD.	0.46	0.30	0.02	0.02	0.03	0.03	0.02	0.0	0.13	0.11	0.11	

Remarks : The description of *N. discorbinus* from Kutch by Samanta *et al.* (1990) is the first illustrated account from India. Racey (1995) has treated it as a senior synonym of *N. stamineus* which, according to Samanta *et al.*(1990) belong to the same lineage. The comparison between the two are discussed under the remarks of *N. stamineus.*

Distribution: Fulra Limestone.

Nummulites globulus Leymerie
(Pl. III, figs. 3, 6, 10; Fig. 9)

Nummulites globulus Leymerie, 1846, p. 27, pl. 13, figs. 1401-d.-Schaub 1981, p. 137, pl. 40, figs 1-80.

The megalospheric forms are very small (D=0.7-1.4mm), inflated, lenticular with a sharp periphery; closely spaced radial septal filaments; spire regular; chambes higher than long; slighlty curved septa; small proloculus. The microspheric forms are slightly larger and similar in all other aspects.

Morphometric parameters in mm (10 specimens, B-forms)

	D	T	LI	HI	LL	HL	M	D/T	LI/HI	LL/HL
Mi.	1.45	0.72	0.03	0.03	0.15	0.14	0.09	1.84	0.60	0.83
Max.	2.10	1.02	0.05	0.05	0.19	0.21	0.13	2.24	1.33	1.13
Mean	1.80	0.89	0.04	0.04	0.17	0.16	0.11	2.03	0.97	1.06
SD.	0.21	0.09	0.01	0.01	0.01	0.01	0.01	0.12	0.21	0.36

Morphometric parameters in mm (20 specimens, A-forms)

	D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL
Min.	0.74	0.49	0.06	0.09	0.13	0.14	0.09	0.06	1.25	0.77	0.63
Max.	1.43	1.02	0.09	0.13	0.17	0.21	0.12	0.17	1.96	1.00	0.93
Mean	1.15	0.73	0.08	0.11	0.15	0.18	0.11	0.14	1.70	0.87	0.84
SD.	0.26	0.18	0.02	0.02	0.03	0.03	0.02	0.04	0.13	0.11	0.11

Remarks : It can be differentiated from *N. burdigalensis* by the absence of granules.

Distribution : Naredi Formation.

Nummulites maculatus Nuttall
(Pl. III, figs. 11, 15, 17; Pl. IV, figs. 1, 6; Fig. 9)

*Nummulites maculatus.*Nuttall, 1926, p. 140-141; pl.4, figs. 2-6.-Tandon, 1976, p. 79-80, pl.2, figs. 2-9.-Samanata, 1981b. p. 15, pl.1, figs., 1,2; pl.2, fig.2; pl 3, figs..5,6,pl.4, figs. 1-3,.-Samanta *et al.* 1990, p.53-54, pl. 14, fig. 8, pl. 15, figs. 1-9.-Racey, 1995, p. 52-53, pl. 6, figs, 10, 12.

The microspheric forms are large (D=24-38mm), flattened, lenticular to flat (D/T= 4.4-9.0); slightly undulating, with a fairly sharp margin; septal filaments thin, meandriform, occasionally forming a faint subreticulate network; fine granules on and between septal filaments; spire initialy regular, fairly tight for 5-6 whorls then loose and slighlty irregular; outer 5-6 whorls very tightly coiled; three to four intercalary whorls are developed in the middle to outer part of the spire; 20 to 30 whorl; chambers subrectangular, septa fairly compact, straight to slighlty curved; often thinner in the middle and outer whorls due to the introduction of intercalary whorls in the middle whorls, and and formation of thinner more closely appressed whorls in the outer part of the spire; marginal cord notably thick, up to 2/3 of the chamber height. The megalospheric forms are small (D=2.6-3.7mm), inflated; spirally arranged granules along the thin septal filaments; large proloculus (0.3-0.4mm); rapidly opening spire.

Morphometric parameters in mm (15 specimens, B-forms)

	D	TLI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	24.00	2.86	0.04	0.04	0.37	0.26	0.20	4.41	0.71	1.08	22
Max.	38.00	5.74	0.06	0.07	0.52	0.43	0.35	9.05	1.25	1.75	30
Mean	28.28	4.61	0.05	0.05	0.46	0.34	0.26	6.20	1.00	1.37	
SD.	3.99	0.48	0.01	0.01	0.05	0.04	0.05	1.13	0.17	0.20	

Morphometric parameters in mm (16 specimens, A-forms)

	D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	2.45	1.23	0.18	0.14	0.30	0.21	0.09	0.32	1.30	1.14	0.92	4
Max.	3.65	2.64	0.32	0.28	0.40	0.38	0.18	0.53	2.72	2.13	1.71	5
Mean	3.12	1.95	0.27	0.19	0.36	0.27	0.14	0.49	1.66	1.42	1.36	
SD.	0.35	0.40	0.04	0.04	0.03	0.04	0.02	0.20	0.43	0.27	0.18	

Remarks : Tandon (1976) and Samanta (1981b) have considered *N. maculatus* as a granulated species. However, in the present material from Kutch, granules are absent to faintly developed in the microspheric forms. *N. maculatus* is the second largest species of *Nummulites* from India, next only to *N. vohrai* which also occurs in the same horizon. Besides size, the two species also differ in their equatorial sections. In *N. vohrai,* septa are more curved and chamber height is higher than *N. maculatus*. The megalospheric forms of *N. maculatus* was first described by Samanta (1981b) and the present material is identified on the basis of that description. He has pointed out that these have been treated as *N. bagelensis* by Sen Gupta (1965) and Tandon (1976). The megalospheric forms are also closely similar to *N acutus*, from which it is differentiated by its spirally arranged granules. In *N. maculatus*, the second chamber is much smaller than the proloulus, surrounding it in a crescentic outline.

Distribution: Fulra Limestone.

Nummulites neglectus Samanta, Bandopadhyay & Lahiri

(Pl. IV, figs. 2,4,5,8,13, 14; Figs. 5, 9)

Nummulites neglectus Samanta *et al.*, 1990 p. 35-37, pl.6, figs. 1-6, pl. 7 figs. 1-10.

The microspheric forms are large (D=11.2-23.30mm), lenticular (D/T=2.8-3.8), test with subrounded margin, surface smooth, septal filaments fine, closely spaced, bundled, sigmoidal, wavy to meandriform, usually twisted and curved round the pole forming vortex; spire simple, regular, opening moderately fast; peripheral whorls narrower; marginal cord moderately thick (1/2 of the chamber height); septa perpendicular, more or less straight, slightly inclined and gently curved at the distal ends; chambers distinclty higher than long in early whorls becoming as long as high in later whorls; axial sections unequally biconvex to concavo-convex. often with wide, low, umbonal thicknening; alar prolongtations very narrow in the early whorls. moderately open in the outer whorls. The megalospheric foms are medium sized (D=3.5-5.0mm), inflated lenticular to conical (1.2-1.7) test; margin angular; surface with well developed polar pustules; septal filaments fine, radial; proloculus small (0.14-0.25mm).

Morphometric parameters in mm (20 specimens. B-forms)

	D	T	LI	HI	LL	HL	M	D/T	LI/HI	LL/HL	W
Min.	11.20	3.42	0.03	0.05	0.42	0.40	0.20	2.82	0.50	0.88	12
Max.	23.30	7.12	0.06	0.06	0.60	0.57	0.27	3.75	1.20	1.13	16
Mean	17.31	5.31	0.04	0.05	0.51	0.50	0.24	3.26	0.82	1.03	
SD.	2.49	0.78	0.01	0.00	0.05	0.04	0.02	0.20	0.18	0.06	

Morphometric parameters in mm (20 specimens, A-forms)

	D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	3.21	1.37	0.07	0.10	0.22	0.21	0.10	0.14	1.23	0.92	0.67	4
Max.	4.98	3.36	0.13	0.13	0.31	0.28	0.18	0.25	1.67	1.27	1.09	6
Mean	3.63	2.92	0.10	0.11	0.26	0.24	0.14	0.19	1.42	1.11	0.88	
SD.	0.50	0.28	0.01	0.01	0.02	0.02	0.02	0.03	0.11	0.10	0.11	

Remarks: *N. neglectus* was erected as a new species by Samanta *et al.* (1990) from Kutch. They are of the opinion that the specimens of *N. neglectus* might have been included in *N. biarritzensis* by Carter (1861) and in *N. beaumonti* by Sen Gupta (1965). Externally, the micropshperic forms are somewhat similar to the co-occurring species *N. stamineus* (considered as a synonym of *N. beaumonti* by Sen Gupta). Samanta *et al.* (1990) considered the sigmoidal septal filaments as a characteristic feature by which it can be distinguished from the straight radial septal filaments of *N. stamineus*. However, in the present material few smaller specimens are found to have straight septal filaments but related to *N. neglectus* in equatorial sections. Forms of both generations have larger test and are loosely coiled compared with *N. stamineus*. The chambers are large in size and less in number. It differs from *N. beaumonti* in being larger in size, and in the nature of spire. The megalospheric forms of *N. biarritzensis* which occur together in the Kutch material, can be distinguished by their small size and large proloculus. Another similar species is *N. atacicus*,

which has a different stratigraphical range.

Distribution : Fulra Limestone.

Nummulites obtusus (Sowerby)
(Pl. V, figs. 1-8, 13; Fig. 10)

Nummulites obtusa Sowerby, 1840, p. 329; pl. 24, fig. 14.

Nummulites obtusus (Sowerby); Schaub, 1981, p. 106; table 3, fig.g; text.-fig. 86a-i.-Samanta, 1981a, p.804; pl. 113, figs 3-5; pl. 114; p115.-Samanta *et al.* 1990, p. 37-38, pl. 8, fig. 1-4, pl. 9, figs. 1, 3-10, pl. 10, figs. 19-28, pl. 11, fis. 6-9.-Racey, 1995, p. 55-56, pl. 3, figs. 8-10.

The microspheric forms are medium sized (D=5.4-13.3); test inflated, lenticular (D/T=1.5-2.7) with a broadly rounded margin; septal filaments sinuous to meandriform, fine granules attached to some septal filament; in axial section the early grown stages show a well-developed group of pillars in polar region; spire tripartite, consisting of an inner part of 5-6 regular, closely spaced whorls, a middle part of 17-18 irregular, open whorl including 3-4 intercalary whorls; and an outer part comprising 12-13 tightly coiled whorls; chambers rectangular, initially higher than long but longer than high in later whorls; septa initially regularly spaced, fairly thick, nearly perpendicular, becoming slighlty curved towards the periphery; in intercalary whorls septa are strongly inclined; in the outer whorls the septa are short, thin, perpendicular and straight; marginal cord varies markedly from thick (2/3 chamber height) in early whorls to the thicker and more variable in the middle whorls, often equalling chamber height, and becoming thinner in the outermost whorls. The megalospheric forms are small (D=1.6-4.5 mm); test inflated lenticular (D/T=1.3-1.6) with a rounded periphery; septal filaments irregular, radiating; spire regular, tightly coiled, opening slightly more rapidly in earlier whorls, marginal cord slowly increasing in thickness, chambers numerous, longer than high, septa inclined and curved.

Morphometric parameters in mm (22 specimens, B-forms)

	D	T	LI	HI	LL	HL	M	D/T	LI/HI	LL/HL	W
Min.	5.44	3.60	0.10	0.12	0.20	0.21	0.22	1.51	0.67	0.72	9
Max.	13.32	6.20	0.18	0.18	0.41	0.33	0.35	2.68	1.42	1.64	16
Mean	8.28	4.31	0.15	0.15	0.29	0.27	0.27	1.90	1.01	1.07	
SD.	2.21	0.79	0.02	0.02	0.07	0.03	0.03	0.25	0.20	0.24	

Morphometric parameters in mm (15 specimens, A-forms)

	D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	1.61	0.95	0.25	0.09	0.07	0.11	0.10	0.10	1.34	0.85	0.90	4
Max.	4.47	2.75	0.40	0.12	0.11	0.19	0.16	0.15	1.69	1.36	1.50	8
Mean	2.85	1.91	0.31	0.11	0.09	0.16	0.14	0.13	1.14	1.14	1.18	
SD.	0.76	0.48	0.05	0.01	0.01	0.02	0.02	0.02	0.10	0.14	0.17	

Remarks: Sen Gupta (1965) has treated this species from the Harudi Formation as *N. perforatus*. However, as pointed out by Samanta (1981a) *N. perforatus* is a related but stratigraphically distinct species. The tripartite division of spire considered to be characteristic of microspheric forms are not always present especially in smaller specimens. Samanta (1981a) has shown that although this species has been reported from different parts of Tethyan regions, the only verifiable records are from Kutch in India and the adjoining Sind areas of Pakistan. Racey (1995) reported it from Oman.

Distribution: Harudi Formation.

Nummulites pengaronensis Verbeek
(Pl. IV, figs. 9, 11, 15, 16, 14; Fig. 10)

Nummulites pengaronensis Verbeek, 1871, p.3-6,pl.1, figs 1a-k.-Samanta, 1968 p. 676-680, pl..128, Figs 1-10.-Samanta *et al.* 1990, p. 25-26, 29, pl.4, figs. 18-25, pl. 5, fig. 9.

The microspheric forms are medium size (D=3.8-5.6mm); test inflated, lenticular to lenticular (D/T 1.9-2.6) with angular margin; radial septal filaments closely spaced and curved near the poles. In equatorial sections, the spire is moderately lax, marginal cord well developed, septa are straight for greater part of the whorl height, then sharply curved backward, often extending over the whole length of the preceeding chambers; extremly narrow alar prolongation. The megalospheric forms are small (D=2.1-3.9mm); test inflated lenticular (D/T=1.4-2.0) without distinct polar pustules; spire, chambers and septa identical to those of microspheric forms; small proloculus (0.05-0.11mm).

Morphometric parameters in mm (20 specimens, B-forms)

	D	T	LI	HI	LL	HL	M	D/T	LI/HI	LL/HL	W
Min.	3.82	1.80	0.03	0.03	0.29	0.29	0.12	1.89	0.60	0.78	6
Max.	5.58	2.70	0.05	0.05	0.56	0.52	0.22	2.62	1.33	1.62	8
Mean	4.95	2.29	0.04	0.05	0.39	0.18	0.18	2.18	1.82	1.06	
SD.	0.42	0.27	0.01	0.01	0.07	0.05	0.04	0.23	0.19	0.18	

Morphometric parameters in mm (20 specimens, A-forms)

	D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	2.10	1.36	0.05	0.04	0.05	0.20	0.18	0.07	1.44	0.81	0.50	5
Max.	3.92	1.96	0.11	0.05	0.08	0.29	0.31	0.15	2.00	1.56	1.00	6
Mean	2.75	1.63	0.08	0.05	0.07	0.25	0.23	0.10	1.68	1.08	0.67	
SD.	0.41	0.18	0.02	0.00	0.01	0.03	0.04	0.02	0.14	0.17	0.14	

Remarks: Sen Gupta (1965) has considered *N. pengaronensis* as a synonym of *N. beaumonti*. However, *N. pengaronensis* is a distinct species with a long stratigraphic range. It is characterised by strongly backwardly curved septa.

Distribution: Fulra Limestone, Kolayat Formation.

Nummulites pinfoldi Davies
(Pl. IV, figs. 3,7,12; Fig. 11)

Nummulites pinfoldi Davies, 1940, p. 209-210,pl. X, figs. 1-6,8.- Samanta *et al.*, 1990, p. 20, pl.4, figs 10-17.

The megalospheric forms are small (D 1.7-2.6 mm), inflated (D/T 1.8-2.5), acute margin, characteristically, large, excavated polar pustules, septal filaments fine, straight, extending from the margin of polar pustules to the periphery; spire regular and tighly coiled; marginal cord thin; septa straight, nearly perpendicular; alar prolongation moderately open; polar plugs prominent.

Morphometric parameters in mm (10 specimens, A-forms)

	D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	1.74	1.06	0.08	0.07	0.13	0.11	0.10	0.12	1.37	1.00	0.82	4
Max.	2.55	1.34	0.10	0.11	0.18	0.16	0.16	0.20	2.16	1.33	1.29	5
Mean	2.12	1.22	0.09	0.08	0.16	0.14	0.12	0.16	1.75	1.17	1.12	
SD.	0.29	0.09	0.01	0.01	0.01	0.02	0.02	0.02	0.28	0.09	0.16	

Remarks : According to Samanata *et al.* (1990), *N. pinfoldi* ranges from the upper part of the Harudi Formation to the lower part of the Fulra Limestone. However, in the present material the species is also found from the upper part of the Fulra Limestone, co-occuring with *N. stamineus* from which it is differntiated by the presence of excavated polar pustules and smaller size. The microspheric forms are not found.

Distribution : Fulra Limestone.

Nummlulites praediscorbinus Schaub
(Pl. V, figs. 9-12; Fig. 10)

Nummulites praediscobinus. Schaub, 1981, p.133; pl. 52, figs 28-50.- Samanta *et al.* 1990. p.15,pl.2, fig. 1-4, pl. 10, fig. 18.-Racey, 1995, p.58, pl. 1, figs. 27-28.

The megalospheric forms are very small (D 1.2-2.6mm); test inflated, lenticular (1.5-2.3) with well rounded margin; septal filaments radiating, straight to slightly curved; flattened polar pustules; spire regular; chambers isometric to higher than long, septa straight, inclined, slightly curved towards periphery; marginal cord moderately thick (same as chamber height); proloculus small (0.07-0.15mm). The single specimen of microspheric form shows similar characters.

Morphometric parameters in mm (20 specimens, A-forms)

	D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	1.24	0.58	0.07	0.03	0.05	0.10	0.11	0.08	1.46	0.43	0.55	3
Max.	2.60	1.32	0.13	0.07	0.10	0.19	0.19	0.15	2.35	1.40	0.95	6
Mean	1.67	0.89	0.09	0.06	0.07	0.15	0.15	0.11	1.88	0.88	0.76	
SD.	0.37	0.15	0.01	0.01	0.01	0.02	0.02	0.01	0.24	0.18	0.09	

Remarks: Samanta *et al.* (1990) reported this species for the first time from India. According to them, it has a very regular, tight spire. However, the spiral diagram shows that it is less tightly coiled than *N. discorbinus* and *N. stamineus*, which are of the same lineage. Few individuals show irregularity in spire. The chamber length varies considerably with introduction of many narrow chambers. According to Schaub (1981), it ranges from upper Cusian to middle Lutetian. Samanta *et al.* (1990) also recorded it from the upper part of the Harudi Formation and lower part of the Fulra Limestone, represeting P 12 and P 13 zones respectively. In the present material, it occurs consistently throughout the Fulra Limestone.

Distribution : Fulra Limestone, Harudi Formation.

Nummulites spectabilis Samanta, Bandopadhyay & Lahiri
(Pl.VI, figs. 4, 6, 7, 10; Fig. 10)

Nummulites spectabilis.- Samanta *et al.*, 1990, p. 41-43, pl. 10, figs. 1-9.

The megalospheric forms are very small, compressed, lenticular test with glassy polar pustules and radiate filaments, rapidly opening loose spire, much higher than long chambers with nearly perpendicular septa.

Morphometric parameters in mm (20 specimens, A-forms)

	D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	0.71	0.31	0.04	0.04	0.04	0.11	0.13	0.04	1.97	0.80	0.71	3
Max.	1.12	0.52	0.07	0.07	0.05	0.16	0.17	0.05	3.03	1.75	1.07	3
Mean	0.91	0.40	0.05	0.05	0.05	0.13	0.15	0.05	2.33	1.06	0.86	
SD.	0.11	0.06	0.01	0.01	0.00	0.01	0.01	0.00	0.24	0.22	0.10	

Distribution : Harudi Formation.

Nummulites stamineus Nuttall
(Pl.VI, figs. 1, 2, 9, 11; Fig. 11)

Nummulites stamineus Nuttall, 1926, p. 131-132, pl.1, figs. 1-3.-Samanta *et al.*, 1990, p. 16-20, pl.1, figs. 1-10.

The microspheric forms are moderately large D=8.7-12.6mm); test inflated, lenticular (D/T=1.9-2.5), surface smooth, fine, closely spaced radial to broadly curved septal filaments; spire very regular, closely coiled, marginal cord moderately thick, septa nearly perpendicular to slightly inclined, thin straight; chambers numerous, narrow, alar prolongations moderately open. The megalospheric forms are small (D=2.2-4.2mm); test inflated lenticular (D/T=1.7-2.5) with subangular margin, nearly straight septal filaments radiating from wide but faint polar pustules; spire very regular, opening slowly in height; septa nearly perpendicular, straight; chambers higher than long; axial section inflated biconvex; alar prolongations moderately wide.

Morphometric parameters in mm (15 specimens, B-forms)

	D	T	LI	HI	LL	HL	M	D/T	LI/HI	LL/HL	W
Min.	8.70	4.42	0.03	0.04	0.25	0.24	0.24	1.94	0.60	1.00	14
Max.	12.60	5.18	0.06	0.06	0.33	0.30	0.30	2.53	1.25	1.32	17
Mean	10.95	4.73	0.04	0.05	0.30	0.26	0.26	2.31	0.94	1.18	
SD.	1.06	0.20	0.01	0.01	0.02	0.01	0.02	0.16	0.17	0.08	

Morphometric parameters in mm (20 specimens, A-forms)

	D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	2.21	1.25	0.09	0.07	0.15	0.12	0.10	0.12	1.67	0.90	0.83	5
Max.	4.15	2.22	0.14	0.11	0.23	0.19	0.16	0.37	2.52	1.71	1.40	8
Mean	2.47	1.74	0.11	0.09	0.18	0.16	0.13	0.23	2.00	1.18	1.13	
SD.	0.59	0.31	0.01	0.01	0.02	0.02	0.02	0.08	0.23	0.20	0.17	

Remarks : Nuttall (1926) created *N. stamineus* on the basis of microspheric specimens only. The megalospheric generation was described by Samanta *et al.* (1990). Smout (1954) and Racey (1995) have considered it as a synonym of *N. discorbinus*. The primary difference between the two is shown to be size of the test. Samanta *et al.* (1990) have mentioned that marginal cord is less conspicuous in *N. stamineus*. However, no significant difference in marginal cord thickness is found between the two species. Racey (1995) is of the opinion that the large size of the microspheric forms may be due to ecological variation. However, both *N. discorbinus* and *N. stamineus* are found in the same sample.

Distribution: Fulra Limestone.

Nummulites vicaryi d'Archiac and Haime
(Pl.VI, figs. 3,8; Fig. 11)

Nummulites vicaryi d'Archiac and Haime, 1853, p. 139-140, pl.9, figs. 1a-c.-Schaub, 1981, p. 136-137, table 14, pl.54, figs. 6-15.-Samanta *et al.*, 1990, p. 22, 25, pl.3, figs. 1-14.

The microspheric forms are moderately large (D=11-20.6mm); test flattened, lenticular (D/T=3.2-5.3), smooth, sharp to rounded margin; septal filaments fine, nearly straight, radial to turbulent and weakly meandriform; spire very regular, tight; septa are short, straight, gently inclined, chambers isometric to slighlty longer than high. Axial sections show alar prolongations between thin spiral laminae and buried polar plugs. Megalospheric forms are not found.

Morphometric parameters in mm (20 specimens, B-forms)

	D	T	LI	HI	LL	HL	M	D/T	LI/HI	LL/HL	W
Min.	11.00	3.44	0.03	0.03	0.41	0.24	0.18	3.20	0.50	1.08	12
Max.	20.55	5.46	0.05	0.06	0.57	0.40	0.35	5.31	1.25	2.38	26
Mean	16.19	4.11	0.04	0.05	0.47	0.34	0.34	3.96	0.89	1.42	
SD.	2.73	0.65	0.01	0.01	0.06	0.04	0.04	0.51	0.18	0.29	

Remarks: Samanta *et al.* (1990) have observed that it is larger and thicker than *N. beaumonti*. However, the thickness data show it is less inflated than *N. beaumonit.*

Distribution : Fulra Limestone.

Nummulites vohrai Tandon
(Pl. VI, figs. 13, 14; Pl. VII, 7-9; Fig. 11)

Nummulites vohrai, Tandon, 1976, p.80-82, pl.3,figs. 1-6; pl.4, fig.1.-Samanta *et al.* 1990, p.30, pl.5, figs. 1-8.

The microspheric forms are very large, thin and wavy; septal filaments wavy; spire slowly opening, somewhat irregular; long, strongly curved wavy septa. It is the largest species of the genus known from India..The megalospheric forms are large (3.7-7.00 mm); compressed lenticular, often slighlty undulating, margin obtuse; septal filaments very fine, long, losely spaced, turbulent; spire more or less

regular, opening gradually in height; marginal cord thick; septa thin, very long, often wavy, sharply curved backwards, extending quite often over the whole length of the preceding chamber; megalosphere conspicuously large; second chamber strikingly narrow; later chambers falcate, usually higher than long.

Morphometric parameters in mm (20 specimens, A-forms)

	D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	3.72	1.28	0.70	0.23	0.25	0.30	0.30	0.12	2.91	0.56	0.52	3
Max.	6.98	1.98	0.90	0.30	0.45	0.45	0.46	0.24	4.51	1.16	1.10	5
Mean	5.72	1.59	0.81	0.27	0.34	0.36	0.37	0.17	3.60	0.79	0.79	
SD.	0.72	0.17	0.07	0.02	0.05	0.04	0.04	0.03	0.38	0.15	0.16	

Remarks: While Tandon's (1976) description was based only on microspheric forms, Samanta *et al.* (1990) have reported only the megalospheric forms. In the present sample, both the generations are found. The microspheric forms can be differentiated from *N. maculatus* by their larger size and by their higher chambers in equatorial sections. The megalospheric forms are also the largest among the megalospheric forms of other species. Externally, they somewhat resemble the microspheric forms of *N. pengaronensis.*

Distribution: Fulra Limestone.

Nummulites vredenburgi Prever
(Pl. VII, figs. 1-6; Fig. 11)

Nummulites douvillei Vredenburg, 1906, p.79-85, pl. 8, figs. 1-13.

Nummulites vredenburgi Prever; Samanta, 1982; p. 32-44, figs. 6-10.- Samanta *et al.* 1990, p.43-44,47, pl. 10, figs. 10-17, pl. 11, figs. 1-5,13-28

The microspheric forms are moderatley large (D=5.6-10mm); test inflated (D/T=2.0-3.6) with a broad narrow flange at the periphery; closely packed granulations all over the lenticular portion of the test, excluding the peripheral portion; fine rather crooked, widely spaced and irregularly disposed septal filaments; marginal cord thin; straight, thin septa, curving backward near marginal cord; rapidly increasing height of convolutions. The megalospheric forms are small (D=1.7-4.4mm); test inflated lenticular to lenticular (D/T 1.4-3.4); the last whorl constitutes a broad, thin flange-shaped rim; covered with coarse granulations; large spherical megalosphere; rapidly opening spire resembling *Operculina* in appearance.

Morphometric parameters in mm (10 specimens, B-forms)

	D	T	LI	HI	LL	HL	M	D/T	LI/HI	LL/HL	W
Min.	5.60	1.96	0.02	0.02	0.42	0.78	0.15	1.98	0.67	0.35	6
Max.	10.0	4.50	0.03	0.03	0.72	1.30	0.34	3.59	1.50	0.56	8
Mean	7.70	2.61	0.03	0.02	0.51	1.12	0.23	3.02	1.12	0.46	
SD.	1.56	0.70	0.00	0.00	0.10	0.16	0.05	0.47	0.27	0.07	

Morphometric parameters in mm (17 specimens, A-forms)

	D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	1.65	1.15	0.24	0.24	0.22	0.30	0.48	0.10	1.43	0.78	0.52	2
Max	4.28	1.38	0.35	0.48	0.37	0.53	0.59	0.13	3.37	2.00	1.10	4
Mean	3.13	1.26	0.29	0.33	0.29	0.42	0.54	0.12	2.46	1.17	0.79	
SD.	0.68	0.06	0.03	0.06	0.04	0.07	0.03	0.01	0.46	0.28	0.16	

Remarks: Vredenburg (1906) created this species form the specimens of Kutch. However, Nuttall (1926) cosidered it as a junior synonym of *N. acutus*. This view has been reflected in the work of later authors including that of Sen Gupta (1965). However, Samanta (1981a) has shown the distinctness of the two species. They also occur in stratigraphically different horizons.

Distribution: Harudi Formation.

Genus ***Assilina*** d'Orbigny, 1839

(Type Species: *Assilina depressa* d'Orbigny, 1850, p. 336- *Nummulites spira* de Roissy, 1805,p. 57; SD d' Archiac and Haime, p. 156.)

Test large, lenticular to flattened lenticular, often with a central depression, commonly evolute; surface smooth or granulated; septal traces may be seen; whorls open up moderately fast, numerous chambers per whorl; chambers simple, rectangular; sutures radial, may be slightly curved near the periphery; well developed marginal cord, stolons simple, radial and irregularly distributed; wall finely perforate; no alar prolongation; trabecules absent. Dimporphism is common and for most of the species both megalospheric and microspheric generations are found. d'Orbigny (1826) gave it a generic status and designated A. *depressa* in synonym with *A. spira* as the type species. It is differentiated from *Nummulites* by its evolute tests. However, some authors do not accept the involute/evoluteness of the test to be a criterion for generic distinction. The involutenss seems to be influenced by ontogeny and habitat environment. Some species of *Nummulites* show evoluteness in their later whorls. Though the original description of *Assilina* does not relate to *Operculina*,

Hottinger (1977) considered both as a single genus and found them lacking in trabeculae unlike *Nummulites*. Folloiwng Schaub (1981), *Assilina* is treated as an independent genus in the present study.

Assilina daviesi Cizancourt
(Pl. VIII, figs. 11,17, 18; Fig. 12)

Assilina daviesi Cizancourt, GILL, 1953, p.81 pl.13, figs. 6-13.

The megalospheric forms are medium sized (D= 2.1-5.3mm), rounded margin, with a central depression, chambers are broad, spire opens moderately; septa straight, inclined forward in later whorls; in axial section, wasp-waisted due to absence of lateral laminae.

Morphometric parameters in mm (20 specimens, A-forms)

	D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	2.10	0.80	0.09	0.11	0.36	0.45	0.12	0.08	2.47	0.64	0.69	4
Max.	5.26	1.15	0.24	0.26	0.74	0.80	0.30	0.15	4.72	1.67	1.14	6
Mean	3.97	0.97	0.16	0.16	0.49	0.57	0.18	0.11	4.07	1.02	0.87	
SD.	0.73	0.11	0.03	0.04	0.08	0.08	0.03	0.01	0.44	0.20	0.12	

Distribution : Khuiala and Kolayat Formation.

Assilina exponens (Sowerby)
(Pl. VIII, figs. 4, 12,14-15, 19; Fig. 12)

Nummulites expnens, Sowerby 1840, p.719, pl.41, figs. 14a-e,

Assilina exponens (Sowerby) Nuttall, 1926, p.43, pl.5, figs. 5-6; pl.6, fig.1.-Schaub 1981, p.213, table 18, fig. I; pl. 92, figs. 1-15; pl. 94, figs 1-34.-Majob 1982, p. 88-89, pl.3.2, figs. e-g,j,k; pl.3.3, figs. a-c; pl.3.4, figs, a-c.e, pl. 3.7, figs a-d.-Racey, 1995, p. 70, pl. 9, figs 6-10.

The microspheric forms are large (D=19-27.5mm); test flattened, lenticular, often with a slight central depression surrounded by a slightly raised rim, spire and septa often visible in relief on the surface of the test; polar region markedly pillared; ornament consists mainly of septal ridges but these are occasionally replaced by a series of granules; granules common towards the centre of the chambers; spire regular, compact with some irregularities due to doubling in the middle to outer whorls; chambers rectangular, about 1.5 times higher than long, occasionally isometric; septa thin, straight, slightly inclined, gently arcuate towards periphery. The megalospheric forms are medium sized (D=6.8-9.8mm), lenticular to flattened lenticular, with a slightly swollen polar region, often with a small polar depression; ornament similar to B-form; spire fairly regular with rare intercalary whorls; chambers isometric or a little higher than long, occasionally smaller chambers occur in some specimens; septa thin, nerly straight, slightly inclined; proloculus large (0.5-.85mm).

Morphometric parameters in mm (15 specimens, B-forms)

	D	T	LI	HI	LL	HL	M	D/T	LI/HI	LL/HL	W
Min.	18.92	3.00	0.10	0.09	0.91	1.81	0.08	5.19	0.60	0.48	11
Max.	27.54	4.52	0.16	0.15	1.02	1.99	0.13	8.27	1.25	0.56	16
Mean	24.14	3.71	0.15	0.14	0.96	1.88	0.10	6.56	0.94	0.51	
SD.	2.83	0.47	0.01	0.01	0.03	0.05	0.02	0.84	0.19	0.02	

Morphometric parameters in mm (25 specimens. A-forms)

D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	6.86	1.56	0.32	0.36	0.54	0.62	0.15	0.41	2.91	0.75	0.69	6
Max.	9.84	2.60	0.47	0.49	0.88	0.90	0.17	0.72	5.86	1.05	1.17	8
Mean	8.23	1.99	0.38	0.43	0.70	0.79	0.16	0.53	4.21	0.89	0.90	
SD.	0.87	0.25	0.03	0.04	0.09	0.08	0.01	0.08	0.72	0.09	0.12	

Distribution: Fulra Limestone.

Assilina laxispira de la Harpe
(Pl. VIII, figs. 5,6,9,10, 16; Fig 12)

Assilina placentula vel granulosa form A var *laxispira* nov. var. De La Harpe, 1926, p. 92.

Assilina granulosa (d' Archiac). GILL, 1953, p. 82, pl.4, figs. 8-15.-

Assilina laxispira de la Harpe. Blondeau, 1972 p. 71, pl. 38, figs. 5-7.-Schaub, 1981, p.99, table 16 fig. g; pl. 73, figs 56-73; pl. 74, figs. 1-50, 53,54.

The megalospheric forms are small (D=2.5-5.3mm); test evolute, flattened lenticular to flat; faint central depresion and a sharp periphery; surface ornamented with radiating septal ridges, often formed by coalescing granules; spire visible in relief; spire fairly regular, opening rapidly in last whorls; chambers higher than long, subrectangular; septa thin, straight or faintly curved, almost perpendicular to preceding whorl, septa leaving the marginal cord at an angle, with a distinct forward curvature for the first quarter or third of their length, thereafter becoming straight and normal to the marginal cord, marginal cord fairly uniform, 1/4-1/3 of chamber height.

Morphometric parameters in mm (20 specimens, A-forms)

	D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	2.46	0.77	0.11	0.10	0.45	0.41	0.13	0.10	2.80	0.85	0.68	4
Max.	5.25	1.15	0.17	0.16	0.58	0.73	0.25	0.16	5.36	1.42	1.14	6
Mean	3.77	0.90	0.14	0.13	0.51	0.55	0.16	0.13	4.21	1.11	0.94	
SD.	0.67	0.11	0.02	0.02	0.04	0.08	0.03	0.02	0.51	0.14	0.11	

Remarks: This species is commonly cited as *A. granulosa* in Indian literatures.

Distribution : Khuiala and Kolayat Formations.

Assilina spinosa Davies
(Pl. VIII, figs. 1,2, 7; Fig. 12)

Assilina spinosa Davies, 1937, p. 31, pl.IV, figs. 11, 12, 16, 17, 19, 20, 23-26.-Schaub, 1981, p. 196, pl. 71, figs. 53-55.

The megalospheric forms are small (D=1.8-3.7mm), thin with central depression; spirally arranged pustules along the whorl laminae; septa curved near periphery; small proloculus (0.1-0.18mm). Some specimens show aborted chambers.

Morphometric parameters in mm (20 specimens, A-forms).

	D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	1.80	0.54	0.10	0.08	0.26	0.27	0.09	0.10	3.33	0.83	0.81	4
Max.	3.70	0.80	0.15	0.14	0.43	0.36	0.13	0.18	5.81	1.44	1.23	5
Mean	3.14	0.67	0.12	0.11	0.33	0.31	0.11	0.14	4.69	1.11	1.09	
SD.	0.43	0.06	0.01	0.01	0.04	0.03	0.01	0.02	0.59	0.16	0.09	

Remarks: *A. spinosa* has been considered by some to be synonym of *A. granulosa* and sometimes used interchangeably. However, besides presence of pustules, *A. spinosa* is found to be biometrically different from *A. laxispira* (=*A. granulosa*). Ray *et al.* (1984) have identified this species from the Naredi Formation of Kutch as *A. irregularis* Carter and advocated a Middle Eocene age for the formation. Though few specimens show an irregularity in their spire, the consistent wavy nature of the whorl as characteristically seen in *A. irregularis* are not present in the material of Kutch.

Distribution : Naredi Formation.

Assilina suteri Schaub
(Pl. VIII, figs. 8, 13; Fig. 12)

Assilina suteri Schaub, 1981, p. 216, pl. 96, figs. 1-9, fig-34-53.- Racey, 1995, pl. 8, figs. 12, 13-19.

The megalospheric forms are small, evolute, lenticular, inflated in the polar region; septal ridges are arranged spirally, central depression; regular spire in equatorial section; septa are slightly inclined, isometric chambers.

Morphometric parameters in mm (40 specimens, A-forms)

	D	T	LI	HI	LL	HL	M	P	D/T	LI/HI	LL/HL	W
Min.	1.45	0.73	0.13	0.13	0.24	0.22	0.08	0.12	1.84	0.60	0.59	2
Max.	4.69	1.38	0.31	0.33	0.46	0.62	0.19	0.30	3.67	1.29	1.48	5
Mean	2.63	0.94	0.21	0.24	0.34	0.40	0.13	0.20	2.74	0.88	0.92	
SD.	0.91	0.13	0.05	0.04	0.06	0.04	0.04	0.04	0.63	0.15	0.23	

Remarks: The bimodal distribution of the test diameter may give an impression of the presence of sexual dimorphs. However, no such bimodal distribution in proloculus size is found.

Distribution: Khuiala and Kolayat Formation.

DISCUSSION AND CONCLUSONS

It is a common observation that the morphological features, which form the basis of definition of taxonomic units at all hierarchical levels of the system, varies within some limits. The morphological definition of a palaenotologic species is, therefore, not based on set values of morphological parameters but on a statistically obtained range of variation (Engelhardt and Zimmermann, 1982). In view of this, morphometric data, determined on large population, is increasingly substituting or complementing the typological speices concepet in palaeontology. In the present study, 19 species of *Nummulites* and 5 species of *Assilina* are subject to a detailed biometric study. This cannot be considered to represent all the species from this region but a biased choice of common species for which an optimum number of specimens could be recovered for statistical analysis.

In all the measured parameters, the megalospheric forms show less interspecific variation than the microspheric ones. The size of megalospheric forms ranges from 0.6 mm to 10mm, though most of the speices occur in the range of 2 to 5mm. Only *N. vohrai* and *A. exponens* have tests larger than 5mm. In the lower range are the species *N. burdigalensis*, *N. cuvillieri*, *N. variolarius*, *N. orbignyi* and *N. spectabilis*. For micropspheric forms, size ranges from 2mm to 70mm. *N. voharai*, *N. maculatus* and *A. exponenes* are the large (D>30mm) species. The microspheric forms of *N. burdigalensis*, *N. cuvillieri* and *N. globulus* are less than 3mm. However, for most of the species the size range is 5 to 15 mm. The megalospheric individuals of *N. obtusus*, *N. acutus* and *N. neglectus* are inflated, having D/T ratio less than 1.5. The maximum value of D/T attained by megalospheric nummulitids in this region is 4.0 in *N. vohrai*. The microspheric

forms of *N. vohrai*, *N. maculatus* and *A. exponens* are flat, in which D/T ratio is more than 9.0. The general observation is that larger specimens tend to have a relatively flatter test.

The number of whorls in megalospheric forms are less than 10 and for some smaller spcies it is 2 to 3. On the other hand, the large microspheric individuals can have more than 30 whorls. The whorl number is closely related to the test diameter. However, the different degrees of coiling of the spire also determine the number of whorls. In the individuals of comparable diameter, the laxly coiled species such as *N. neglectus* or *N. vredenburgi* have fewer number of whorls than the individuals of tightly coiled species such as *N. stamineus* or *N. acutus*. The spiral diagrams can be useful in discriminating some species, especially their microspheric generations. However, in megalospheric forms it has limited application. The number of chambers in each whorl increases from initial to last whorl, though the trend is not so regular. Some forms, such as *N. maculatus* and *N. stamineus*, contain more than 100 chambers in the last whorls.

The proloculus size in the megalospheric generation ranges from 0.05 mm in *N. burdigalensis* and *N. praediscorbinus* to more than 0.6mm in *N. acutus*, *N. maculatus* and *N. vohrai*. The intraspecific variation in proloculus size in some species is relatively high (0.14 to 0.38mm in *N. discorbinus*). The early Eocene species in general have small proloculus. In the upper part of the Fulra Limestone, species with large proloculus co-occur with species having small proloculus. The thickness of marginal cord in the last whorl varies from 0.08 to 0.18 mm in megalospheric forms and from 0.13 to 0.35mm in microspheric forms. The wide intraspecific variation with large area of overlap between species makes it a character of less diagnostic value.

The length and height of chambers in the initial whorls of megalospheric forms vary from 0.03mm to about 0.50mm and in the last whorl range between 0.10 and 0.6mm. In microspheric forms, the size of chambers in the last whorl mostly ranges from 0.20 to 0.70 mm except in *N. vredenburgi* and *A. exponens* where the height of chambers is more than 1.30mm. The ratio of length to height of chambers varies from 0.5 to 2.0 and a wide variation can be observed within a species. The terms 'higher than long; or 'longer than high', to describe chamber size in conventional identification, are difficult to apply in many species. For most of the species, the height of chambers within a whorl remains constant. An exception to this is *N. vredenburgi.* Some species, such as *N. stamineus*, are characterized by uniform chamber size which, according to Hottinger (1983), may have an adaptive advantage in farming endosymbiotic algae. The large-sized species do not necessarily have large chambers.

The inter-relation between morphological parameters of the two genera have been studied by partial correlation and factor analysis. Size of chambers in the first whorl is not correlated with the size of the test. However, the size of chambers in the final whorl and protoconch diameter are moderately correlated with the test size (table 2). It appears that size of the chambers is not strongly influenced by the size of the test. This is further supported by the factor analysis of the morphometric data. In the factor analysis, three factors explain major variance in microspheric forms and two factors in the megalospheric ones. In microspheric forms (table 3), the three factors account for 85% of variance. After varimax rotation, it shows that the first factor which accounts for 38% of variance controls diameter, thickness, number of whorls, marginal cord thickness and, to a certain extent, the length of chamber in the last whorl. The second factor explains about 26% of variance and is strongly loaded on length and height of chambers in the first whorl.The length and height of chambers in the last whorl are loaded on third factor and it accounts for about 20% of the variance. In the megalospheric forms, the first and the second factors explain about 52% and 25% of the total variance, respectively. The size variables of the chambers and size of the protoconch are loaded on the first factor. But, unlike the microspheric forms, the diameter of the test is loaded on both the factors. The above result indicates that while the variables related to test size (such as diameter and thickness of the test and number of whorls) are influenced by one factor, the variables related to chamber size (such as length and height of chambers in first and the last whorls) are

Table 2: Partial correlation analysis of the morphometric parameters of *Nummulites* and *Assilina*.

B-Forms (N=247, 14 species)

	D	T	LI	HI	LL	HL	M	W
D	1.000							
T	.2467	1.000						
LI	-.0017	.2006	1.000					
HI	-.0455	.0051	.7839	1.000				
LL	.4452	.0094	-.1431	.0905	1.000			
HL	.1736	.0243	.1127	-.2074	.4904	1.000		
M	-.3351	.4252	.0218	.1188	.1735	.1486	1.000	
W	.8681	.0384	.0019	-.0298	-.2509	-.3573	.3631	1.000

A-Forms (N=428, 21 species)

	D	T	LI	HI	LL	HL	M	P	W
D	1.000								
T	.3408	1.000							
LI	-.2926	.3035	1.000						
HI	.2650	-.1098	.6106	1.000					
LL	.1551	.0201	-.1343	-.0032	1.000				
HL	.4568	-.4291	.2153	.1369	.5399	1.000			
M	-.0648	.2467	-.0478	-.1219	.0938	.2855	1.000		
P	.4273	-.0537	.2497	.3577	-.0228	.5205	.2791	1.000	
W	.7576	.0970	.0383	-.2349	-.1182	-.1635	.0204	-.2389	1.000

controlled by another. Test size is konwn to be influenced by the surrounding environment. Chambers, as mentioned above, are postulated to be adaptive to endosymbionts. It is possible that factor 1 in microshperic forms and factor 2 in megalospheric forms are related to environment, while factors 2 and 3 in micropsheric forms and factor 1 in megalospheric forms are palaeobiologically controlled (e.g. the influence of the endosymbionts).

The taxonomic implication of the above result is that in the discrimination of the species of nummulitids, size of chambers should be given priority over the diameter and thickness of the test. Some other morphological features have been considered diagnostic in species identification but the present observation suggests a cautious use of these features. Intercalary whorl is considered by some workers as of specific importance (e.g. Arni, 1967). Racey (1992) has considered this feature next only to shape and form of septa and chambers (which are given relatively highest taxonomic value). It is characteristically present in microspheric forms of *N. maculatus*, *N. voharai*, *N. vicaryi, N. obtusus* and *A. exponens*. In the present study, it is observed that it is not a consistent feature in a species. In *N. obtusus,* it is seen that while the large individuals possess intercalary whorls the relatively smaller forms of the same microspheric generation lack it. Another inconsistent feature is septal filaments. Within a species also smaller individuals have less complex septal filaments. It also appears to have changed through ontogeny, as seen in *N. obtusus*. This speices is characterised by meandriform septal filaments, resembling thumb impression, in final whorls. However, when the outer layers are removed, the inner layers show radial pattern. In view of the above observations, the intercalary whorls and septal filaments are considered to be of less diagnostic value.

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Table 3: Factor Analysis of Morphometrc Variables of *Nummulites* & *Assilina*.

Microspheric Forms

Variables	Communality	Factor	Eigen Value	% Variance	Cummulative %
D	.91278	1	3.52320	44.0	44.0
T	.70197	2	2.09208	26.2	70.2
LI	.72824	3	1.16919	14.6	84.8
HI	.72031	4	.51074	6.4	91.2
LL	.64389	5	.28828	3.6	94.8
HL	.52960	6	.22288	2.8	97.6
M	.56405	7	.14710	1.8	99.4
W	.90488	8	.04654	.6	100

Varimax rotated Matrix

Factovs/Variables	1	2	4	Communality
D	.93834	-.04699	.16150	.90876
T	.80244	.37928	.15043	.81039
LI	.12192	.92887	-.08389	.88470
HI	.05615	.92765	-.14085	.88352
LL	.45139	-.08687	.78395	.82587
HL	-.09030	-.09075	.94209	.90393
M	.60083	.48349	.19439	.63253
W	.96177	.04587	-.08746	.93476
Rotated variance	38.00%	26.51%	20.29%	

Megalospheric Forms

Variables	Communality	Factor	Eigen Value	% Variance	Cummulative %
D	.93229	1	5.54920	61.7	61.7
T	.60016	2	137391	15.3	76.9
LI	.88676	3	.97242	10.8	87.7
HI	.93747	4	.51228	5.7	93.4
LL	.88704	5	.30972	3.4	96.9
HL	.91720	6	.12038	1.3	98.2
M	.55375	7	.07918	.9	99.1
P	.85475	8	.04388	.5	99.6
W	.76782	9	.0321	.4	100.0

Varimax Rotated Matrix

Variables/Factors	1	2	Communality
D	.67894	.66089	.89937
T	.21761	.81884	.70687
LI	.93892	.11799	.85140
HI	.95992	.18734	.90878
LL	.89498	.22621	.82591
HL	.86326	.18598	.74613
M	.60906	.53199	.57122
P	.80506	.26523	.62263
W	.05645	.89223	.79421
Rotated variance %	51.61%		25.27%

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EXPLANATION OF PLATES

Plate I

Morphometric parameters of *Nummulites* and *Assilina* as measured in the present stidy.

Plate II

1,2,4,5, 11,14. *Nummulites acutus* (Sowerby), Fulra Limestone, Kutch
1. From-B, equatorial section, X 11.
2. Form-B, axial section, X 11.
3. Form-A, equatorial section, X 15.
5. Form-B, surface, X 1.5.
11. Form-A, axial section, X 11.
14. Form-A, surface X 25.

3, 6.*Nummulites atacicus* Leymerie, Khuiala Formation, Jaisalmer
3. Form-B, equatorial section, X 11.
6. Form-B, surface, X 2.

12, 13. *Nummulites beaumonti* d'Archiac and Haime, Fulra Limestone, Kutch
12. Form-B, equatorial section, X 11.
13. Form-B, axial section, X11.

7-10, 15. *Nummulites burdigalensis* (de la Harpe) Naredi Formation, Kutch
7. Form-B, surface, X 25.
8. Form-A, surface, X 38.
9. Form-B, equatorial section, X 22.
10. Form-A, equatorial section, X 36.
15. Form-A, equatorial section, showing marginal and septal canals X 180.

Plate III

1,2,12 *Nummulites biarritizensis* d' Archiac and Haime, Fulra Limestone
1. Form-A, equatorial section, X 18.
2. Form-A, surface, X 10.
12. Form-A, axial section, X 11.

4,5,7,8. *Nummulites cuvillieri* Sander, Fulra Limestone, Kutch
4. Form-B, equatorial section, X 20.
5. Form-A, equatorial section, X 38.
7. Form-A, axial section, X 16.
8. Form-A, surface, X 25.

9,13,14,16,18. *Nummulites discorbinus* (Scholotheim), Fulra Limestone, Kutch
9. Form-A, euqatorial section, X 11.
13. Form-A, axial section, X 11.
14. Form-B, surface, X 7.
16. Form-B, equational section x 11.
18. Form-B. surface, showing showing septal filaments X 27.

3,6 ,10. *Nummulites globulus* Leymerie, Naredi Formation, Kutch
3. Form-A, equatorial section, X 66.
6. Form-B, equatorial section, X 33.
10. Form-A, surface, X 30.

11, 15,17. *N. maculatus* Nuttal, Fulra Limestone, Kutch
11. Form-A, equatorial section, X 11.
15. Form-B, axial section, X 11.
17. Form-A, axial section, X 11.

Plate IV

1,6 *Nummulites maculatus* Nuttall, Fulra Limestone, Kutch
1. Form-B, equatorial section, X 11.
6. Form-A, surface (of a half-cut section), X 12.
2,4,5,8,13,14 Nummulites neglectus Samanta, Fulra Limestone, Kutch
2. Form-A, surface showing septal filaments, X 33.
4. Form-B, equatorial section, X 11.
5. Form-A, surface, X 12.
8. Form-A, equatorial section, X 9.
13. Form-B, axial section, X11.
14. Form-A, axial section, X 11.
10 *Nummulites orbignyi* (Galeotti), Fulra Limestone, Kutch
10. Form-A, equatorial section, X 38.
9,11,15,16. *Nummulites pengaronensis* Verbeek, Fulra Limestone, Kutch
9. Form-A, equatorial section, X 18.
11. Form-A, surface, X 15.
15. Form-B, axial section, X 11.
16. Form-B, equatorial section, X 11.
3, 7,12. *Nummulites pinfolid* Davies, Fulra Limestone, Kutch
3. Form-A, equatorial section, X 11.
7. Form-A, equatorial sectoin, X 11.
12. Form-A, surface, X 18.

Plate V

1-8,13. *Nummulites obtusus* (Sowerby) Harudi Formation, Kutch
1. Form-B, equatorial section, X 8.
2. Form-B, axial section, X 11.
3. Form-B, bee-hive like structure of pores in a chamber in equatorial section X 1375.
4. Form-B, surface, showing trabecules X 11.
5 Form-B, surface (enlarged view of Fig.4), X 165.
6. Form-B, surface showing thumb impresssion like septal filaments, X 6.5.
7. Form-B, equatorial section showing trabeculae X 520.
8. Form-B, equatorial section, X 8.
13. Form-A, equatorial section, X15.
9-12 *Nummulites praediscorbinus* Schaub, Fulra Limestone, Kutch
9. Form-A, surface, X 50.
10. Form-A equatorial section, X 33.
11. Form-B, equatorial section, X 15.
12. Form-A, axial section, X 16.

Plate VI

5. *Nummulites semiglobulus* Doornink, fulra Limestone, Kutch
5. Form-A, equatorial section, X 33.
4,6,7,10 *Nummulites spectabilis* Samanta, Harudi Formation, Kutch
4. Form-A, surface showing perforations, X 93.
6. Form-B, equatorial section, X 25.
7. Form-B, surface, X 33.
10. Form-A, axial section, X 44.
1,2,9,11 *Nummulites stamineus* Nutttal, Fulra Limestone, Kutch
1. Form-B, equatorial section, X 11.

2. Form-A, equatorial section, X 30.
9. Form-B, surface, X 2.
11. Form-A, axial section, X 16.
12. *Nummulites variolarius* (Lamarck), Fulra Limestone, Kutch
12. Form-A, equatorial section, X 55.
3,8 *Nummulites vicaryi* d' Archiac and Haime, Fulra Limestone, Kutch
3. Form-B, equatorial section, X 11.
8. Form-B, surface, X 2.
13, 14. *Nummulites vohrai* Tandon, Fulra Limestone, Kutch
13. Form-B, axial section, X 11.
14. Form-A, axial section, X 11.

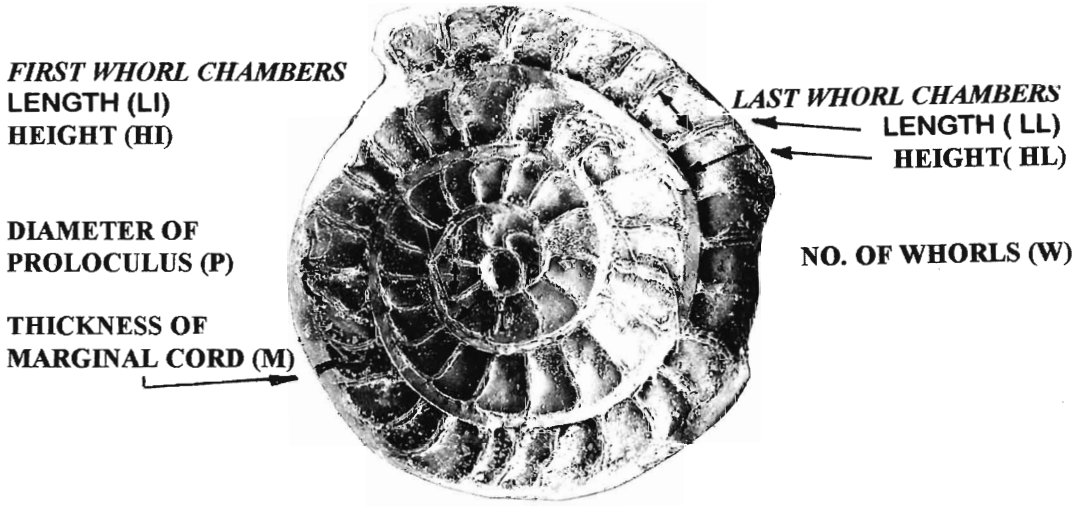
Plate VII

1-6 *Nummulites vredenburgi* Perver, Harudi Formation, Kutch
1. Form-B, equatorial sectoin, X 14.
2. Form-B, surface, X 1.5.
3. Form-B, equatorial section, showing septal canals X 165.
4. Form-B, equatorial section, showing pores in the chamber X 1975.
5. Form-A, equatorial section, X 14.
6. Form-A, surface, X 14.
7-9. *Nummulites vohrai* Tandon, Fulra Limestone, Kutch
7. Form-A, equatorial section, X 11.
8. Form-B, surface, X 0.3.
9. Form-B, equatorial section, X 11.

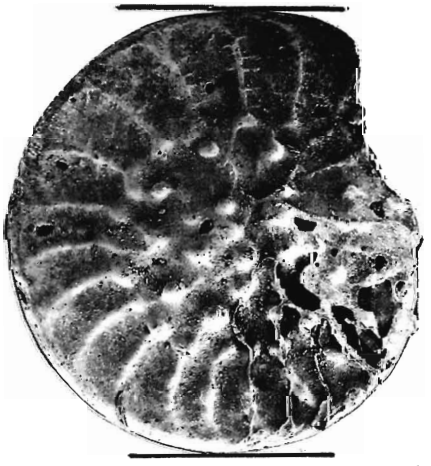
Plate VIII

11, 17,18. *Assilina daviesi* Cizancourt, Khuiala Formation, Jaisalmer
11. Form-A, equatorial section, X 11.
17. Form-A, surface, X 10.
18. Form-A, axial section, X 11.
4,12,1415,19 *Assilina exponens* (Sowerby), Fulra Limestone, Kutch
4. Form-B, equtorial section, X 11.
12. Form-B, surface, X 1.5.
13. Form-A, equatorial section, X 11.
14. Form-A, axial section, X 11
15. Form-A, surface, X 3.
19. Form-A, equatorial section, X 11.
5,6,9,1016. *Assilina laxispira* de la Harpe Khuiala Formation, Jaisalmer
5. Form-A, equatorial, X 11.
6. Form-A, surface, X 10.
9. Form-B, surface, X 9.
10. Form-A, axial section, X 11.
16. Form-B, equtorial section, X 11.
1,2,7. *Assilina spinosa* Davies, Naredi Formation, Kutch
1. Form-B, equatorial section, X 28.
2. Form-A, equatorial section, X 24.
7. Form-B, surface, X 9.
3 *Assilina spira* de Roissy, Fulra Limestone, Kutch
3. Form-A, surface, X 13.
8,13. *Assilina suteri* Schaub, Kolyat Formation, Bikaner
8. Form-A, surface, X 18.

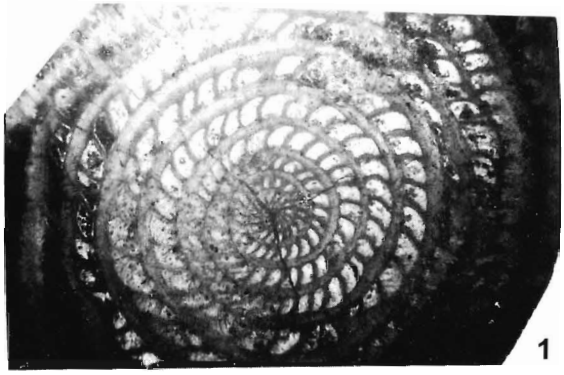
MORPHOMETRIC PARAMETERS



THICKNESS (T)



DIAMETER (D)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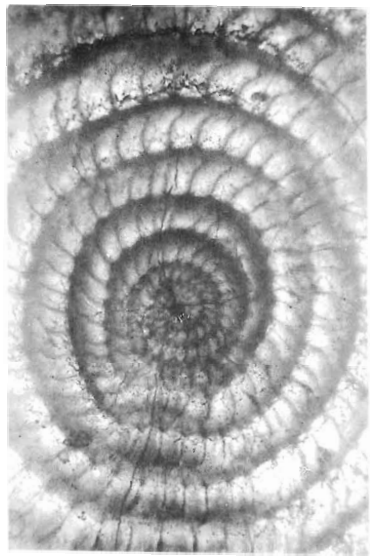
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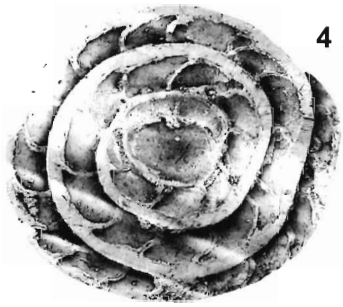
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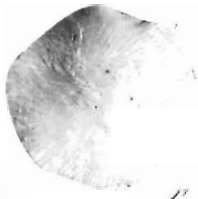
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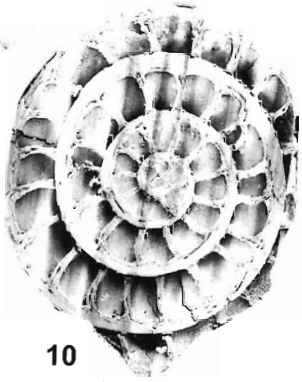
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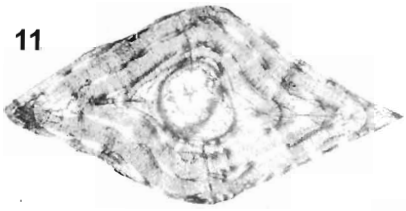
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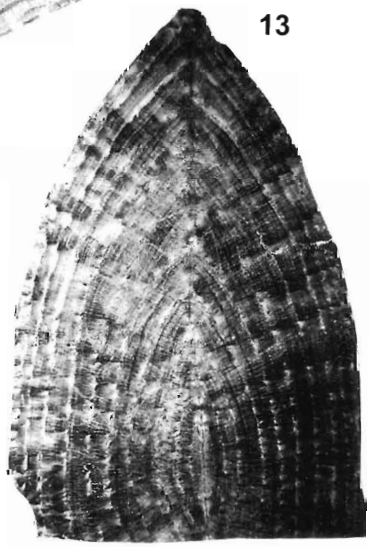
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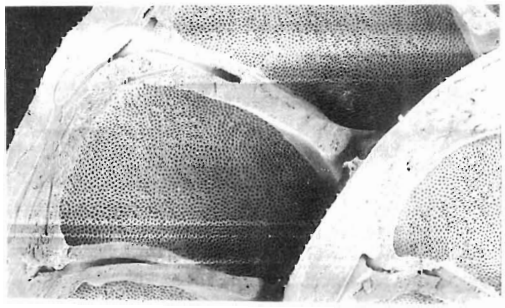
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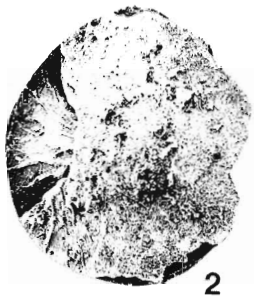
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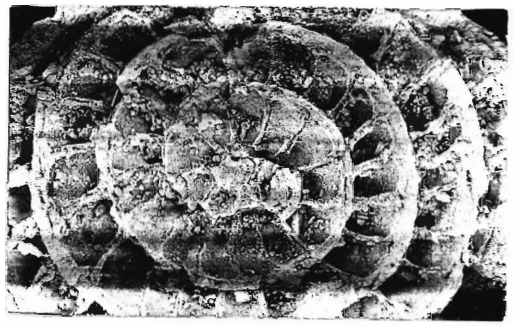
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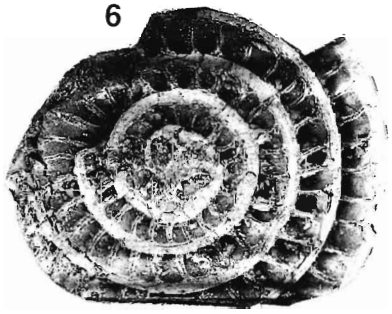
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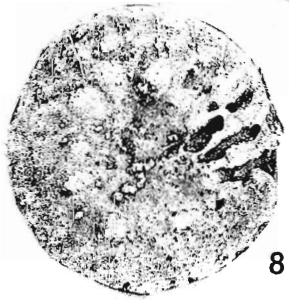
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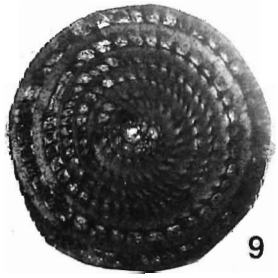
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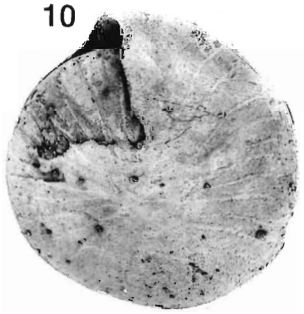
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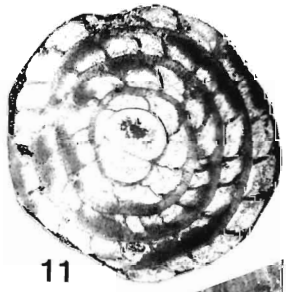
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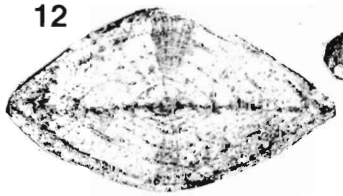
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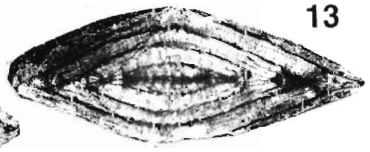
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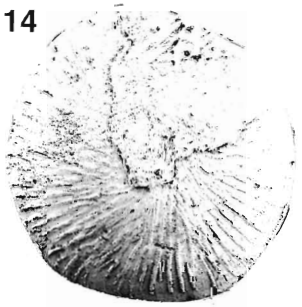
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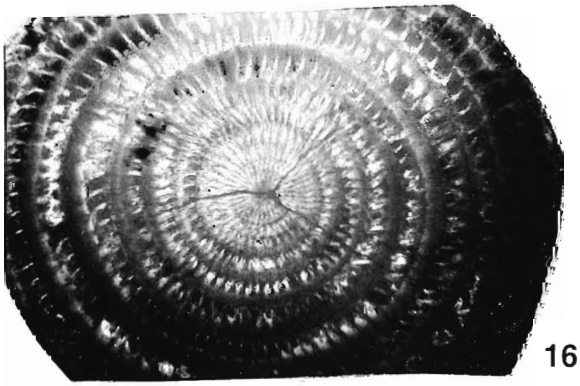
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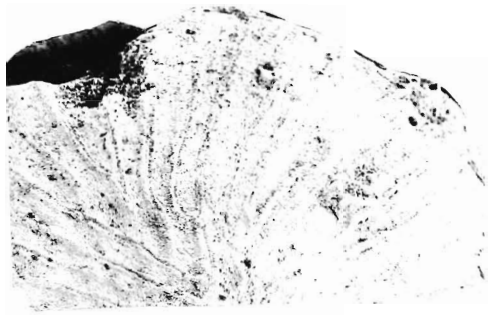

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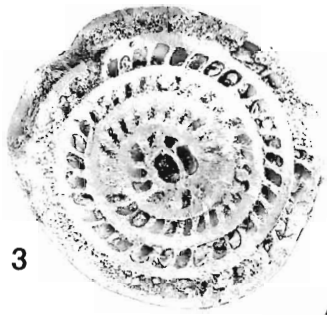

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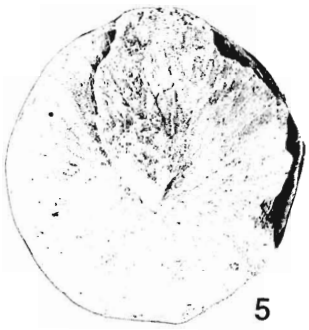

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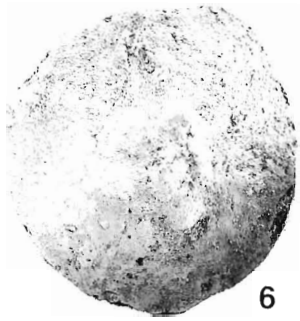

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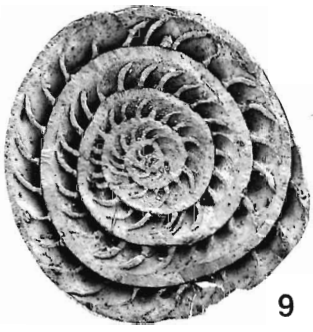

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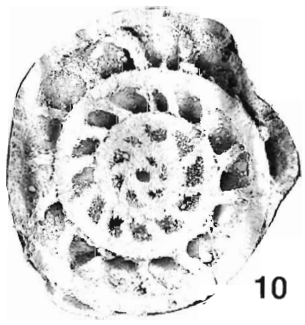

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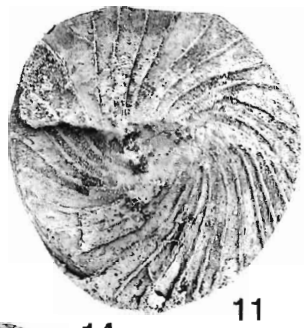

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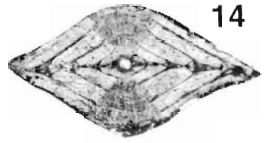

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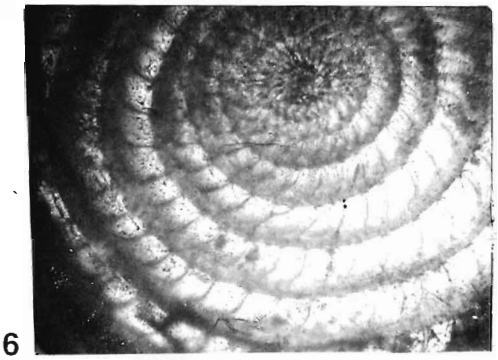

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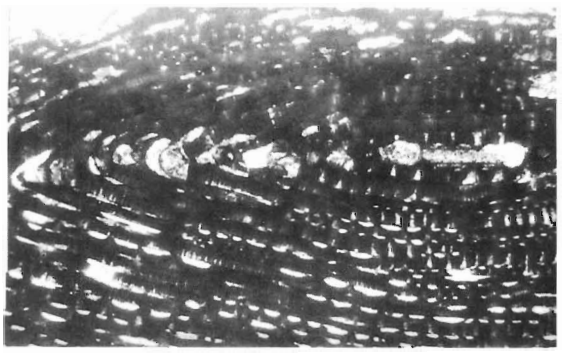

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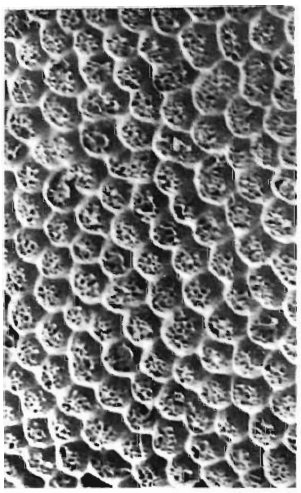

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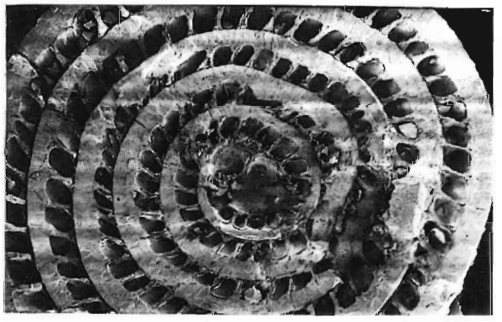

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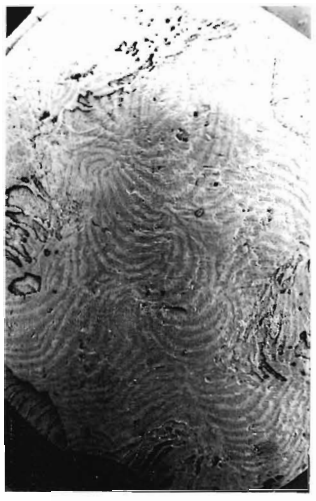

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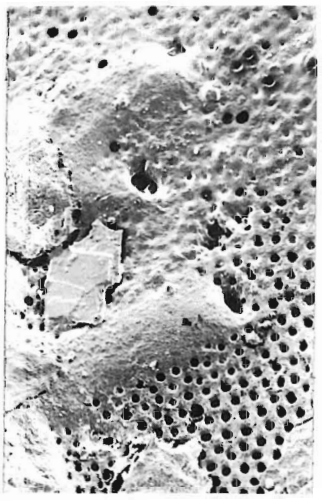

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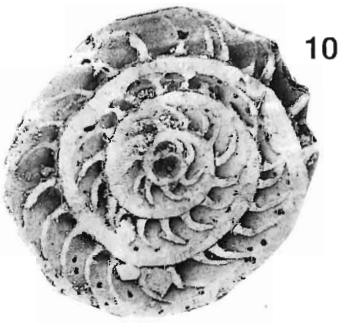

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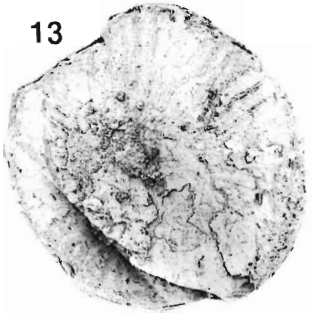

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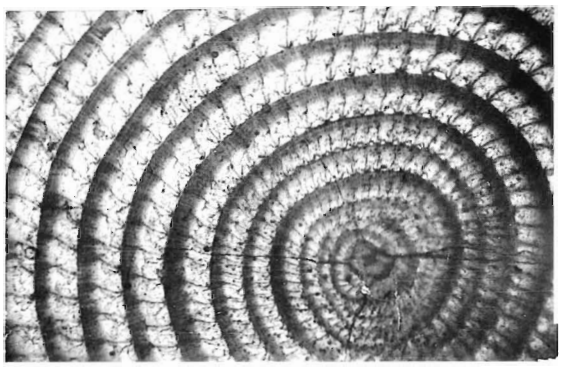

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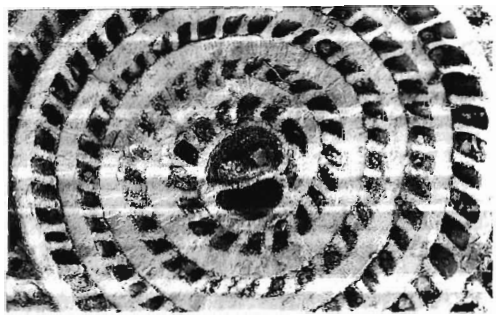

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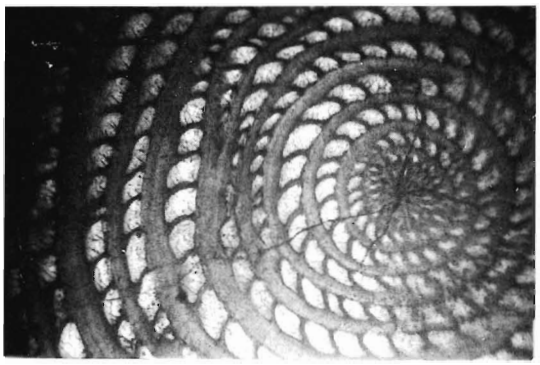

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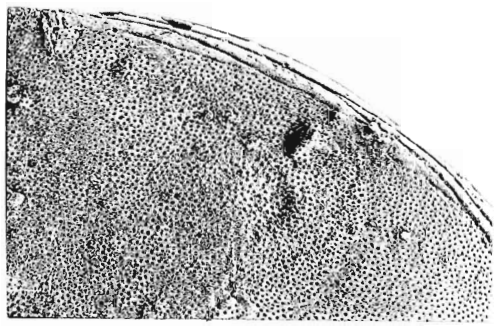

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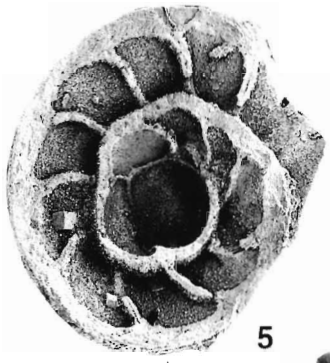

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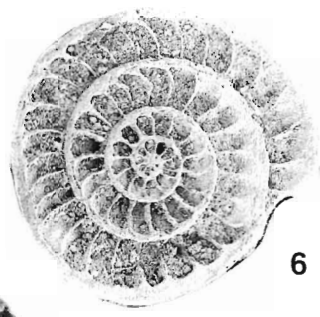

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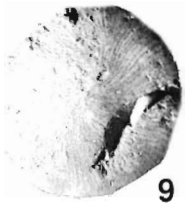

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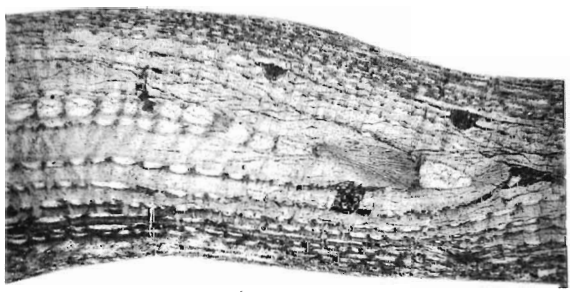

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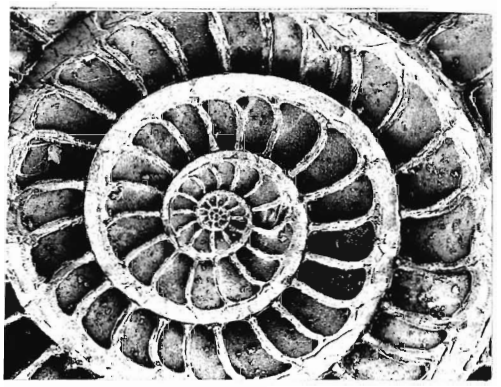

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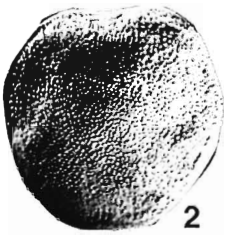

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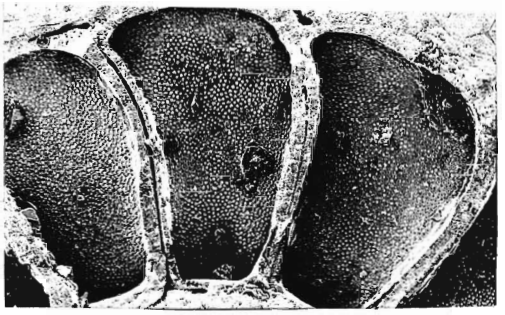

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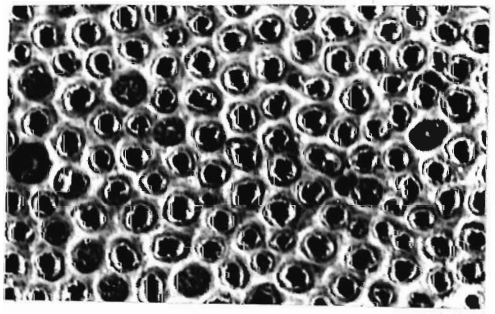

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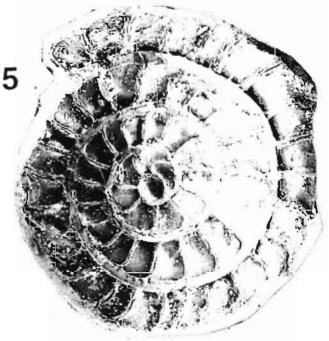

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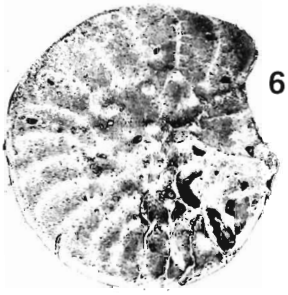

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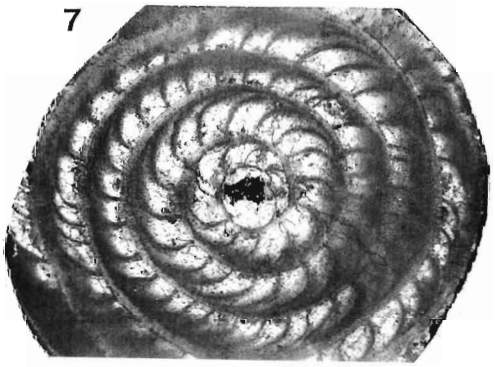

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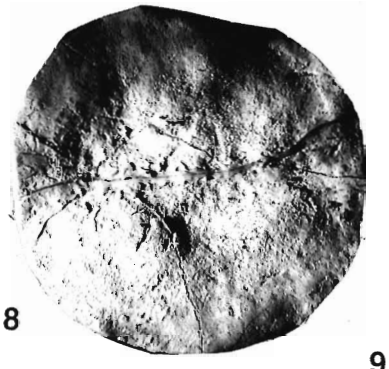

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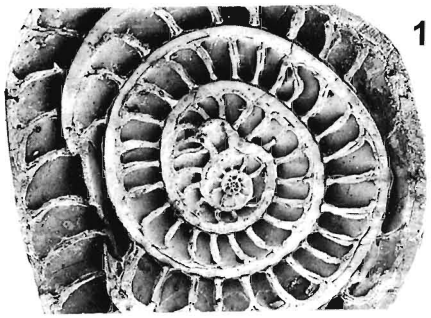
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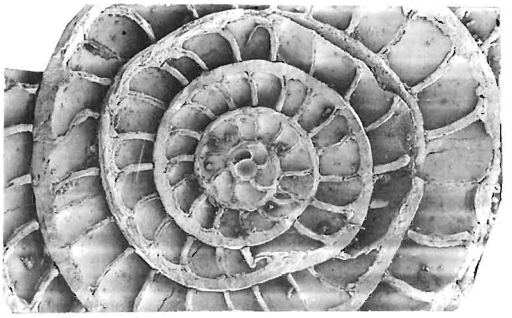
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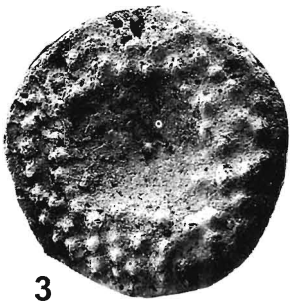
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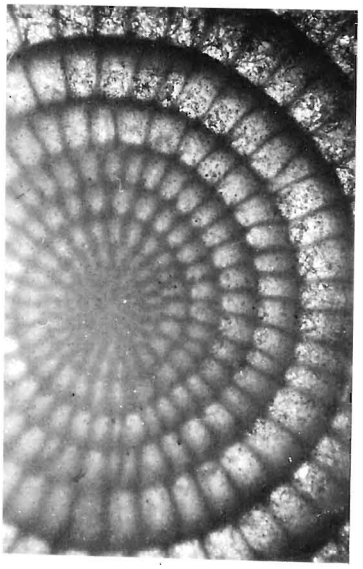

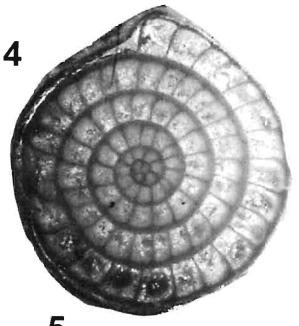
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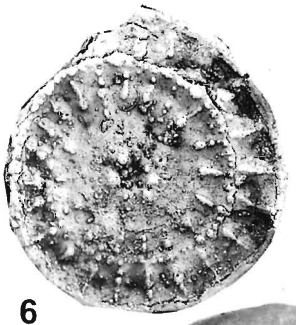
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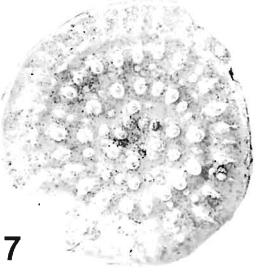
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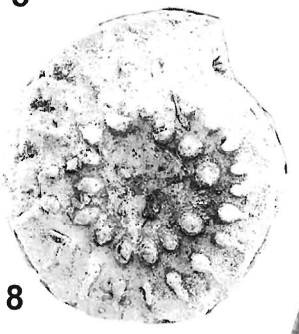
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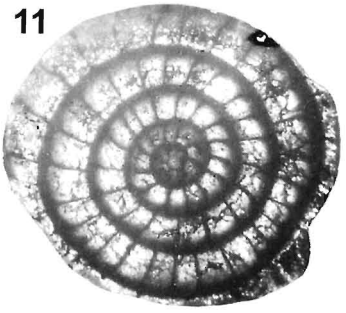
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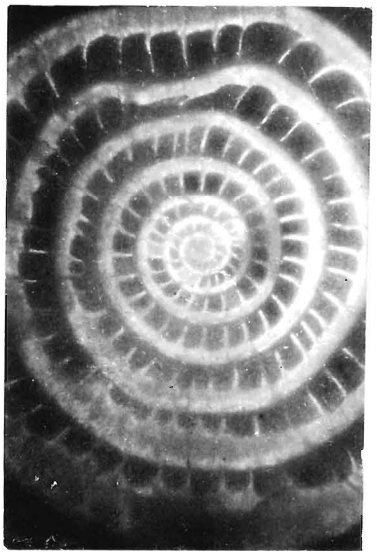
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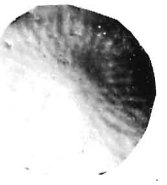
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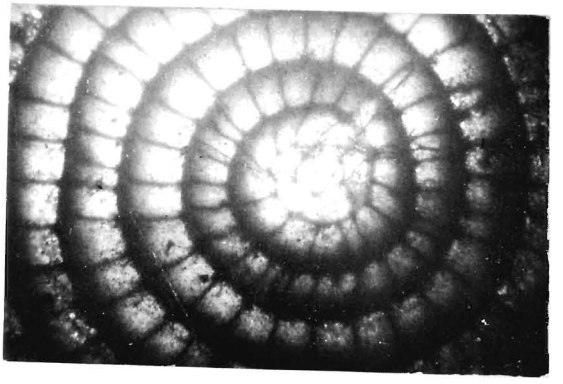


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