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ON THE VALIDITY AND SIGNIFICANCE OF *NUMMULITES STAMINEUS* NUTTALL IN THE PERSPECTIVE OF *NUMMULITES DISCORBINUS* (SCHLOTHEIM) AND *NUMMULITES BEAUMONTI* D'ARCHIAC AND HAIME IN THE MIDDLE EOCENE OF CAMBAY BASIN, INDIA

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Abstract. The incompletely described and hitherto controversial *Nummulites stamineus* Nuttall has been re-described from the Cambay Basin, India as a taxonomically valid species. Its distinctive characters include irregular septal filaments, rudimentary transverse trabecules and irregularity in the spire with increased thickness of whorl wall at the middle or late part, a few thick spiral canals and curved chamber top. Closely resembling *Nummulites discorbinus* and *Nummulites beaumonti* differ in the above characters, in the ratio of diameter to thickness of test, number of septal filaments and character of transverse trabecules. In true equatorial sections the three forms mutually differ in the size ratio of protoconch to deuteroconch, height to length of chamber, whorl height to chamber height and whorl height to thickness of whorl wall, and also in the number of whorls, number of chambers in specified whorl and height of foramina. The three species, moreover, differ in stratigraphic range in the Cambay Basin sequence. Consequently, the earlier treatments of *N. stamineus* as synonym of *N. discorbinus* or *N. beaumonti* stand invalid. The re-evaluation increases its stratigraphic significance in the upper Middle Eocene sequence and suggests wide biogeographic range in the Tethyan-Mediterranean Province.

Riassunto. La specie *Nummulites stamineus* Nuttall sinora mal definita e pertanto controversa, viene considerata tassonomicamente valida e qui ridescritta su materiale proveniente dal Cambay Basin, India. I suoi caratteri distintivi sono filetti settali irregolari, trabecole trasverse rudimentali, irregolarità nella spira con l'aumentare dello spessore della parete nelle sue parti mediane e distali, ed infine pochi, spessi canali spirali e sommità delle camere ricurve. Le specie affini *Nummulites discorbinus* e *Nummulites beaumonti* differiscono nei caratteri sopra ricordati, nel rapporto tra diametro e spessore del guscio, numero dei filetti settali e caratteristiche delle trabecole trasverse. In sezione equatoriale le tre forme si distinguono per il diverso rapporto dimensionale tra protoconca e deuteroconca, rapporto altezza/larghezza della camera, e anche nel numero di giri, numero di camere per giro e altezza dei foramina. Le tre specie hanno diversa distribuzione stratigrafica nel Cambay Basin. Pertanto non si ritiene corretto considerare *N. stamineus* come sinonimo di *N. discorbinus* o di *N. beaumonti*. Ne aumenta pertanto il significato stratigrafico nella successione della parte superiore dell'Eocene medio, così come l'importanza biogeografica nella provincia mediterraneo-tetidea.

Introduction

Radiate *Nummulites* have long been known to constitute a significant element in the foraminiferal biostratigraphy of the Middle Eocene shelf sediments of the Tethyan Province (Nagappa 1959; Schaub 1981; Racey 1995; Papazzoni & Sirotti 1995; Serra-Kiel et al. 1998). Some of the index forms owe their origin in the Indian subcontinent, where occasional presence of certain forms closely resembling them create problem in regard to the proper taxonomic evaluation of the index forms. The radiate *Nummulites stamineus* Nuttall, 1926 is one such form that cannot be ignored when evaluating *Lenticulites discorbinus* Schlotheim, 1820 and *Nummulites beaumonti* d'Archiac & Haime, 1853, especially in the context of Paleogene biostratigraphy of the Indian subcontinent. *Nummulites discorbinus* (Schlotheim) is characterized by wide morphological variation that lead to the naming of a number of subspecies and varieties. D'Archiac & Haime (1853), while illustrating it for the first time, observed its resemblance with the Indian representatives of *N. beaumonti*. In the Middle Eocene sequence of Kirthar Range, Pakistan, Vredenburg (1906) observed *N. discorbinus* appearing earlier than *N. beaumonti*. Smout (1954), while admitting a long history of confusion between the two, inferred a lineage

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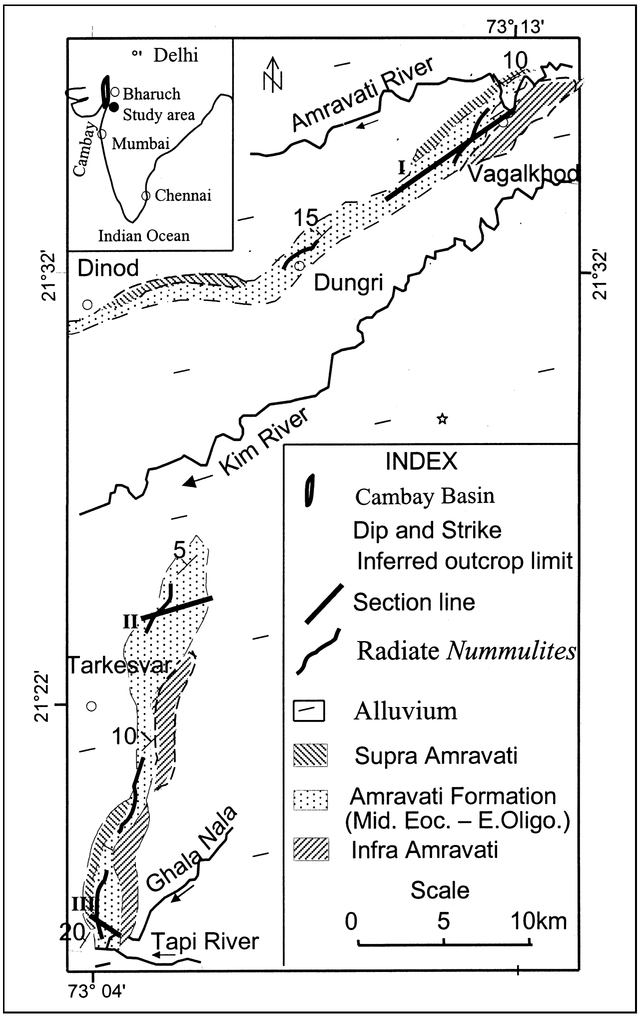

Fig. 1 - Geological map of the study area showing Amravati Formation (Middle Eocene-Early Oligocene), the radiate *Nummulites* band and the measured section lines.

in-between. Meanwhile, Nuttall's (1926) *Nummulites stamineus* from the Middle Eocene of Kutch and Baluchistan became a problematic form in respect of its relationship with *N. discorbinus* and *N. beaumonti*. Though Nuttall (1926) considered his species to be 'closely related' with *N. discorbinus*, workers differ widely on its status. Smout (1954) and Racey (1995) consider it synonymous with *N. discorbinus*. Samanta et al. (1990) described it as a distinct species and thought its evolution from *N. discorbinus*, a view propounded by Rozlozsnik (1929), Nagappa (1959) and Blondeau (1972). Sengupta (1965a, b), on the other hand, considered *N. stamineus* as synonymous to *N. beaumonti*, and Schaub (1981) thought *N. discorbinus* and *N. beaumonti* as phyletically unrelated species evolving into different descendants, the former to *N. cyrenaicus* Schaub (= *Lenticulites discorbinus* Schlotheim var. *libyca* Checchia-Rispoli = *N. stamineus* Nuttall by Smout) and the latter to *N. vicaryi* d' Archiac & Haime. Such diverse views have lead to much confusion as to their stratigraphic use. A part of the confusion arose from the inadequate materials and descriptions of the type species. The description of *Lenticulites discorbinus* by Schlotheim (1820) is not supported by a holotype. D' Archiac and Haime created *Nummulites beaumonti* on specimens from Egypt and India, of which the Indian types, neither preserved nor illustrated, were originally compared with *N. discorbinus*. For *Nummulites stamineus*, its original description was based on external and equatorial section of only microspheric forms and this might have been the cause for its non-recognition by most of the workers. In their larger foraminiferal biozones of the Paleogene shelf sequence of the Tethyan Province, Serra-Kiel et al. (1998) have shown that *N. discorbinus* appears at SBZ14 and terminates at the end of SBZ16, while *N. beaumonti* emerges at SBZ15 and disappears at the end of SBZ17. But these ranges as such cannot be applied in the Indian basins since their work is based on Schaub's (1981) concept of *N. discorbinus* and *N. beaumonti*, and in the Indian subcontinent a group of workers accepts *N. stamineus* as a valid species. Almost similar view was reflected in the work of Papazzoni & Sirotti (1995). The occurrence of all the three forms in a single Indian basin is rare, though the Indian localities including Meghalaya (d'Archiac & Haime 1853), Subathu (d'Archiac & Haime 1853) and Kutch (Nuttall 1926) had been the type and reference areas for the above species. From the Middle Eocene of the last mentioned locality, Samanta et al. (1990) described the three forms but their concept of *N. stamineus* appears slightly different from that of Nuttall's (1926). In the adjoining Cambay Basin, where Upper Eocene overlies the Middle Eocene, *N.* cf. *beaumonti* and *N. discorbinus* have been reported from the exposed Middle Eocene part (Rao 1941; Nagappa 1959; Mohan 1982). During the present work in the same area a large number of radiate *Nummulites* including forms superficially resembling all of the above species have been recovered. These have been studied in detail with a view to test the validity of *N. stamineus* as a distinct species vs *N. discorbinus* and *N. beaumonti*.

Stratigraphy

The Paleogene shelf sequence comprising calc shale, marl and earthy limestone is sporadically exposed on a peneplained terrain at the eastern margin of the Cambay Basin. Originally referred to as Nummulitic limestone by Carter (1861) and redesignated as Amravati Formation by Sudhakar & Basu (1973) this 20 m (approx.) thick formation is exposed linearly in two blocks demarcated by the Kim River (Fig. 1). Its undisturbed beds occurring in-between the Infra- and Supra-Amravati units strike ENE-WSW and dip 5°-20° north-

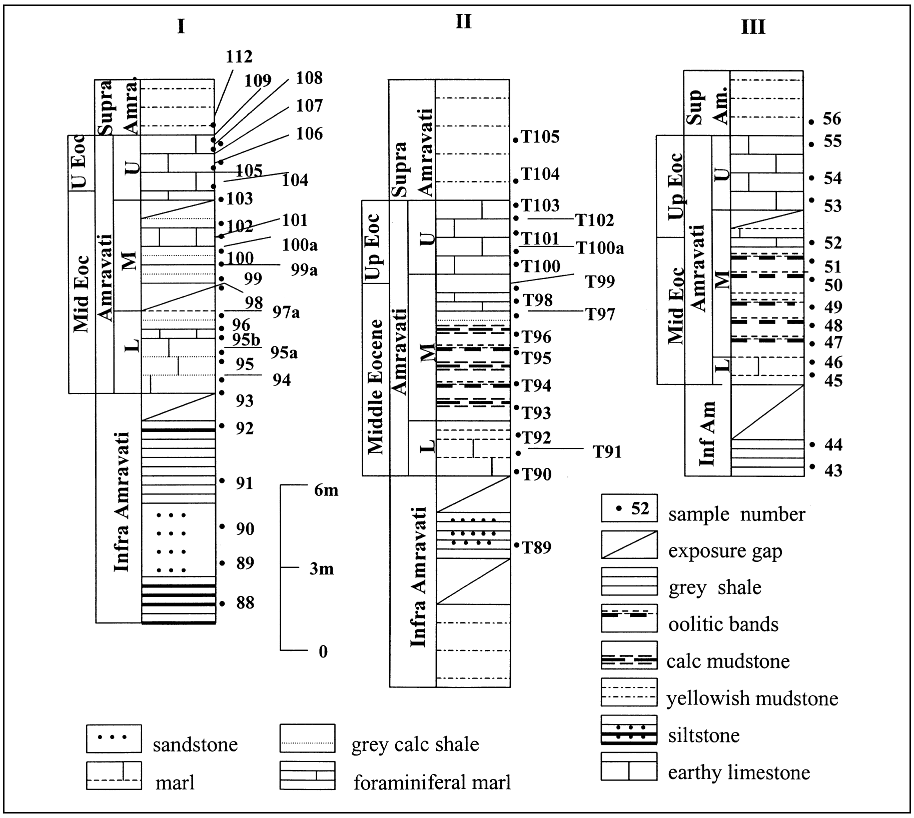

Fig. 2 - Lithostratigraphic sections along traverse lines and sample location. 2a – Distribution of selected foraminifera in the litho section of section line I. 2b -Distribution of selected foraminifera in the litho section of section line II. 2c -Distribution of selected foraminifera in the litho section of section line III.

Geologic age	Plank. foram zones	*Nummulites* zones	Formation		sample no/ foraminifera	*Nummulites atacicus*	*N. beaumonti*	*N. bearritzensis*	*N. boninensis*	*N. discorbinus*	*N. globulous*	*N. pengaroensis*	*N. pinfoldi*	*N. stamineus*	*N. striatus*	*N. vicaryi*	*Truncorotaloides rohri*	*T. topilensis*
Middle Eocene			AMRAVATI	U	104										X			
	P14	*N. stamin eus*		M	102		X	X				X		X		X	X	
					101			X	X					X				
					100a			X	X			X						
					100		X		X	X				X				X
		N.discor binus			99a		X		X	X								
					99		X		X	X	X		X			X		
	1				98								X			X		
	P13			L	97						X		X					
					95	X					X							

a

Geologic age	Plank. foram zones	*Nummulites* zones	Formation		sample no/ foraminifera	*Nummulites atacicus*	*N. beaumonti*	*N. bearritzensis*	*N. boninensis*	*N. discorbinus*	*N. lahirii*	*N. pengaroensis*	*N. pinfoldi*	*N. stamineus*	*N. striatus*	*Orbulinoides beckmanni*	*Truncorotaloides rohri*
Middle Eocene			AMRAVATI	U	T100							X			X		
	P 14	*N. stamin eus*		M	T99			X						X			X
					T98		X							X			
					T97			X				X					
		N.disco rbinus			T96				X	?							
					T95		X		X				X				
					T94	X				X							
					T93					X			X				
	P 13			L	T91	X					X		X			X	

b

Geologic age	Plank. foram zones	*Nummulites* zones	Formation		sample no/ foraminifera	*Nummulites beaumonti*	*N. bearritzensis*	*N. boninensis*	*N. discorbinus*	*N. . lahirii*	*N. pengaroensis*	*N. . pinfoldi*	*N. stamineus*	*N. striatus*	*Orbulinoides beckmanni*	*Truncorotaloides rohri*	*T. topilensis*
Middle Eocene			AMRAVATI	U	53						X			X			
	P14	*N. stami neus*		M	52		X						X				
					51												
					50											X	
		N.disc orbin us			49	X			X								
					48		X										
					47							X					
					46			X									
					45				X								
				L	44							X					
	P 13				43					X		X			X		X

c

erly. The local successions (Fig. 2) of the formation, however, are punctuated by gaps.

The formation is broadly divisible into three parts; the lower and middle parts are well developed in the northeastern area and the upper part in the western and southwestern areas. The lower part overlying the non-calcareous infra-Amravati sediments is a calc-shale marl unit, which contains *Assilina papillata*, *Discocyclina* aff. *dispansa*, *Pellatispira* spp., *Nummulites atacicus*, *N. lahirii*, *Operculina* spp., *Silvestriella tetraedra* and *Globigerapsis beckmanni* of middle Middle Eocene age (= *Globigerapsis beckmanni* Zone, Berggren et al. 1995). In addition to the above, it has yielded *Elphidium* sp., *Rotalia* sp., pelecypods, gastropods and corals. The middle part in the northeastern area is a gray calc-shale, marl and mudstone unit with a yellow siderite band (about 0.5 m). In the southwestern area this part comprises an alternation of oolitic mudstone with calc-shale and marl. A thin (0.3 m-0.5 m) lenticular siderite band occurs in the calc-shale. This part has yielded radiate *Nummulites* including *N. discorbinus*, *N. beaumonti*, *N. stamineus*, *N. biarritzensis*, *N. vicaryi*, *N. globulus*, *N. pengaroensis*, *N. pinfoldi* and granulo-radiate *N. boninensis*. A few planktonic forms including *Truncorotaloides topilensis* and *T. rohri* occur in the argillaceous facies. The *Nummulites* assemblage is richer in the northeastern area while calcarinidae are conspicuous in the southwestern area. Based on planktonic zonal indices this part may be divided into *Globigerapsis beckmanni* Zone (Berggren et al. 1995) of late Lutetian age and *Truncorotaloides rohri* Zone of Biarritzian age. Successive larger foraminiferal zones in this part are *Nummulites discorbinus* Zone followed up by *Nummulites stamineus* Zone. The local range of *N. discorbinus* defines the *N. discorbinus* Zone whose upper boundary is also marked by the disappearance of *T. topilensis* and the appearance of *T. rohri*. This zone is characterized by *Nummulites pinfoldi*, *Nummulites atacicus*, *Nummulites globulus* and *Globigerapsis beckmanni*. Immediately overlying is the *Nummulites stamineus* Zone, marked by the partial range of the nominate taxon between the last occurrence of *N. discorbinus* and the first occurrence of *N. striatus*. The occurrence of *N. pengaroensis* characterizes this zone whose upper boundary is marked by the disappearances of a number of radiate *Nummulites* including the zonal index.

The upper part of the formation, best developed in the Dinod area, comprises discocyclinid marl, marlite and earthy limestone. Four successive foraminiferal assemblages are recognized in this part. The lowermost assemblage contains *Discocyclina* spp., *Nummulites fabianii*, *N. striatus*, *Pellatispira* spp. and *Turborotalia cerroazulensis*. The assemblage lying immediately above has yielded *Nummulites retiatus*, *N. chavannesi*, *Discocyclina* spp, *Hantkenina alabamensis* and *T. cunialensis*. The next higher assemblage comprises *N. pengaroensis*, *Cassigerinella chipolensis* and *Pseudohastigerina micra* while the uppermost assemblage contains *Nummulites fichteli*, *N. vasca* and *Globigerina ampliapertura*. These assemblages indicate Upper Eocene to Early Oligocene age for the upper part of the formation (Mukhopadhyay 1997, 2003a).

The local successions of the Amravati Formation, in general, represent a fining upward sequence with increasing calcareous sediments of a transgressive regime. The paleoenvironment of the formation is interpreted as one of gradual building-up of an inner shelf. Its lower part is an impure calcareous facies that corresponds to a low energy shelf environment where the water was laden with substantial amount of suspended clay. The middle part represents regressive regime with a complex of coastal environments of varying energy conditions similar to one that prevailed in the adjoining Kutch Basin (Mukhopadhyay & Shome 1996). The gray shales with impoverished foraminifera, siderite lenses and rare gypsum veins may represent a lagoonal environment. The oolites of the oolitic beds in the southwest area appear to be transported ones and redeposited as beds (Krumbein & Sloss 1953, p. 101). An environment resembling a nummulitic bank replaces the lagoonal environment in the basinal direction. The overall energy condition in the coastal environments had been low as revealed from the presence of marl throughout the middle part. The upper part represents a low energy inner shelf that was unable to clear the water from suspended clay, but was open enough for free movement of foraminifera.

Materials and Methods

The formation is covered with three measured section lines along which systematic samples each about 1 kg were collected. About 300 g of each sample was processed for foraminifera following standard procedure and screened through 80-240µm mesh. About 0.5g residues of +140 and +250 mesh were examined for planktonic and smaller benthic foraminifera and the whole of +80µm residue for radiate *Nummulites*. Additional material from the selected samples was processed for B-form. The stratigraphic distribution of the recognized forms was recorded (Figs. 2a-2c). For statistical study both *in situ* and loose specimens are considered. The tests of B-form are partly broken and often with matrix; while those of A-form are better preserved. After preliminary grouping, equatorial axial tangential and split sections were prepared and studied under zoom and scanning electron microscope. In order to know the growth and development of the species conventional parameters as used by Racey (1995) and Papazzoni (1998) are followed. Count of septal filaments was done following Adams (1988), who discussed its taxonomic significance. The suture and septal filaments are used as a single parameter (Glaessner 1963, p. 173). Counts and measurements of internal parameters are made in 'true equatorial section' (Fig. 3), which is a plane of bilateral symmetry passing through the maximum curvatures of all the whorls of a test and through the center of the proloculus to retain a sub-triangular space between the oppositely bending septal walls and the proximal sheet of the whorl wall (d' Archiac & Haime 1853, pl. ix, fig.2d), a foramina at the base of a septum (d' Archiac & Haime 1853, pl. viii, fig. 1e, and pl. ix, fig.2d) and a spiral canal at the proximal end of the marginal cord (d' Archiac & Haime 1853, pl. ix, fig.2d). This section, whether complete or part, provides optimum values of the examined parameters.

It is assumed that four whorls occur in a radius of 0.4 mm around the center of a B-form, and measurement of a parameter in a part of a whorl remains valid for the entire whorl. For some parameters in A-form the minimum specimens studied are 30, for some other parameters it is 15-22. The mean height and mean length of a chamber are computed by the formulae SH_n / N and $(Sl_n - Ss_{n+1}) / N$; the mean height and mean thickness of a whorl by Sh_n / N and St_n / N; and the mean height of foramina in a whorl by the sum of individual foramina height/ number of observations. In these formulae H_n stands for the height of n^{th} chamber, l_n = length of n^{th} chamber, s_n = thickness

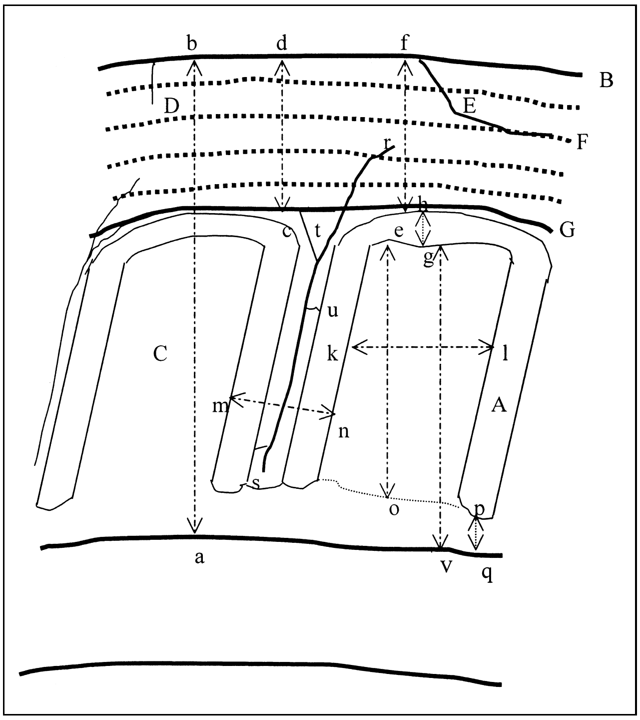

Fig. 3 - Hypothetical diagram of a part of a true equatorial section of the *N. discorbinus* - *N. beaumonti* group showing distinctive characters; A = septum, B = distal canal of the marginal cord, C = chamber cavity, D = radial canal in the marginal cord, E = diagonal canal in the marginal cord, F = spiral canal in the marginal cord, G = proximal canal of the marginal cord, a-b = height of a whorl, c-d = thickness of marginal cord, e-f = thickness of whorl wall, g-h = thickness of roof wall, k-l = length of chamber cavity e-o = height of chamber cavity, m-n = thickness of septal wall between successive chambers, p-q = height of foramina, r-s = septal canal, t = subtriangular space, u = stolon, a-q = proximal surface of a whorl, o-p = separating line between secondary shell material in the foramina and the shell material of chamber cavity; it is usually a manifestation of different optical appearances of the two materials in thin section; gv = eo + pu.

		d'Archiac (1853)	Smout (1954)	Samanta et al. (1990)	Racey (1995)	This work
1.	Diameter (mm)	9	B-form: 7.5-15, Av. 9.5 A-form: 3.3- 4.8, Av. 4.2	5 – 8	6.53 - 14.62 (mean 11.12)	A-form 3.1 – 6.0 B- form 6.8 – 12.05)
2.	Thickness (mm)	3	B- form: 6 to 2.8, Av. 3.8 A- form: 2.7 – 1.6, Av. 2.2	_ _	2.66 - 5.34 (mean 2.37)	B- form 2.2 – 3.1 A-form 1.6 –3.1
3.	D/T	3.6	B- form: 2.5 to 2, Av. 2.3 A-form: 2.0 to 1.6, Av. 1.7	_ _	2.15 -2.87 (mean 2.38)	1.82 – 2.79 2.34 – 3.12
4.	Margin	Bluntly acute	very rounded	obtuse	rounded	bluntly rounded
5.	Septal filaments; no. in a quarter	Almost straight to very weakly curved; 16-18.	fine regular, radial; about 20	straight to gently curved, close spaced radial; about 19.	radiating straight to gently curved; number could not be counted.	fine straight, radiating; in A-form 11 –15, Av: 12.66; in B-form 20-35; Av.:28.33.
6.	Transverse trabecules	Very faint (as in illustration)	not mentioned; B-forms with faint trabecules	_ _	_ _	faint on external surface; thin in tangential section. .
7.	Polar pustule/ plug (polar pillar)	faint polar swell/ polar pillars buried	In A-form/ polar plug buried.	_polar pustule indistinct in the illustrations _ / polar plug buried	-- /buried polar plug	A- form with polar pustule/ with buried polar pillars.
8.	Proloculus; P/D	_ _	Protoconch (P) smaller than the deuteroconch (D)	_ _	0.18 to 0.34 mm diameter of megalosphere	bilocular; P=0.15 – 0.2mm; D=0.15 – 0.2mm; P/D=1
9	No. of whorls	13 in $4^1/_2$ mm diameter	B-form: 18 A-form: 7	B-form:13 A-form:7	_ _	B-form:14 in 10mm; A-form:7 in 4.5mm.
10	Septa; no. in one qtr. of middle wrl,B-form	straight, 10^0-12^0 inclined at base; 16 in one qtr. of 8 th whorl.	nearly straight;17 to18 in one qtr. of approx. 8^{th} whorl	perpendicular at base, weakly curved later; about 17-19 in one qtr.	slightly inclined at base.	straight, vertical to weakly inclined near base, distal gently curved; in one qtr.of 8^{th} whorl 12-15in B-form, 16 in A-form.
11	Ch. in one qtr. of 10^{th} whorl	21	18	about 25	about 33	18-22
12	Spire	regular	last few whorls loosely coiled with squarer chambers	regular, close coiled	regular, tight coil.	tight, regular; slightly loose in last few whorls of A-form;
13	Spiral canal	3-4,traceable to some extent.	1-2, distinct for a while	--	--	3-5, distinctly traceable to some extent.
14	Alar prolongation	Very narrow, almost closing	Distinctly open	moderately open	_ _	narrow, closing towards polar area.
15	H/L of ch. in 8^{th} whorl	double	height is slightly greater than the length; 1.25:1	higher than long; rarely 2:1	1.5 : 1, slightly accurate to subrectangular	1.44
16	marginal cord	thick,subequal to height of ch.	Thick, subequal to height of chamber	very thick	thick, about half the ch. height	about half to subequal the ch. height

Tab. 1a - Concept of *N. discorbinus* (Schlotheim) by different authors.

of n^{th} septa, h_n = whorl height of n^{th} whorl and t_n = thickness of whorl wall adjoining a chamber. N represents the number of observations and S is the sum.

Systematic Paleontology

The concepts of *N. discorbinus* and *N. beaumonti* by various workers who described them either from Indian subcontinent or referred to *N. stamineus* while describing them are summarized in Tables 1-3. The salient morphological differences between the three species in the study materials are abridged in Table 4. For the suprageneric classification, Loeblich & Tappan (1987) has been followed.

Suborder **Rotaliina** Delage and Herouard, 1896

Superfamily Nummulitacea de Blainville, 1827

Family Nummulitidae de Blainville, 1827

Genus *Nummulites* Lamarck, 1801

d'Arch. & Haime (1853)		Smout (1954)		Samanta et al.(1990)		Racey(1995)		This work	
Whorl No.	A- & B-form undifferentiated	A-form	B-form	A-form	B-form	A-form	B- form	A-form	B- form
1.	- - -	4	- - -	- - -	- - -	16		4 – 6	
2.	5	7	- - -	- - -	- - -	28		7 – 8	5
3.	5 – 8	11	- - -	- - -	- - -	45	36	8 –10	6 – 9
4.	7 – 12	13	10	6 – 7	- - -	55	42	9 – 12	8 – 11
5.	8 – 15	11	11	8 – 11	- - -	47	48	10 – 12	10 – 12
6.	10 – 15	12	13	11 – 12	- - -	49	54	11 – 12	11 – 12
7.	12 – 19	13	14	12 – 14	16	56	69	9 – 13	11 – 12
8.	14 – 19		17	13 - 16	17		75	16	12 – 15
9.	16 – 19		18		17		77		13 – 17
10.	18 – 21		18		19		82		15 – 18
11.	21 – 23		20		19		100		16 – 20
12.	26		24		26		111		16 – 22
13.			- - -		- - -		110		20 – 22
14.			28		28		117		21 - 25
15.			- - -				120		23 – 26
16.			- - -				121		
17.			- - -						
18.			30						

Tab. 1b - Number of septa in a quarter of a whorl in *N. discorbinus* (Schlotheim) compiled from the text and illustrations provided by different authors.

sl. no	Parameter	D'Archiac & Haime (1853)	Davies (1940)	Samanta et al. (1990)	Racey 1995	This work
1.	Diameter(D) (mm)	5.75 – 10.25;Av. 8.00	5.25 – 10.0; Av. 7.5	7.00 to 11.0 mm	8.31- 5. 34	A-form: 3.1 – 6.5; B-form:8.4 – 12.0
2.	Thickness(T) (mm)	2.25 – 3.0; Av. 3.25	2.5 – 10.0; Av. 3.25	- - -	4.72-2.21	A-form:1.5 – 2.7 B-form:2.8 – 4.3
3.	Septal filaments; number in a quarter of a whorl	Radiating, weakly curved at the middle, straight at pole & periphery; no 14 - 17.	curved round near pole, straight near periphery; no. 17.	fine radial, straight to curve near poles; no. about 20.	compact, radiating often with Polar twisting.	Radiating, swerve near Periphery; A-form. 11 – 19,av. 13.66. B-form 18-31, av. 24.66
4.	D/T	2.55 – 3.41; Av. 2.46	2.1 – 2.22; Av. 2.3	not given	3.12 -2.13	A-form: 1.72 – 2.58; av.2.18; B-form: 2.42 – 3.18, av.2.73.
5.	Peripheral margin	Acute, rounded tip	Sharp with round tip	Sharp	sharp, gently to Well rounded	acute
6.	Transverse trabecules	Faint	Faint & characteristic	not mentioned	not mentioned	Distinct to bold in peripheral part
7.	polar pustule/ polar plug (polar pillar)	Faint polar swell/ not shown;	Not present/ buried plug ucceeded by pillars	Only in A- forms/ buried	polar pillar may occur / often buried	polar swell, pustule indistinct/ with or without buried polar pillar.
8.	Proloculus; protoconch (P) / deuteroconch (D)	Bilocular; subequal	not mentioned ;	not mentioned ; bilocular (as in illustration)	proloculus 0.16-0.027mm	P=0.2- – 0.25 mm D=0 75 – 0.225mm P/D=1.11-2.6.
9.	Distal part of septa; number in a quarter of a whorl	gently curved to straight; 10 in outer most whorl	gently curved; 14 in 10th whorl	straight and inclined/ 10 in 7th whorl	gently inclined	gently curved; 10-12 in one qtr. 0f 7th whorl
9a	alar prolngation	moderately open	moderately open	wide open	not mentioned	Open across polar part
10.	No. of ch. in 10th whorl (one qtr)	54	51	70	57	51-61
14.	H/L of ch. in 10th or last whorl	1.25 to 1.5	2 : 1; in the outer whorl 1 : 1	2 : 1	subrectangular, a little longer than high to isometric.	1.2
15.	No. of whorls	8 mm diam. has 12 - 13 whorls; 10 whorls in 4 mm; 3 whorls in outer 2 1/2 mm	7.5 mm diam. has 12 - 13 whorls; 5 whorls in outer 2.5 mm	6 –7 in A-form, > 10 in B-form.	10 whorls in 3.24 mm ;5 whorls in 1.16 mm	12 – 13 in 7.5 mm diam 14-15 in 9.5 mm
16.	Marginal cord	Moderately thick	thin, 1/6 th of chamber height	thin	uniform, ¼ of ch height	moderately thin; 1/4th of chamber height.

Tab. 2a - Definition of *Nummulites beaumonti* d'Archiac & Haime by different authors.

D'Arc-hiac &Haime (1853)		Davies (1940)		Samanta et al. (1990) (from illustrations)			Racey (1995)			This work		
whorl no	no of septa per quadrant (forms undifferentiated)	whorl no	no of septa per quadrant	whorl no	no of septa per quadrant		whorl no	no of septa per quadrant		wh orl no	no of septa per quadrant	
					A-form	B-form		A-form	B-form			
1	3	1		1	6		1			1	3-4	5
2	3-4	2		2	7		2	4		2	4-7	5
3	4-5	3	6	3	7		3	6		3	6-10	6
4	6	4	6	4	9		4	6-7		4	7-8	8-9
5	6-7	5	9	5	11	13	5	8	4-5	5	8-9	7-10
6	8-9	6	11	6	11	15	6	9	4-5	6	9-10	9-11
7	9-10	7	11	7		17	7	9-10	6-7	7	8-10	7-13
8	10-12	8	11	8		17	8		6-7	8	11-14	9-12
9	11-15	9	13	9		19	9		7-8	9		13-14
10	16	10	13	10		20	10		8-9	10		13-15
11		11	15	11		19	11		12-14	11		14-15
12		12		12		20	12			12		13-16
13										13		16-17
14										14		16-19
15										15		20-22
16										16		21-24
17										17		23-25
18										18		24-27

Tab. 2b - Number of septa in a quarter of a whorl in *N. beaumonti* (d' Archiac& Haime) compiled from the text and illustrations provided by different authors.

Tab. 3 - Concept of *Nummulites stamineus* by different authors.

		Nuttall (1926) (microspheric)	Samanta et al.(1990)	This work	
				Microspheric	Megalospheric
1.	Test diameter	15.0 – 20.4 mm (Av. 14.7 mm)	7.5 to 15 mm	6.8 – 14 mm, av. 10.4	3.5 to 6.5 mm, av.4.46
2.	Thickness	Max. 8.3 mm (Av. 5 mm)	2.8 to 3.9 mm	2.2 – 4.7 mm , av. 3.23	1.7 to 2.6 mm, av.2.43
3.	Surface	Fine, radiate, gently curved somewhat irregular (38 septal filaments in holotype; 23 in tangential section.)	Radial, broadly curved septal filaments;12 (mega) 23 (micro)	18-41, av. 28.66	13 – 19, av.16.66
4.	D/T	3 to 1	Not mentioned	3.12	1.83;
5.	Peripheral margin	Not mentioned, described as bevelled	Not mentioned; in fig. subrounded	Appressed with round tip	Appressed, acute.
6.	Polar pillar	Not mentioned	buried polar pillar	buried polar pillar may occur	buried polar pillar
7.	Proloculus	Not mentioned	Megalosphere 0.2 – 0.3mm		Megalosphere moderate, P= 0.25-0.35;D=0.125-0.25; P/D=1.4-2
8.	Septa	Straight to slightly curved	Thin, straight	weakly slanting	Straight to slant
9.	Alar Prolongation	Not mentioned	Moderately open	narrow,	narrow,
10.	No. of Ch. in 10^{th} whorl (one qtr.)	14 to 18			14-20
11.	Septal inclination	Right angle	Nearly perpendicular to very slightly inclined	Right angled to inclined	Right angled to inclined
12.	H/L of Ch.	N>L; subrectangular	H>L; narrow; in outer whorl L>H	H>L	H>L
13.	No. of whorls	9 to 11 in 3 mm 17 to 20 in 8 mm	7-8 in A-form; about 17 in B-form	9 in 4.9mm	20 in 12.03mm
14.	Marginal cord	Thick	Moderately thick (variable in the illustrations)	Variable, thick in middle or late part	Variable, thick in middle or late part

Tab. 4 - Main differences (*) in the morphological characters of *N. discorbinus*, *N. beaumonti* and *N. stamineus* at eastern Cambay Basin.

Serial No	Distinctive character*	*N. discorbinus*		*N. beaumonti*		*N. stamineus*	
		A-form	B-form	A-form	B-form	A-form	B-form
A.	**External view**						
1.	shape	inflated lenticular	inflated lenticular	inflated lenticular	inflated lenticular	inflated lenticular	inflated lenticular
2.	Peripheral margin*	bluntly rounded	bluntly rounded	acute	acute	acutely rounded	acutely rounded
3.	Septal filaments*						
i.	nature	fine radial, straight	radial, straight	radial, curve at polar part-	radial, curve at polar part	irregularly radial.	irregularly radial
ii.	number in a quadrant	12-13	26-30	12-14	23-27	16-18	24-32
4.	transverse trabecule*	fine, short	fine, short	strong	distinct	tiny	tiny
5.	polar pustule*	distinct	not found	indistinct	not found	rare	not found
6.	Diameter(D)/ Thickness(T).	2.22 mean of 106 spec	2.79 mean of 19 spec.	2.18 mean of 110 spec.	2.73 mean of 28 spec.	1.83 mean of 81 spec.	3.12 mean of 115 spec.
B.	**Tangential section**						
1.	polar pillar	distinct	distinct	apparent	distinct	indistinct	distinct
2.	transeverse trabecule*	fine	fine	strong	strong	rudimentary	rudimentary
3.	septal filaments*	regular radiating	regular radiating	regular polar bending	regular polar bending	locally irregular	strongly irregular
C.	**Equatorial section**						
1.	nature of spire*	early tight, regular	early tight, later slightly loose.	tight, regular, uniform	tight, regular, uniform	middle or late part irregular	middle or late part irregular
2.i.	whorl wall*	thick, ½ the height of ½ equatorial chamber		moderate to thin; ¼-½ the height of equatorial ch		varying, < ½ to > ½	
ii.	spiral canal in marginal cord*	fine , proximal & distal canal equally nanifested		proximal canal more prominent		proximal &distal canal strong and prominent	
iii.	radial & diagonal canal*	insignificant, short,straight, thin		a few, short, straight, thin		common thick & prominent	
3.i.	number of chambers in about ½ of a quarter whorl,	4.5 IN 3^{RD}	8 IN 11^{TH}	3 IN 3^{RD}	8 IN 11^{TH}	4.5 IN 3^{RD}	5.5 IN 11^{TH}
		5.5 IN 4^{TH}	8.5 IN 12^{TH}	4 IN 4^{TH}	7.5 IN 12^{T}	4.5 IN 4^{TH}	9.5 IN 12^{TH}
		5.5 IN 5^{TH}	8.5 IN 13^{TH}	4.5 IN 5^{TH}	6.5 IN 13^{TH}	5 IN 5^{TH}	8.5 IN 13^{TH}
		5.5 IN 6^{TH}	9 IN 14^{TH}	5 IN 6^{TH}	7.5 IN 14^{TH}	5 IN 6^{TH}	8.5 IN 14^{TH}
		7-8	15-18	6-8	15-18	6, RARELY 9	17-19
3. ii.	height: length of chamber	1: 0.5 in inner whorl		1: 0.8 in inner whorl		1: 0.5 in inner whorl	
		1: 0.8 in middle whorl		1: 1 to 1: 1.3 in middle whorl		1: 1.7 IN MIDDLE WHORL,	
		1: 1 or 1: 1.2 in outer whorl		1: 1 to 1: 1.3 in middle whorl		1: 1 to 1: 1.2 in outer whorl	
4.	proloculous*	bilocular, subspherical protoconch = sub-ellipsoidal deuteroconch		apparently bilocular subspherical; P > D		BILOCULAR, SUBELLIPSOIDAL P > SUB-SPHERICAL D	
5. i.	septum*	thin, almost upright near the base, distal part almost straight		moderately thick, weakly slanting near base, weak bend at distal part		THICK, ALMOST UPRIGHT near base, distal part markedly bends.	
ii.	chamber top*	nearly flat		weakly curved		markedly curved	

Serial No	Distinctive character*	*N. discorbinus*		*N. beaumonti*		*N. stamineus*	
		A-form	B-form	A-form	B-form	A-form	B-form
6.	stolon (Av. of 3 specimens)	fine to medium, 6-9		fine, a few		COARSER, 7-8 IN A SEPTUM	
7.	spiral canal: number in the marginal cord*	3 – 5 fine canals		1 – 2 mod. thick canals		2 – 4 thick canals	
8.	relation of septal canal with the proximal spiral canal	high angle cross-cutting		nearly right angle cross cutting		bending to merge with the proximal canal	
9.	foramina* (at late part) i. peripheral view	low, wide, slit-like gap at septal base		high, narrow gap		high, narrow gap	
	ii. equatorial view	thin gap at septa base		moderate wide gap		moderate wide gap	
10.	septa base	narrow,varying width,'u' shape with round tip, hanging on whorl wall.		uniform width, thin; tip, hanging' markedly on whorl wall		width varying,'u'shape with round tip,'hanging' on whorl wall.	
11.	space between distal part of septa & whorl wall*	subtriangular narrow uniform		subtriangular apparently uniform		subtriangular,area varies	
D.	**Axial section**						
1.	marginal cord	thick, about half the height of chamber; about about 10 spiral canals and a number of radial canals as pores seen on the distal surface		thin, regular, about¼th the height of a chamber spiral canal on the distal surface are lesser		varying, thickest at the-central part; strongly developed spiral canals about 5 in number on the distal surface	
2.	alar prolongation*	narrow, rarely continues across the polar area		open, continuous across the polar area		Narrow, difficultly continues across the polar area	
3.	spiral lamina	moderately thick, almost equal to marginal cord		thin, slightly thicker than the marginal cord		varying in thickness, distinctly thicker than the marginal cord	
E.	**Split test**						
	perforation in spiral sheet	uniform		uniform		in cluster	

Tab. 4

Nummulites discorbinus (Schlotheim, 1820)

Pl.1, figs 1-9, 11-14, 17

1820 *Lenticulites discorbinus* Schlotheim, p.30, not figured

1850 *Nummulina discorbina* - d' Archiac, p.236.

1853 *Nummulites discorbina* - d' Archiac & Haime, p.140-141, pl. ix, figs 2, 2a-f, 3.

1928 *Nummulites discorbina* var. *libyca* Checchia-Rispoli, p.2, pl. 1, figs 4-8.

1954 *Nummulites discorbinus* - Smout, p.77-79, pl.xiii, figs 4-6 (non fig. 7).

1966 *Nummulites discorbinus* - Sirotti, p. 67, pl. 27, figs 10-12.

1967 *Nummulites discorbinus* var. - Arni, p. 45, pl. 2, figs A5-A5e

1972 *Nummulites discorbinus* - Blondeau, p. 47, pl. 18, figs 15-21.

1981 *Nummulites discorbinus* - Schaub, p.134, pl. 52, figs 51-68, chart 14, fig. m.

1990 *Nummulites discorbinus* - Samanta, Bandopadhyay and Lahiri, p. 15-16, pl. 2, figs. 12,14,16, 18, 19, 20,21, pl. 5, fig. 12; (non pl. 2, figs. 13, 15, 17 & 22).

1995 *Nummulites discorbinus* - Racey, p.41-42, pl.2, figs 29-30, text fig.35 (non pl.2, fig. 31).

Material. From the three locations, 125 individuals of both generations including 7 equatorial, 3 axial and 1 tangential sections of B-form, 33 equatorial, 5 tangential and 15 axial sections of A-form and a number of split and random sections of both generations are available.

Remarks. The species is characterized by inflated lenticular test with bluntly rounded peripheral margin, fine radial almost straight septal filaments, fine transverse trabecules, small polar pustule (A-form), tight spire, almost straight thin septa at high angle near base, thick marginal cord with a number of subparallel spiral

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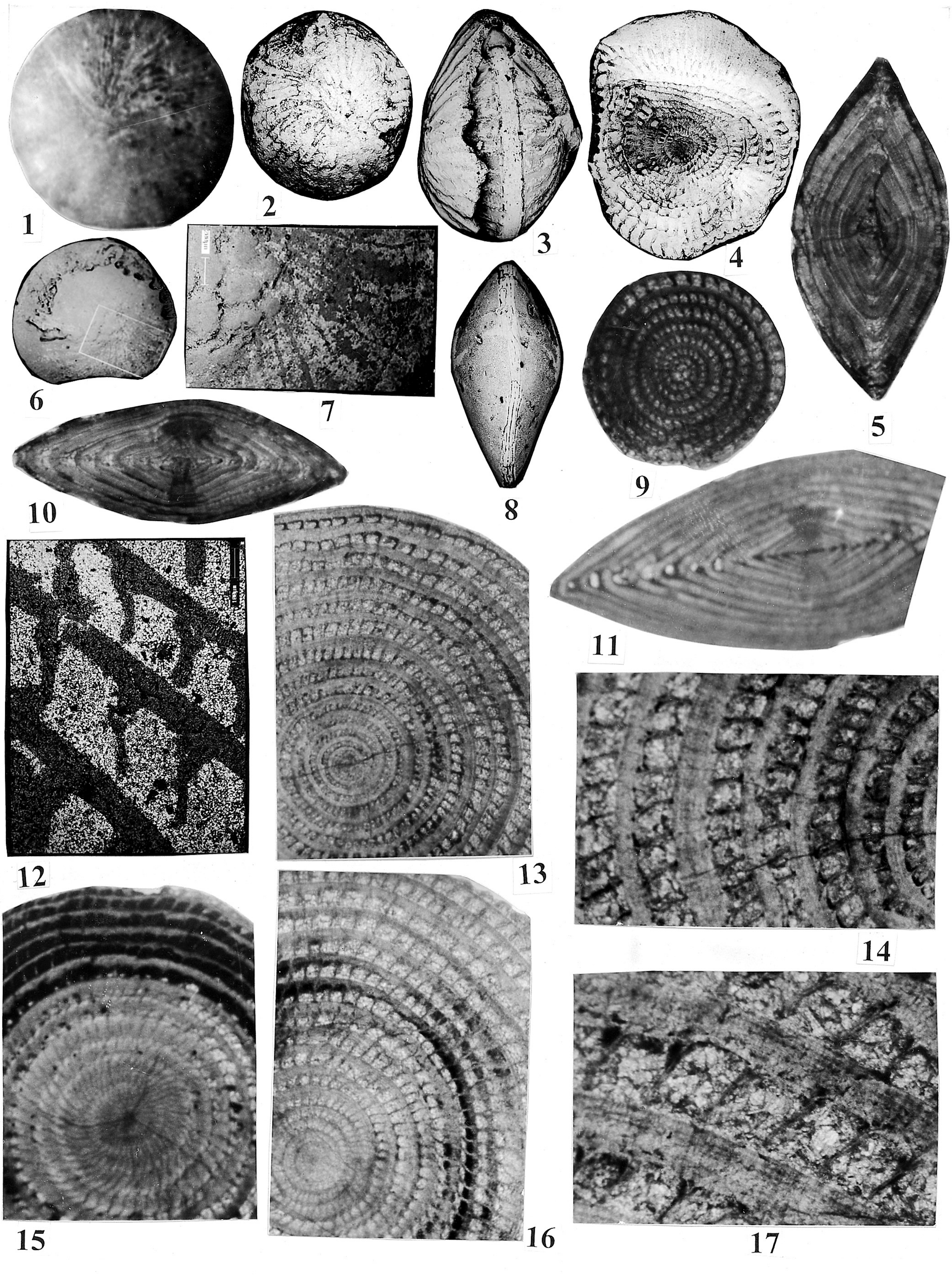
PLATE 1

Nummulites discorbinus (Schlotheim)

Fig. 1 - external polar view, B- form, x4.5, s. no. 99a, sl.I. Fig. 2 - external polar view, A-form, x11, s.no.99, sl.I. Fig. 3 - external peripheral view, A-form, x22, s. no. nil, Vagalkhod, showing strong marginal cord with longitudinal grooves and low foramina. Fig. 4 - eroded B-form showing polar pillar and faint transverse trabecules, x 4.7, s. no. nil, Vagalkhod. Fig. 5 - axial section, A-form, x.12, s,no. T93, sl.II. Fig. 6 - external polar view A-form, x 9. Fig. 7 - enlarged part of specimen in fig.6, x 40, showing fine trabecules s. no. T96, Tadkesvar. Fig. 8 - external peripheral view, A-form, x11, s. no. 45, sl. III. Fig. 9 - almost equatorial section, A-form, x8.3, s.no.100, sl.I. Fig. 10 - axial section of a transitional individual, A-form, with small proloculus, x11, s. no. nil, Vagalkhod. Fig. 11 - axial section, B-form, x8.3, s. no.100, sl.I. Fig. 12 - equatorial section (in part), x 55, A-form, s. no.49, sl.III. Fig. 13 - part of a nearly equatorial section, B-form, x 10, s.no.T94, sl.II. Fig. 14 - equatorial section (in part), B-form, x33, s. no. nil, Vagalkhod. Fig. 15 - transitional form, tangential section showing regular septal filaments but variation in marginal cord, B-form, x10.8, s. no. T96, sl.II. Fig. 16 - nearly equatorial section of a transitional form with flat chamber tops and varying thickness of whorl wall, B-form, x 10, s. no.100, sl.I. Fig. 17 - equatorial section (in part), B-form, x43, s. no.T94, sl.II.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(longitudinal) canals, higher than long chambers, thin alar prolongations, buried polar pillars, low foramina and a medium bilocular proloculus (diameter 0.3- 0.4 mm) having protoconch almost equal to the deuteroconch. A septal canal often subdivides the small subtriangular space and intrudes the whorl wall over a short distance maintaining almost the same trend.

D'Archiac & Haime (1853) for the first time illustrated the species with distinct characters of the canal system. Although no mention is made about transverse trabecules, their faint development is seen in the illustration (d'Archiac & Haime 1853, pl ix, fig. 2). *Nummulites discorbina* var. *libyca* Checchia-Rispoli (1928), a homonym of *Nummulites libyca* Prever, in its microspheric forms contains 22-26 septal filaments in one quarter, faint transverse trabecules, about 18 whorls of which the 10^{th} one (approx.) has 25 chambers in one quarter, and the nearly equatorial section of the last three whorls shows longer than high chambers and low foramina. From the characters of septa, whorl wall and regularity of spire this form is considered a synonym of *N. discorbinus* (Schlotheim), but Schaub (1981) has elevated it to a new species, *Nummulites cyrenaicus* Schaub, on consideration of preoccupation of the name '*libyca*'. Schaub (1981) from Libya, Aquitaine, Spain and Southern Alps, and Samanta et al. (1990) from Kutch have shown a wide variation in *N. discorbinus*. The microspheric form from Oman with greater number of chambers in specified whorls and very thin marginal cord (Racey 1995, pl. 2, fig. 31) seems to be a transitional form. In the studied population a variation occurs in tightness of spire, thickness of marginal cord, number of spiral canals, clarity of transverse trabecules, number of chambers in a specified whorl and presence or absence of polar pustule. The ratio of diameter (d) to thickness (t) ranges between the values of the European forms and the forms of the Middle East Asia. The number of septal filaments appears slightly less compared to the two regions. Although a number of subspecies and varieties have been erected but none of them shows any significant difference from *Nummulites discorbinus*, and some of them are also inadequately described. Thus, *Nummulina discorbina* var. a, *minor* d'Archiac (d'Archiac 1850, p. 236) and *Nummulina discorbina* var. *minor* de la Harpe (de la Harpe 1926, p. 38) are not provided with type figures; *Nummulina discorbina* var. b, *minima* d' Archiac is described on immature biconical specimens (d' Archiac 1850, p.236); *Nummulite discorbina* var. *la harpei* Martelli was created on only one equatorial section (Martelli 1902, pl. 6, fig. 5); and *N. discorbina* var. *rozloszniki* Thalmann was based exclusively on the Rozlozsnik's type illustrations (Thalmann 1952, p. 983).

Stratigraphic range. The reported range is from lower to upper part of middle Kirthar (Vredenburg 1906), middle Lutetian to Bartonian (Sirotti 1966), middle Lutetian to lower Biarritzian (Schaub 1981; Racey 1995), and *Globigerapsis beckmanni* Zone (Samanta et al. 1990). In the study area *N. discorbinus* ranges from P13 Zone to P14 Zone indicating upper Middle Eocene age. It is restricted to *Nummulites discorbinus* Zone, in the lower part of which it occurs in the association of *N. beaumonti*, *N. atacicus*, *N. pinfoldi*, *N. boninensis*, *N. globulus*, and *N. vicaryi*, and towards the upper part *N. stamineus* and *Truncorotaloides topilensis* accompany it.

Distribution. It has been recorded from the Apennine of Central Italy (d'Archiac & Haime 1853; Checchia-Rispoli 1925), Northern Italy (Sirotti 1966), Spain, Aquitaine and Southern Alps (Schaub 1981), Libya (Arni 1966), Adriatic (Blondeau 1972), Somalia (Silvestri 1939), Egypt (d' Archiac & Haime 1853), eastern Saudi Arabia (Sander 1962), Qatar Peninsula (Smout 1954), Oman (Rozlozsnik 1929; Racey 1995), Pakistan (Vredenburg 1906) and western Indian basins of Cambay and Kutch (Mohan 1982; Samanta et al. 1990). The occurrences reveal its distribution in the Tethyan Province.

Nummulites beaumonti d'Archiac and Haime

Pl. 2, figs 1-14

1853 *Nummulites beaumonti* d'Archiac & Haime, p.133-134, pl. VIII, figs 1a-e, 2,3.

1883 *Nummulites subdiscorbinus* de la Harpe, p.185, pl. XXXII, Figs. 8-15.

1926 *Nummulites beaumonti* - Nuttall, p. 130-131, pl. 1, figs 4&5.

1940 *Nummulites beaumonti* - Davies, p.206-209, pl. 9, figs 1-9.

1952 *Nummulites migiurtina* Azzaroli; p. 120, pl. 10, figs 1-4 (non fig. 2a).

1959 *Nummulites beaumonti* - Nagappa, p. 180, pl. 8, fig. 17; pl. 9, figs 1-2 (non p. 178, pl. 5, fig. 2; p. 180, pl. 8, figs 15,16).

1966 *Nummulites beaumonti* - Sirotti, p. 66-67, pl. 27, figs 8-9, text-fig. 3.

1981 *Nummulites beaumonti* - Schaub, p. 135, pl. 53, figs 17-19, 22-25, tab. 14, fig. *p*.

1990 *Nummulites beaumonti* - Samanta, Bandopadhyay & Lahiri, p. 21, pl. 2, figs 7-8, 11; pl. 5, figs 10-11, (non pl. 2, figs. 9-10).

1995 *Nummulites beaumonti* - Racey, p.34-35, pl.5, figs 15-17, 19, Text- fig. 26.

Material. From the three locations, 138 individuals of both generations including 9 equatorial, 4 axial, 2 tangential sections of B-form, 33 equatorial, 16 axial, 5 tangential sections of A-form and a number of split and random sections of both the generations are available.

Remarks. *Nummulites beaumonti* is characterized by inflated lenticular test, acute peripheral margin, radial septal filaments slightly curving at the polar part, strong transverse trabecules, tight spire, markedly slant septa; chambers of mature whorls having length nearly equal to height, uniform whorl wall containing a few spiral canals including a thick proximal canal, fairly wide alar prolongations, thin marginal cord, buried polar pillars, moderately high foramina and moderately large bilocular proloculus (diameter 0.275 mm – 0.475 mm) having protoconch larger than the deuteroconch. The septal canals intrude into the marginal cord through the subtriangular space maintaining the same trend.

D'Archiac & Haime (1853) while creating the species showed variation in the test inflation, peripheral margin, canal system and thickness of septa. Vredenburg (1906), however, opined that the variation in the d'Archiac & Haime's (1853) material might partly be due to their dealing with immature specimens of *N. gizehensis* as *N. beaumonti*. Nuttall (1926) while describing the species from Baluchistan province of Pakistan did not provide an axial section. Davies (1940) disagreed with Nuttall s (1926) identification of *N. beaumonti* as the diagnostic characters like transverse trabecules and buried polar pillars are lacking. In support of *Nummulites migiurtina* Azzaroli from Somaliland, Azzaroli (1952) illustrated some forms, which belong to *N. beaumonti* B-form (Azzaroli 1952, pl. 10, fig. 1a & figs 1-4) and *N. pinfoldi* A-form (Azzaroli 1952, pl.10, fig. 2a). Some of the forms from Kutch (Samanta et al. 1990, pl. 2, fig.7, and pl. 5, fig.10) have characters both of *N. discorbinus* and *N. beaumonti*. Racey (1995, pl. 5, figs. 15 & 19) illustrated a megalospheric form, which is not uniform in its thickness of the marginal cord. In the study material a variation occurs in the density of transverse trabecules, heights of polar pillar, character of chamber top, number of chambers in a specified whorl and in the height of foramina.

Stratigraphic range. The reported range is upper middle Kirthar (Lutetian) (Vredenburg 1906), highest Middle Eocene to Upper Eocene (Smout 1954), middle Lutetian to early Biarritzian (Schaub 1981), and middle part of *Globigerapsis beckmanni* Zone to the top of *Truncorotaloides rohri* Zone (Samanta et al. 1990). In the study area *N. beaumonti* is restricted to P14 Zone, where it first appears in the *Nummulites discorbinus* Zone in association with *N. discorbinus*, *N. boninensis* and *N. pinfoldi* and ranges into the *Nummulites stamineus* Zone to occur with *N. stamineus*, *N. biarritzensis, N. pengaroensis, N. vicaryi* and *Truncorotaloides rohri* indicating upper Middle Eocene interval.

Distribution. It has been recorded from Somaliland (Azzaroli 1952), Apennines of Central Italy (d'Archiac & Haime 1853), Northern Italy (Sirotti 1966, Papazzoni & Sirotti 1995), Egypt (d'Archiac & Haime 1853), Libya (de la Harpe 1883), Pakistan (Vredenburg 1906; Nuttall 1926; Davies 1940; Nagappa 1959), and Burma (Davies 1940). The Indian occurrences include Kutch (Samanta et al. 1990), Surat and Bharuch (Rao 1941; Nagappa 1959), Subathu (d'Archiac & Haime 1853) and Meghalaya (d'Archiac & Haime 1853; Nagappa 1959).

Nummulites stamineus Nuttall

Pl. 3, figs 1, 3-13, 16-17; Pl. 2, fig. 17

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

1929 *Nummulites discorbina* (Schlotheim) var. *major* Rozlozsnik, p.123-124, pl. 6, figs 16 & 25.

1930 *Nummulites discorbina* var. *major* - Nuttall & Brighton, p. 51, pl. I, figs 9,10.

1967 *Nummulites discorbina* – Arni, p.45, pl.2, figs. A4 – A4 – e.

1990 *Nummulites stamineus* - Samanta, Bandopadhyay & Lahiri, p. 16-20, pl.1, figs 1,3,6,10 (non figs 2,4,5 & 7).

Material. From the three locations, 196 individuals of both generations including 32 equatorial, 7 axial, 2 tangential sections of B-form, 38 equatorial, 15 axial, 3 tangential sections of A-form and a number of split and random sections of both generations are available.

Description. *Microspheric form (B-form)*. Test medium to large, lenticular, biconvex, peripheral margin acute with a round tip, polar part flattened, septal filaments radial locally irregular, curved, transverse trabecules rudimentary to extremely faint. In tangential section irregular septal filaments contain rudimentary transverse trabecules. In equatorial section spire slightly irregular, moderately tight, whorl wall thicker in the middle or at the late part of spire; equatorial chambers subrectangular to spatulate in the early part, higher than

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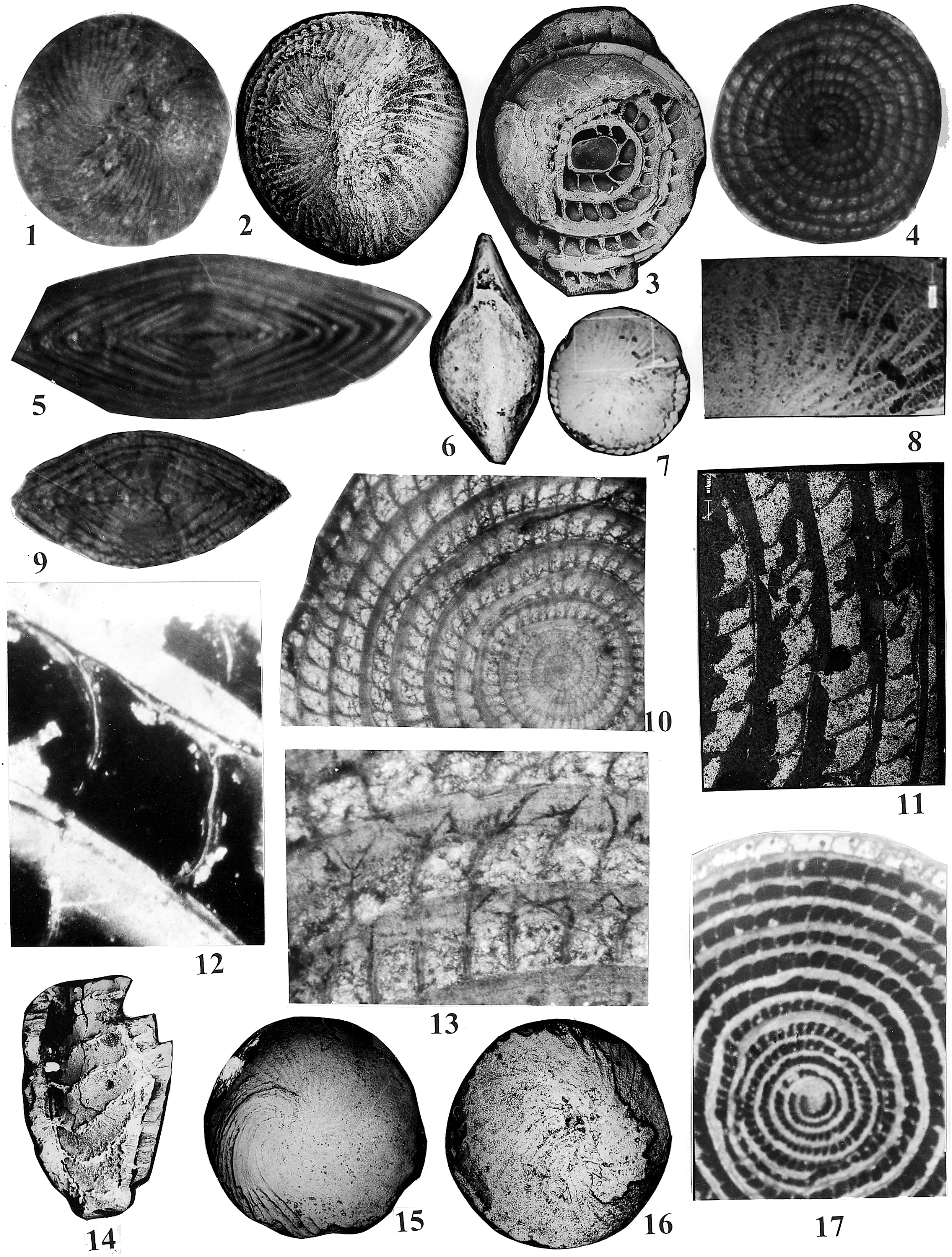
PLATE 2

Nummulites beaumonti d' Archiac and Haime

Fig. 1 - external polar view, B-form, x 4.5, s. no.100, sl.I. Fig. 2 - external polar view, B-form, sl.II, s. no. T98, x 4.1. Fig. 3 - split test showing part of true equatorial section, s. no. nil, x30, Tapi River. Fig. 4 - nearly equatorial section, A-form, x 9.5, s. no.T95,. sl.II. Fig. 5 - axial section, B- form, s. no. 49, x10, sl.III. Fig. 6 - external peripheral view, A-form, x37.5, s. no. nil, Tarkesvar. Fig. 7 - external polar view, A-form, x6.5, s. no.49, sl.III. Fig. 8 - part of test in fig.7 enlarged, x36.5. Fig. 9 - axial section, A-form, sl., s. no.99a, x11, sl. I. Fig. 10 - nearly equatorial section, B-form, x 12, s. no.102, sl.I. Fig. 11 - equatorial section (in part) with proximal spiral canal, B-form, x 17, s. no.48, sl. III. Fig. 12 - equatorial section (in part) showing subtriangular space, A-form, x85, s. no.102, sl.I. Fig. 13 - equatorial section (in part), B-form, x42, s. no.102, sl.I. Fig. 14 - *Nummulites* sp. aff. *N. beaumonti* d' Archiac & Haime, B-form, x17.3, part of split section showing well developed proximal spiral canal, s. no. nil, Tapi River. Fig. 15 - external polar view, strongly curved septal filaments grading to radial, x 11, s. no. nil, Tarkesvar. Fig. 16 - external polar view, showing curved septal filaments with incipient transverse trabecules, x11, s. no. nil, Vagalkhod. Fig. 17 - *Nummulites stamineus* Nuttall, nearly equatorial section showing irregular spire, B-form, x10, s. no nil, Tarkesvar.



long and also equate at the late part, chamber top curved; septa short, moderately thick, almost at right angle with the whorl wall near the base, distal part curved; thin septal canal bends inward at the distal part to join the proximal spiral canal; spiral radial and diagonal canals are a few and thick; subtriangular space intruded by septal canal is of varying shape and size; height of foramina increases with ontogeny. In axial section higher than wide equatorial chambers gradually increase; alar prolongation between thin lateral walls moderately wide, marginal cord varies in thickness in the middle or late part, subconical polar pillars short, buried.

Megalospheric form (A-form). Test lenticular biconvex, peripheral margin acute with round tip, periphery often weakly bent; septal filaments largely radial, locally irregular, weakly curved; transverse trabecules rudimentary, occasionally indistinct; polar pustule indistinct. In equatorial section spire irregular, early tight, later slightly loose; whorl wall thick at the middle or late part of spire; proloculus bilocular, large, 0.37 mm – 055 mm diameter, protoconch subcircular, larger than the semi-circular deuteroconch, separating wall thin inward curving; early chambers small subrectangular subcircular and spatulate, longer than high, later chambers subrectangular to subrounded, higher than the long, gerontic chambers may be longer than high; chamber top curved; septa moderately thick, perpendicular at base, distal part leaned inward; foramina high at late part resulting in 'hanging septa'; septal canal thin, spiral canal a few and thick accompanied by radial and diagonal canals. In axial section equatorial chambers with almost equal height and width gradually increase in size, alar prolongation moderately wide, marginal cord varying in thickness; polar pillars short, buried.

Remarks. In the studied material *Nummulites stamineus* is distinguished by tiny transverse trabecules, curved chamber top and the irregularities in septal filaments, spire, whorl wall and marginal cord. *Nummulites discorbinus* and *N. beaumonti* have flatter chamber tops, more prominent transverse trabecules and more regularity in septal filaments, spire, whorl wall and marginal cord. The number of spiral canals is minimum in *N. stamineus*. A variation occurs in test inflation, peripheral margin, septal filaments, tightness of spire, thickness of whorl wall, height of polar pillar and number of chambers in specified whorl.

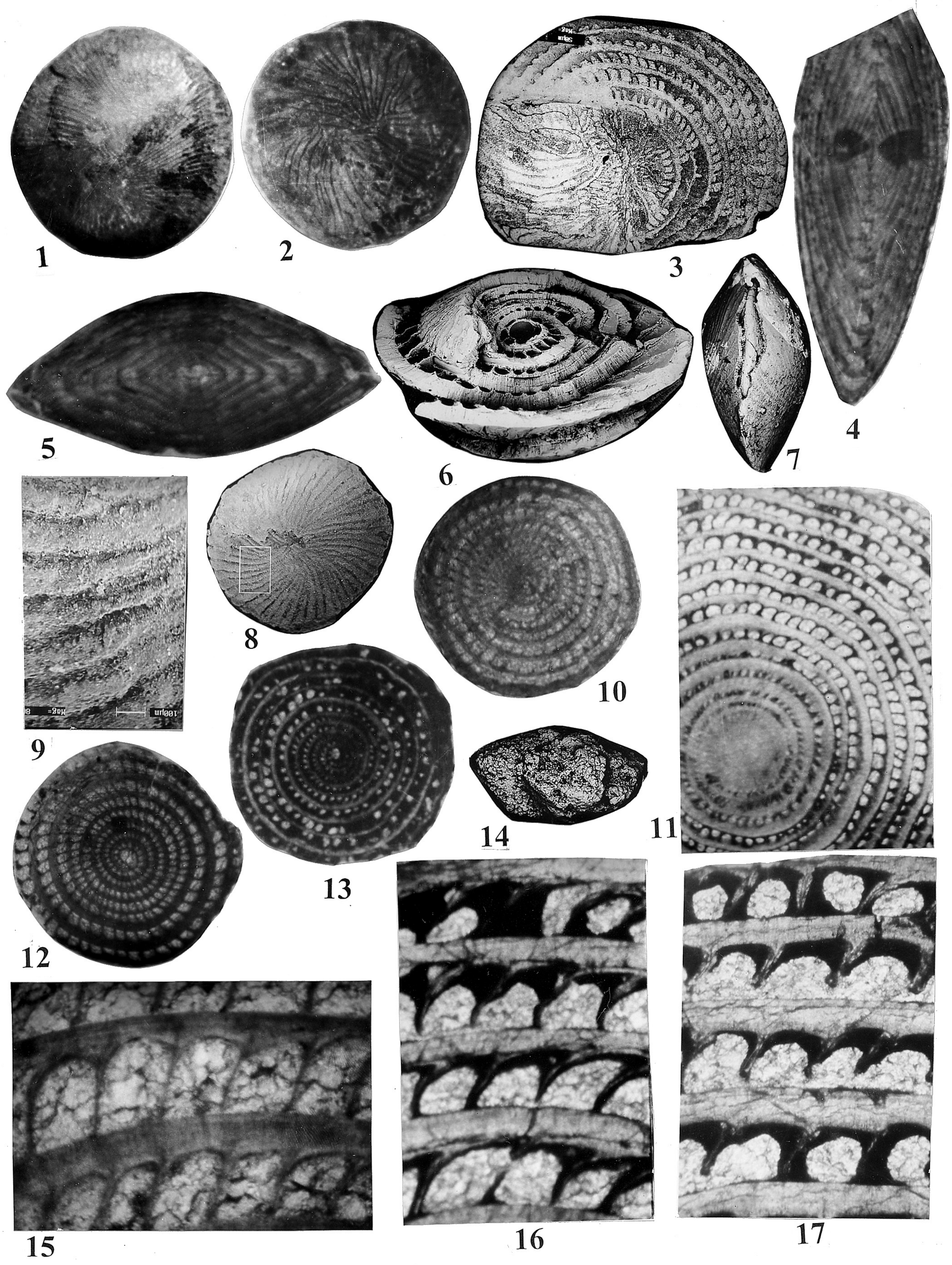
Nuttall (1926) found his species different from *N. discorbinus* on being 'larger size and less inflated'. Sudies by Reiss & Hottinger (1984), Hallock & Glenn (1986), Racey (1992, 1995), Pecheux (1995), Trevisani & Papazzoni (1996) and Papazzoni (1998) indicate that the external test shape, diameter, thickness and ornamentation are generally influenced by environment. Nuttall (1926) used the presence of 'numerous whorls and septa' in *N. stamineus* to differentiate it from *N. atacicus*, *N. kelatensis* and *N. discorbinus*. Although he noted his species closely related to *N. discorbinus*, he did not show the relationship based on whorl and septa. Smout (1954), however, did not find any significant difference between *N. stamineus* and *N. discorbinus* although the axial section of *N. discorbinus* (Smout 1954, pl.13, fig.7) shows distinct variation in the thickness of marginal cord. Sengupta (1965 a,b) also failed to recognize *N. stanineus* in the Kirthar beds from Kutch. It appears that these workers did not give due credence to the distinctive features of *N. stamineus*. While redescribing it from Kutch, Samanta et al. (1990) illustrated a megalospheric specimen having large polar pustule and radially straight septal filaments containing structures resembling well-developed transverse trabecules. This form, as revealed from the present study, does not belong to *N. stamineus*. Rozlozsnik (1929) created *N. discorbina* (Schlotheim) var. *major* with two illustrations of B-form; in the external view (pl. 6, fig. 16) the radial septal filaments are with obscure transverse trabecules, and in the equatorial section (pl. 6, fig. 25) the characters of chamber, whorl wall and spire closely resemble those of *N. stamineus*.

Stratigraphic range. The reported range is lower part of Middle Kirthar (Lutetian) (Nuttall 1926), middle part of Middle Eocene to Upper Eocene (Nagappa 1959) and *Truncorotaloides rohri* Zone of late Middle

PLATE 3

Nummulites stamineus Nuttall

Fig. 1 - external polar view, B-form, x 3.7, s. no.102, sl. I. Fig. 2. *Nummulites atacicus* Laymerie, external polar view, A-form, x 15, s. no.95, sl.I, with complex septal filaments as in *Nummulites stamineus*. Fig. 3. external polar view of a split B-form, x8, s. no. nil, Vagalkhod. Fig. 4 - axial section, B- form, s. no. 52, x10, sl.III. Fig. 5 - axial section, A-form, x 15, s. no.52, sl.III. Fig. 6 - split test, A-form, locally exposing features of true equatorial section, sl.II, s.no.T99, x30. Fig. 7 - external peripheral view showing high foramina, A-form, x15, s. no.52, sl. III. Fig. 8 - external polar view, A-form, x9.5, sl.II, s. no.T98. Fig. 9 - enlarged part of the surface, x57. Fig. 10 - *N. beaumonti* d' Archiac & Haime, A-form, tangential section, x9.5, s. no.T98, sl.II. Fig. 11 - nearly equatorial section (in part), B-form, x9.5, s. no.100, sl.I. Fig. 12 - tangential section, A-form, x.9.8, s. no.52, sl.III. Fig. 13 - nearly equatorial section, A-form, s. no.100, x9.5, sl. I. Fig. 14 - *Truncorotaloides rohri*, oblique side view, x120, s. no. 102, sl.I. Fig. 15 - equatorial section (enlarged part of pl.1, fig.16), B-form showing straight septal canals in the whorl wall, x.50, s. no 100, sl.I. Fig. 16 – equatorial section, B-form, x.50, s. no 100, sl.I. Fig. 17 – equatorial section, A-form, x.50, sl.I., s. no 100.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Eocene (Samanta et al. 1990); in the study area the species ranges from the upper part of P13 Zone to P14 Zone indicating upper Middle Eocene age. It first appears in association with *N. discorbinus*, *N. beaumonti, N. boninensis* and *Truncorotaloides topilensis* at the upper part of *Nummulites discorbinus* Zone; in the overlying *Nummulites stamineus* Zone it finds new association with *N. biarritzensis, N. boninensis, N. beaumonti, N. pengaroensis, N. vicaryi* and *Truncorotaloides rohri* (Pl. 3, fig. 14).

Distribution. Nuttall (1926) described the species from Kutch and Pakistan. In this study its occurrence is extended to Oman (Rozlozsnik 1929), Sirte Basin of Libya (Arni 1967), Somaliland (Nuttall & Brighton 1931) and Cambay basin.

Discussion of results

The main points that emerged from the comparative study of the parameters listed in Tables 5 & 6 are as follows.

1. *Nummulites stamineus* has the largest test diameter, highest ratio of diameter to thickness of B-form (3.12, compared to 2.79 in *N. discorbinus* and 2.73 in *N. beaumonti*); largest proloculus and largest protoconch, maximum height of foramina in the 5th and 6th whorls of A-form, highest ratio of chamber height to whorl wall thickness in the middle (4th) and late (6th) whorl in A-form, highest number of septal filaments in both A- and B-form and lowest ratio of chamber height to chamber length in the middle (4th) and late (6th) whorl of A-form. Moreover, its B-form has maximum number of whorls and maximum number of chambers in the later whorls (5th whorl onward).

2. *Nummulites discorbinus* has smaller proloculus with lowest ratio of protoconch to duteroconch, and highest ratio of the height to length of a chamber except for the last whorl. The number of chambers in the later whorls of A-form is greater compared to *N. stamineus*.

3. *Nummulites beaumonti* has the least number of septal filaments and lowest number of chambers in the later whorls; its proloculus size ranges between the values of the other two species.

The study largely confirms the observations of previous workers on the distinctive characters of the three species and reveals some common trends among them such as the diameter of B-form is almost double the diameter of the respective A-form, the ratio of test diameter to thickness is usually more in B-form than the respective A-form, and the number of septal filaments is more than double in the B-form compared to the respective A-form. Moreover, a gradual increase in the height of foramina and marginal decrease in the height of chambers are recorded with ontogeny. The latter may lead to square and spirally long chambers in the whorls of the late stage.

The taxomonic status of *Nummulites stamineus* remained open for discussion since its erection. Despite its confusion with the members of the *N. discorbinus-N. beaumonti* group and consequent effect on the Middle-Upper Eocene biostratigraphy no detailed study has been carried out to resolve the issue of its identity. The present study indicates that it is a distinct species in the Cambay Basin, where it occurs in association with other radiate *Nummulites* close to the Middle-Upper Eocene boundary and has helped in understanding the diverse concepts on *N. discorbinus* and *N. beaumonti*. Workers from North Africa, Europe and Middle East Asia usually did not recognize *N. stamineus*, probably because of its incomplete description, apparent lack of distinctive characters and possession of external features similar to those of the other two forms. There occur a number of identical external characters including test shape, peripheral margin, polar character and septal filaments in *N. stamineus*, *N. beaumonti* and *N. discorbinus*. Whether the apparent similarity in these characters is due to the influence of the shelf environment of the Cambay Basin is not yet known. Studies by Reiss & Hottinger (1984), Hallock & Glenn (1986), Racey (1992, 1995), Pecheux (1995), and Papazzoni (1998) concerning the influence of ambient environment on external characters of foraminifera might be helpful for careful consideration of external characters in taxonomic use. The nature of transverse trabecule – an external feature of great taxonomic value, however, differentiates the other two species from *N. stamineus*. The separate identity of *N. stamineus* is more pronounced from the distinctive internal characters in true equatorial sections, mode of occurrence, stratigraphic range and geographic extent. With high foramina in the late part, thick canal, distinct curving of chamber top, irregularity in spire and occasional thick whorl wall in the middle or late part of the spire *N. stamineus* is morphologically distinct. Among the three species it commonly occurs as B-form with largest test and occasionally as A-form with largest proloculus. Contrary to *N. discorbinus* and *N. beaumonti*, in which the number of B-form is less than A-form, the prevalence of B-form in *N. stamineus* (Nuttall 1926; Samanta et al. 1990) is yet to be satisfactorily explained. Plastogamy was recorded in the life history of the associated *N. boninensis* (Mukhopadhyay 2002; 2003b). Similar life cycle in *N. stamineus* might have given rise to a large number of B-form. Its test size and the size of proloculus in A-form, when compared with those of *N. discorbinus* from successive stratigraphic levels reflect a relatively advanced stage in the evolutionary development, a fact noted earlier by Blondeau (1972), Samanta (1981), Racey (1995) and Papazzoni (1998) for other species of Middle Eocene

Tab. 5 - Measurements of B-form of *N. discorbinus*, *N. beaumonti* and *N. stamineus* from three locations of the study area; VS= Vagalkhod, TS= Tarkesvar & TR= Tapi River

Sl no	species	a. *N. discorbinus*			No of Obs.	b. *N. beaumonti*			No of Obs.	c. *N. stamineus*			No of obs.	Remarks	
	Parameter locality	VS	TS	TR		VS	TS	TR		VS	TS	TR			
i	diameter				19				28				115		
	Min	6.8	6,9	6.9		8.7	8.4	8.5		8.5	7.4	6.8		a	9.6
	Max	11	11.5	12.05		12	11.7	10.8		14	12.5	13		b	8.9
	Av	9.6	9.1	10.1		9.2	8.5	9.1		11	9.7	10.5		c	10.4
ii	Thickness				do				do				do		
	Min	2.35	2.2	2.3		2.2	2.3	2.25		3.5	3.0	2.2		a	3.44
	Max	4.1	4.3	4.2		4.3	4.1	4.28		5	4.5	4.7		b	3.26
	Av	3.5	3.43	3.4		3.35	3.25	3.18		3	3.5	3.2		c	3.23
iii	Septal filaments in one qtr				do				do				do		
	Max	20	22	20		18	19	23		18	20	21		a	28.33
	Min	35	32	31		29	32	31		41	37	38		b	24.66
	Av	30	29	26		23	27	24		30	32	24		c	28.66
iv	Number of whorls in a test				7				9				32		
	Min	14 in 7.4 mm				13 in 8.5 mm				14 in 7.5 mm				a	14 in 10
	Max	16 in 10.7 mm				17 in 11 mm				20 in 12.03 mm				b	13 in 8.5
	Av	13 in 9.3 mm				15 in 9.8 mm				15 in 10.05 mm				c	15 in 10
v	Number of chambers in 5th whorl				7				9				32		
	Min	39	40	41		29	35	35		50	42	44		a	41.6
	Max	46	43	44		36	37	39		51	50	49		b	34
	Av	40	43	42		34	35	35		48	45	47		c	46
vi	-Do- in 6th whorl				7				9				37		
	Min	44	43	44		38	33	38		45	48	46		a	43.66
	Max	44	46	45		43	44	42		51	54	52		b	42
	Av	43	44	44		43	42	41		46	51	50		c	49
vii	- Do- 7			in 7th whorl					9						
	Min	38	43	44		35	41	36		50	44	52		a	44.33
	Max	44	45	47		48	47	49		52	52	53		b	40.66
	Av	43	45	45		40	42	38		51	48	50		c	49.66
viii	- Do- 7			in 8th whorl					9				32		
	Min	51	48	46		38	39	41		47	53	54		a	52..33
	Max	56	56	59		40	39	43		57	55	57		b	40
	Av	53	53	51		39	39	42		54	54	53		c	52.66
ix	- Do- in 10th whorl				7				9				32		
	Min	65	62	62		49	51	49		56	67	61		a	64.66
	Max	69	67	71		61	55	60		82	73	67		b	54
	Av	66	65	63		56	51	55		76	70	65		c	70.33
x	- Do- in 13th whorl				7				9				32		
	Min	82	85	84		62	61	65		73	81	97		a	84
	Max	86	85	83		65	66	65		97	107	103		b	63.66
	Av	84	85	83		63	63	65		87	103	99		c	96.33
xi	-Do- in 15th whorl				7				9				32		
	Min	93	95	96		81	86	83		97	95	89		a	96.66
	Max	104	101	99		87	88	86		111	110	99		b	85.33
	Av	97	97	96		85	87	84		102	105	92		c	99.66

xii	Height/Length of chambers in qtr whorl ; minimum no. of observation 3 per whorl															
	Whorl no	5	8	10	13	15	5	8	10	13	15	5	8	10	13	15
	Min	1.3	1	1	1.25	0.8	1.4	0.9	0.77	0.3	0.46	1.5	0.5	0.85	1.1	1.1
	Max	2.5	1.8	1	1.25	0.8	1.6	2.0	1.7	1.0	0.77	2	1.3	1.57	1.5	0.8
	Av	1.8	1.4	1	1.1	0.84	1.4	1	1.2	0.9	0.6	2.0	1.0	2.0	1.4	0.8
xiii	Height of foramina in µm; minimum no of observation 5 per whorl															
	Whorl no	5	8	10	13	15	5	8	10	13	15	5	8	10	13	15
	Min	6	6	12	20	25	6	12	25	35	50	6	10	20	25	25
	Max	12	25	25	25	25	12	25	25	35	75	6	10	35	40	50
	Av	10	10	15	20	25	10	15	20	35	50	6	10	25	30	35
xiv	Chamber height/ thckness of whorl wall; minimum no of observation 3 per whorl															
	Whorl no	5	8	10	13	15	5	8	10	13	15	5	8	10	13	15
	Min	1	1.3	1	1.3	1.09	0.2	1.42	1.66	1.0	1.66	0.6	0.6	0.81	1.4	0.8
	Max	1.2	2	1.6	3.7	2.6	1.3	2.2	1.71	2.3	2.3	1.5	6.0	2.0	2.4	1.8
	Av	1.0	1.8	1.0	1.4	1.14	0.3	1.5	1.69	1.5	1.74	0.66	2.8	1.57	1.6	1.5

Sl no	species	a. *N. discorbinus*			No of Obs.	b. *N. beaumonti*			No of Obs.	c. *N. stamineus*			No of obs.	Remarks		
xv	Whorl height/ chamber height; minimum observation 3 per whorl															
	Whorl no	5	8	10	13	15	5	8	10	13	15	5	8	10	13	15
	Min	1.8	1.5	1.5	1.1	1.6	1.4	1.45	1.58	1.4	1.4	0.5	1.2	1.51	1.4	1.7
	Max	2	1.8	2	1.8	2	1.8	1.7	1.9	2	1.62	2.5	1.6	2.22	1.6	3.8
	Av	1.9	1.5	1.7	1.7	1.87	1.4	1.66	1.6	1.5	1.5	1.66	1.4	1.63	1.4	1.8

Tab. 5

Sl. no	species	d. *N. discorbinus*			e. *N. beaumonti*			f. *N. stamineus*			Remarks
Parameter/ Location		VS	TS	TR	VS	TS	TR	VS	TS	TR	Mean value
i	diameter	No of spec. 106			110			81			
	Min	3.25	3.1	3.15	3.1	3.4	3.6	3.9	3.5	3.6	d 4.85
	Max	6.0	6.0	5.9	6.0	6.5	6.2	6.2	6.1	6.5	e 4.8
	Av	4.55	4.9	5.1	4.5	5.1	4.8	4.4	4.5	4.5	f 4.46
ii	thickness	No of spec. 106			110			81			
	Min	2.35	2.2	2.3	2.1	1.5	1.6	1.8	1.7	1.7	d 2.18
	Max	3.05	3.0	3.1	2.6	2.7	2.6	2.6	2.7	2.6	e 2.2
	Av	2.16	2.18	2.20	2.3	2.4	1.9	2.3	2.5	2.5	f 2.43
iii	Septal filaments; no of spec. 56			50		40					
	Min	11	11	13	11	11	12	15	15	13	d 12.66
	Max	15	14	15	16	15	19	16	18	19	e 13.66
	Av	13	13	12	13	14	13	16	18	16	f 16.66
iv	No. of whorls; no of spec. 33				33			38			
	Min	7 whorls in 4.2 mm			6 whorls in 4.2 mm			7 whorls in 4.2 mm			d 7 whorl
	Max	8 whorls in 5 mm			8 whorls in 4.7 mm			9 whorls in 4.9 mm			e 7 whorl
	Av	7 whorls in 4.5 mm			7 whorls in 4.2 mm			8 whorls in 4.5 mm			f 8 whorl
v	Megalosphere; bilocular				bilocular			bilocular			P/D
	Protoconch (P): 0.15- 0.2 mm				P= 0.2-0.25 mm			P= 0.25-0.35 mm			d 1
	Deuteroconch (D): 0.15- 0.2 mm				D= 0.075-0.225 mm			D= 0.125-0.25 mm			e 2
	P/D=1				P/D= 1.11 – 2.6			P/D= 1.4 - 2			f 1.85
vi	Chambers in 1st whorl; spec. 17				12			18			
	Min	15	13	14	12	12	12	12	12	15	d 14
	Max	15	14	14	13	12	12	15	16	19	e 12
	Av	14	14	14	12	12	12	14	14	16	f 14.66
vii	Chambers in 2nd whorl; spec. 25				22			20			
	Min	22	22	24	20	19	20	23	21	25	d 24
	Max	31	27	25	23	22	22	28	25	28	e 21
	Av	24	23	25	21	21	21	25	23	26	f 24.66
viii	Chambers in 3rd whorl; spec. 23				23			21			
	Min	37	36	31	26	24	25	37	28	38	d 36
	Max	37	37	38	26	26	25	38	38	39	e 25.33
	Av	37	36	35	26	25	25	38	38	38	f 38
ix	Chambers in 4th whorl; spec. 33				33			38			
	Min	37	41	38	30	30	31	34	32	31	d 41
	Max	43	47	41	31	32	31	38	37	42	e 31
	Av	41	43	39	31	31	31	35	33	35	f 34.33
x	Chambers in 5th whorl; spec. 33				33			38			
	Min	42	40	38	36	33	33	38	37	39	d 41.66
	Max	42	48	41	37	37	35	41	40	39	e 35.33
	Av	42	43	40	37	35	34	40	39	39	f 39.33
xi	Chambers in 6th whorl; spec. 33				33			38			
	Min	43	42	43	37	35	38	35	30	43	d 44.66
	Max	43	43	44	37	40	41	43	46	46	e 37.66
	Av	43	47	43	37	37	39	41	42	44	f 42.33
xii	Chambers in 7th whorl; spec. 33				33			38			
	Min	37	39	41	33	38	35	43	41	43	d 43.33
	Max	49	45	48	38	38	37	44	45	43	e 36.33
	Av	43	43	44	37	36	36	43	42	42	f 42.33
xiii	Chambers in 8th whorl; spec. 7				4			3			
	Min	53	51	56	56	43	57	49	53	51	d -
	Max	61	-	-	-	57	-	-	-	-	e -
	Av	57	-	-	-	-	-	-	-	-	f -

xiv																					
wh	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	1	2	3	4	5	6
Min	1.4	1.3	1.2	2.0	2.2	1.0	0.9	0.9	1.3	0.3	1.3	1.5	1.5	1.4	1.3	1.3	1.6	1.5	1.2	0.7	1.1
Max	2	2.6	3	2.2	2.7	3	1.8	1	2	0.9	1.4	1.6	1.8	1.6	1.3	1.5	2.5	1.6	1.6	0.8	1
Av	1.5	1.7	1.9	2.1	2.4	2.5	1.5	0.9	1.4	0.8	1.3	1.5	1.7	1.5	1.3	1.4	1.7	1.5	1.3	0.8	1
xv																					
Min				12	25	12	25	30				12	12	20	30				12	12	35
Max				12	25	25	30	40				12	12	30	40				12	25	35
Av				12	25	20	35	35				12	12	25	35				12	20	30
xvi																					
Whl	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	1	2	3	4	5	6
Min	1.3	1	1.6	1.5	2.3	2	2	2	1.0	1.2	2.3	1.5	1.6	1.6	1.5	1.5	1.6	1.2	1.4	0.8	1.4
Max	2	2	1.7	1.7	3.3	3.3	2.0	5.2	2	3	2	1.8	2.5	4.5	2.6	2	2.5	1.6	2.5	1.6	2.3
Av	1	1.7	1.6	1.6	2.5	2.1	2	2.7	1.1	2.4	2.8	1.6	1.6	1.8	2.1	1.6	2.3	1.5	2.2	1.4	2.3
xvii																					
Min	1.5	0.6	0.8	1.5	1.3	1.3	1.4	1.2	1.3	1.3	1.4	1.5	1.6	1.4	1.2	1.5	1.4	1.3	1.4	1.3	1.6
Max	2	2	1.8	1.8	3.3	2.1	2.0	1.4	2	1.8	2	1.6	1.8	2.6	1.6	1.9	1.6	1.8	1.7	1.7	1.7
Av	1.7	2.0	0.8	1.5	1.5	1.4	1.4	1.3	1.4	1.6	1.7	1.5	1.7	1.9	1.3	1.6	1.5	1.6	1.6	1.6	1.7

Tab. 6 - Measurements of A-form of *N. discorbinus*, *N. beaumonti* and *N. stamineus* from three locations of the study area as in tab. 5; minimum three observations are made in a spire for parameters xiv-xvii.

Nummulites. Such progressive trend is also noted in the maximum value of some parameters like the number of whorls, number of chambers per whorl in B-form, the height of foramina in the late ontogenetic stage of A-form, and the ratio of diameter to thickness of test. These trends appear to reflect a phyletic link. Samanta et al. (1990) redescribed *Nummulites stamineus* from Kutch Basin, where it occurs along with *N. beaumonti* and *N. discorbinus*. Since the locations of the illustrated specimens are not specified in the stratigraphic column and since all of their illustrated specimens of a particular species are not accepted in the present synonymic work, this vital information could not be used as an aid for interpretation of inter-specific link, and also the stratigraphic ranges of these species provided by them (Samanta et al. 1990) can only be provisional. In the local successions of the Cambay Basin *N. stamineus* appears at the upper part of the stratigraphic range of *N. discorbinus* and thereafter co-occurs with *N. beaumonti* in the *Truncorotaloides rohri* Zone. Its occurrence extending from Cambay Basin of western India to Libya in north Africa through Kutch, Pakistan, Oman in the Middle East Asia and Somaliland in East Africa covers a small geographic extent within the kingdom of *N. discorbinus*. Neither of the two species is recorded as yet from the northern and eastern Indian basins, from where *N. beaumonti* was originally recognized. While the former two are strictly Tethyan, *N. beaumonti* has its additional presence in the western fringe of the Indo-Pacific Province.

Specimens considered morphologically intermediate between *N. discorbinus* and *N. stamineus* (Pl. 1, figs 10, 15-16; Pl.3, fig.15) occur largely in the overlapping part of the stratigraphic ranges of the two species. These forms, together with progressive trend in some internal morphologic features mentioned earlier, suggest an evolutionary development of *Nummulites stamineus* from *N. discorbinus*. However, in the absence of adequate data the first appearance of the former could not be used for biostratigraphic purpose. Therefore, the zonal boundary between the *N. discorbinus* Zone and the overlying *N. stamineus* Zone was drawn on the basis of the last occurrence of *N. discorbinus*, which appears more persistent in the area and is marked by the co-occurring *Truncorotaloides topilensis* (sample level 100 in Fig. 2a), planktonic foraminifera of great stratigraphic value. *Nummulites stamineus* sensu stricto, on the other hand, helps to fix the upper stratigraphic limit of *N. discorbinus* sensu stricto and in drawing the exact stratigraphic range of *N. beaumonti* sensu stricto by removing the existing morphological confusions in-between (Pl. 2, figs 15-16). While dealing with the stratigraphic ranges of the Tethyan *Nummulites* Serra-Kiel et al. (1998) did not take *N. stamineus* into consideration. Papazzoni & Sirotti (1995) in their biostratigraphic work also did not make a mention of this species. As a result, the stratigraphic ranges of both *N. discorbinus* and *N. beaumonti* in these works appear to have greater extent than what are presently considered. The present study indicates that *N. stamineus* being phyletically linked with and slightly younger than *N. discorbinus*, and occurring close to the Middle Eocene-Upper Eocene boundary, needs due recognition while dealing with the *Nummulites* biostratigraphy of this stratigraphic segment. This is particularly true for the upper Middle Eocene sequence of the Tethyan areas covering Cambay, Kutch, Sind-Baluchistan, Oman, Somaliland and Libya.

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