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SINGHAMINA AND *TANDONINA*, NEW FORAMINIFERAL GENERA—EVIDENCE FOR DISCORBID LINEAGE FROM THE MIDDLE JURASSIC OF JAISALMER, WESTERN RAJASTHAN, INDIA

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ABSTRACT

Two new foraminiferal genera *Singhamina* and *Tandonina* are described from Middle Jurassic rocks exposed around Jaisalmer, western Rajasthan, India. The new genera are placed under the family Duostominidae within the super family Duostominacea in view of the non-lamellar, granular calcareous wall structure and the low trochoid coiling of the test. A comparative study of the test morphology and wall structure based on Brotzen's propositions (1963), suggests that these foraminifers are the probable phylogenetic link between the Late Triassic duostominid Foraminifera and the discorbid Foraminifera of Cretaceous and younger age.

INTRODUCTION

Early Mesozoic rotaliform Foraminifera recorded by Kristan-Tollmann (1960) from the Triassic of Austria were collectively grouped under 'Praerotalioids' and assigned to the families Duostominidae and Asymmetrinidae by Brotzen (1963). He considered that Praerotalioids include the earliest known rotaliform Foraminifera which have given rise to the calcareous, lamellar, perforate Rotaliids of the Late Mesozoic and Tertiary, and the aragonitic, radial, perforate ceratobuliminids and epistominids of the Early to Late Mesozoic. In test morphology, Praerotalioids broadly resemble these Foraminifera but are easily distinguished by their wall structure and apertural characteristics.

Bathonian rocks of Jaisalmer have yielded quite a good number of Foraminifera which can be assigned to the praerotalioid group of Brotzen (1963). Though varying in their detailed morphological characters, all the forms show a low trochospiral test with nearly flat to depressed umbilical side, having an interiomarginal aperture. The test wall is calcareous, non-lamellar, granular, with or without some agglutinated foreign matter and varies from perforate to imperforate. These forms are assigned to the family Duostominidae Brotzen due to similar wall structure and rotaliform test with interiomarginal aperture. They differ from the members of the family Asymmetrinidae Brotzen as the latter are distinguished by their low trochoid test, becoming planispiral with a tendency to uncoil. In apertural characteristics and shape of their rotaliform test, however, present Jurassic forms are morphologically distinct from the known duostominid genera (e.g. *Duostomina*, *Diplotrema* and *Variostoma*) recorded from the Triassic of Austria by Kristan-Tollmann, 1960. This has necessitated erection of two new genera viz. *Singhamina* and *Tandonina* to receive the Jurassic praerotalioids from Jaisalmer. With more data coming about these Foraminifera in future, it might be possible to separate the Triassic and Jurassic genera of Duostominidae under two subfamilies as these differ essentially in the structure of their trochospiral tests and apertural features.

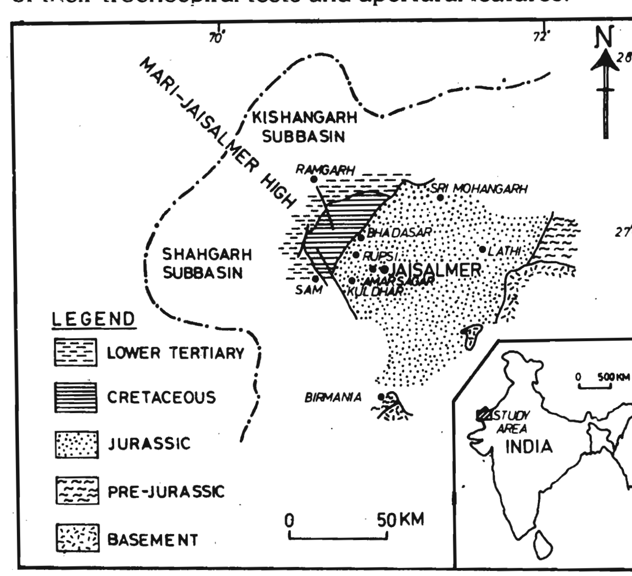

Fig. 1. Geological sketch map of Jaisalmer area. (adopted from Dutta, 1983).

MATERIAL

Jurassic rocks are widespread around the town of Jaisalmer in western Rajasthan, India (Fig. 1). Material for the present study is obtained from the Amarsagar Limestone Member of the Jaisalmer Formation exposed on a scarp facing the Jaisalmer railway station, and further west in road cuttings and rivulet sections in vicinity of Amarsagar, about 3.5 km west of Jaisalmer (Figs. 2,3).

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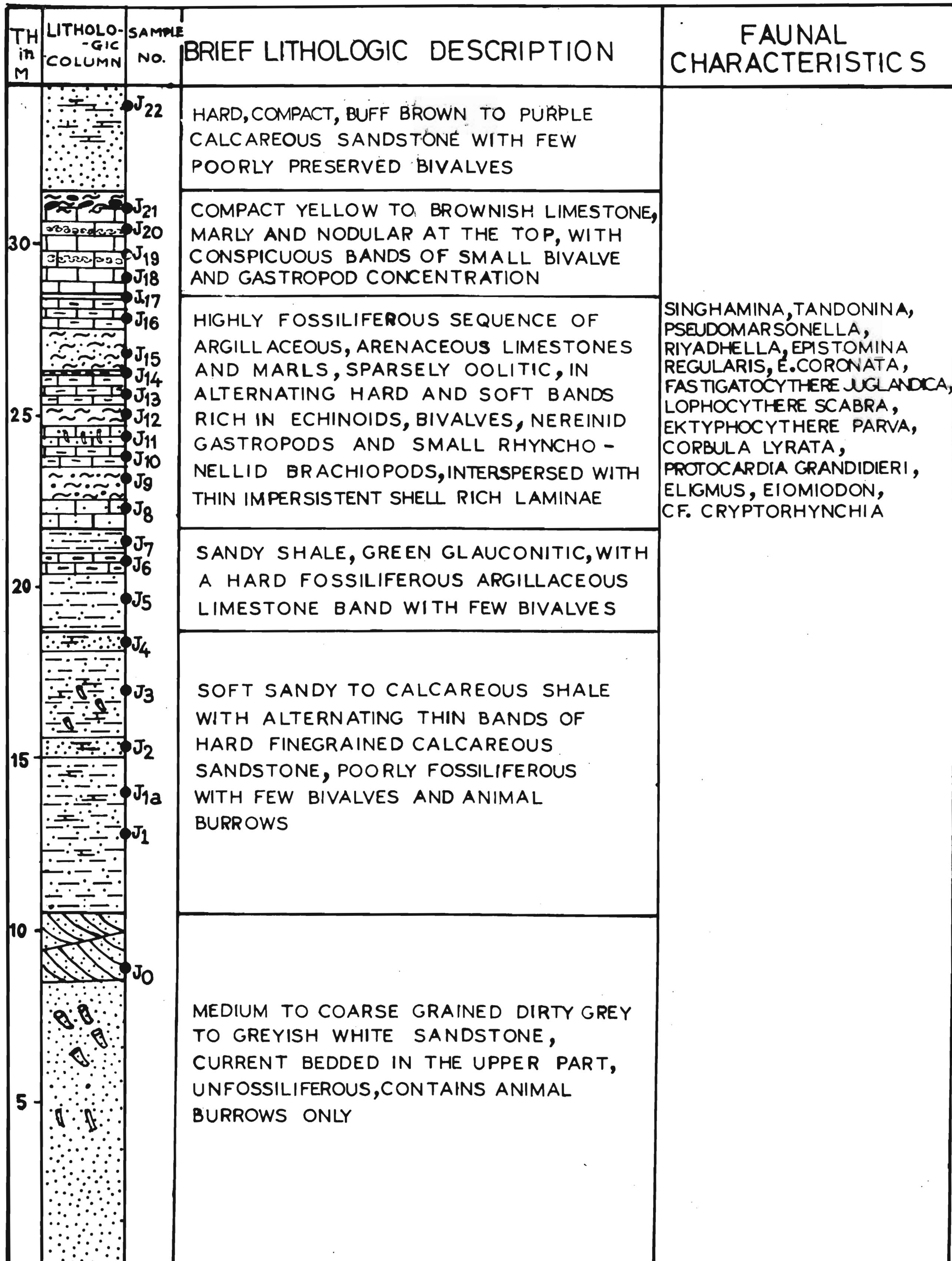


Fig. 2. Lithologic column exposed at Jaisalmer.

The Jaisalmer Formation is highly fossiliferous including prolific mega—as as well as microfaunas. Detailed studies of the microfauna (ostracods and foraminifers) have recently been carried out by Garg (1983). The new genera described herein occur in association with the following characteristic foraminifers and ostracods indicating Middle-Upper Bathonian age:

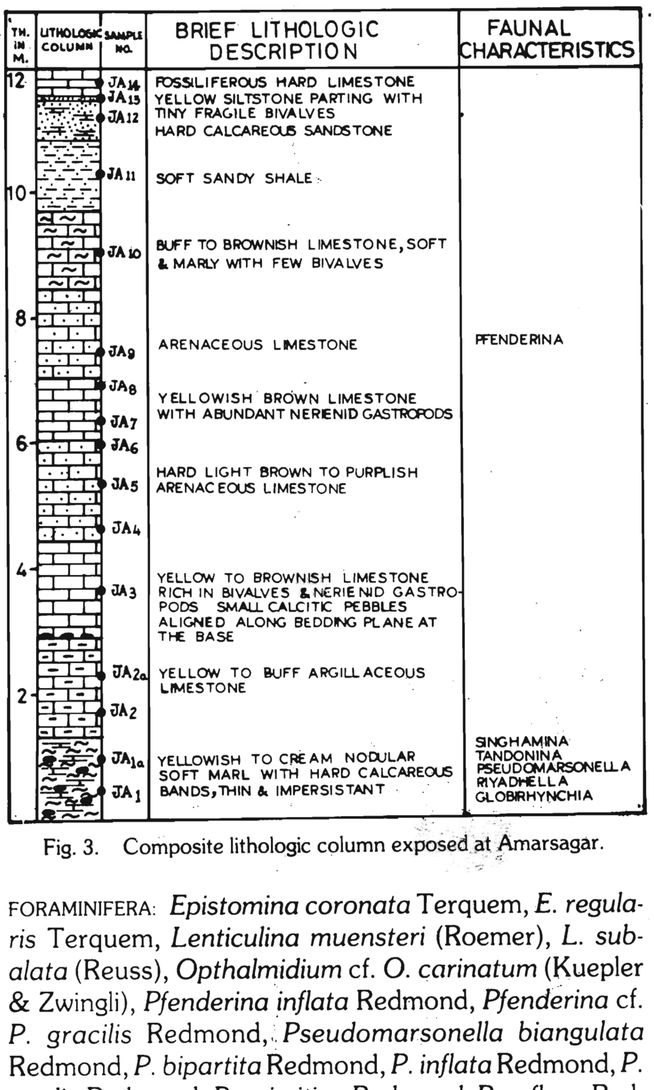


Fig. 3. Composite lithologic column exposed at Amarsagar.

FORAMINIFERA: *Epistomina coronata* Terquem, *E. regularis* Terquem, *Lenticulina muensteri* (Roemer), *L. subalata* (Reuss), *Opthalmidium* cf. *O. carinatum* (Kuepler & Zwingli), *Pfenderina inflata* Redmond, *Pfenderina* cf. *P. gracilis* Redmond, *Pseudomarsonella biangulata* Redmond, *P. bipartita* Redmond, *P. inflata* Redmond, *P. media* Redmond, *P. primitiva Redmond, P. reflexa* Redmond, *Reinholdella* cf. *R. crebra* Pazdro, *Riyadhella arabica* Redmond, *R. elongata* Redmond, *R. intermedia* Redmond, *R. regularis* Redmond, *R. rotundata* Redmond and *Trocholina conica* (Schlumberger).

OSTRACODA: *Amicytheridea ihopyensis* (Grekoff), *A. triangulata* Bate, *Cytherella fullonica* Jones & Sherborn, *Ektyphocythere parva* (Oertli), *Ektyphocythere* cf. *E. triangula* (Brand), *Fastigatocythere accessa* (Grekoff), *F. juglandica* (Jones), *Glyptocythere persica* (Jones & Sherborn), *Lophocythere bradiana* (Jones), *Oligocythereis fullonica* (Jones & Sherborn), *Paracypris contermia* Lubimova & Mohan, *Progonocythere laeviscula* Lubimova & Mohan and *Trichordis* cf. *T. triangula* Bate.

REPOSITORY

All the described and illustrated specimens are deposited in the Department of Geology, University of Lucknow, Lucknow, India.

SYSTEMATIC DESCRIPTION

Superfamily Duostominacea BROTZEN, 1963

Loeblich and Tappan (1974) erected the superfamily Duostominacea Brotzen 1963 (nom-transl. ex family) to receive, in addition to the Praerotalioids of Brotzen (1963), members of the family Oberhauserellidae of Fuchs (1970). The superfamily Duostominacea includes Foraminifera characterized by an enrolled, planispiral to high trochospiral test having calcareous, non-lamellar, fibrous to granular, perforate or imperforate wall which may agglutinate some foreign matter, and with interiomarginal, single or double aperture.

As for the structure of the test wall, Brotzen (1963, p. 77) opines that Praerotalioids have monolamellar, granular or agglutinated, perforate or imperforate wall, while Loeblich and Tappan (1974) consider non-lamellar wall a characteristic feature of the superfamily Duostominacea.

Family Duostominidae BROTZEN, 1963

Remarks: The family was erected by Brotzen (1963) to unite the Triassic genera *Duostomina, Diplotrema* and *Variostoma*, originally ascribed to Rotaliidea by Kristan-Tollmann (1960). Loeblich and Tappan (1964) assigned the above three genera to the family Discorbidae. These genera are characterised by interiomarginal double lobulate apertures separated by an intervening flap extending from the frontal chamber wall. The test is enrolled, high or low trochospiral and has a calcareous granular perforate wall, its lamellar character being unknown. Brotzen (1963) has pointed out that the structure of the wall among these Triassic genera varies from calcareous agglutinated to smooth, calcareous granular and perforate as suggested earlier by Kristan-Tollmann (1960).

Genus *Singhamina* n. gen.

Type species: Singhamina rajasthanensis gen. et n.sp

Diagnosis: Test low trochospiral, tightly coiled both sinistrally and dextrally, compressed; spiral side convex, evolute, umbilical side flat to concave, involute; umbilicus closed, depressed; axial periphery subacute to subrounded, equatorial periphery nearly circular to slightly lobulate. Chambers compressed subangular, rhomboid to triangular, with simple interiors; arranged in about two to three whorls; seven to nine chambers in the last whorl increasing uniformly to rapidly in size, joined in the umbilical area, last chamber larger and little inflated on umbilical side, extending to umbilicus as tongue-like flap; flaps of the earlier chambers apparently depressed into the umbilical area, the latter obscured by irregular secondary masses which may coalesce to form an obscure umbilical disc. Sutures on spiral side gently to strongly curved, depressed; on umbilical side radial to sigmoid, depressed. Wall thick, calcareous, non-lamellar, granular, imperforate, may agglutinate some foreign matter, surface smooth. Aperture interiomarginal, a low arched slit at the base of the inner margin of final chamber.

Remarks: The new genus *Singhamina* is reminiscent of the Discorbid genera *Discorbis, Rosalina* and *Conorbina* which differ primarily in their wall structure and morphology of the umbilical area. Externally, in umbilical characters and position of aperture, it appears closer also to certain Jurassic Reinholdellinae viz. *Reinholdella* and *Pseudolamarckina* but the same are easily distinguished by their wall structure and complexity of the apertural apparatus.

Type horizon and distribution: Amarsagar Limestone Member, Jaisalmer Formation, Bathonian.

Type locality: Jaisalmer, western Rajasthan, India.

Etymology: The genus is named for the Late Professor S.N. Singh of the Department of Geology, Lucknow University, as a tribute to his valuable contributions to the Mesozoic-Tertiary stratigraphy and micropalaeontology of western Rajasthan, India.

Singhamina rajasthanensis n. sp.

(Pl. I—1-6; Pl. II—1-2)

Holotype: LUGMJF 688; Pl. I, figs. 1-3.

Paratypes: LUGMJF 689 to 692.

Material: 50 specimens, only a few well preserved.

Description: Test free, low trochospiral, tightly coiled, compressed, spiral side slightly convex, evolute, umbilical side flat to more or less concave, involute; umbilicus closed, depressed; axial periphery subacute to subrounded, equatorial periphery almost circular to faintly lobulate. Chambers compressed subangular, rhomboid to triangular, with simple interiors; eighteen to twenty-two chambers coiled in about two to three whorls; early chambers increasing regularly in breadth; seven to nine chambers of the last whorl enlarging rather rapidly, increasing more in length than breadth; last chamber large, subtriangular to almost triangular, little inflated on umbilical side covering nearly one-fourth its area, with a narrow flap extending from its inner margin to the umbilical region which is obscured by small, irregular secondary masses. Sutures depressed, strongly curved on spiral side, curved to sigmoid on umbilical side. Wall thick, calcareous, non-lamellar, granular, imperforate, with some agglutinated foreign matter, surface smooth. Aperture interiomarginal low-arched slit about midway between periphery and umbilicus.

Dimensions:

	Holotype	Range (Based on 10 specimens)
Max. diameter of test	0.46 mm	0.35 mm to 0.48 mm
Max. diameter of test	0.39 mm	0.34 mm to 0.4 mm
Thickness of test	0.15 mm	0.11 mm to 0.16 mm

Variation: Slight variation is observed in the size and compression of the test. The spiral side is only broadly raised in almost all the specimens, while the umbilical side varies from almost flat to distinctly concave and excavated, causing the axial periphery to range from subacute to subrounded. The occurrence and distribution of the secondary masses in the depressed umbilical region varies from specimen to specimen. Number of whorls and number of chambers in the last whorl range within rather narrow limits in the entire population. Sinistral coiling of the tests distinctly prevails over dextral coiling.

Remarks: This species is distinguished by rapidly enlarging later chambers of the final whorl, becoming relatively long and narrow, a large, almost triangular last chamber and strongly curved sutures on spiral side and curved to sigmoid sutures on umbilical side. *S. jaisalmerensis* n. sp. differs from it in lacking the rapid increase in length of the last few chambers and also the strongly curved to sigmoid sutures characteristic of the present species.

Type horizon and distribution: Sample J15, soft oolitic marl, Amargsagar Limestone Member, Jaisalmer Formation; Bathonian.

Type locality: Scarp section facing the railway station about 1.6 kms north of the Fort, Jaisalmer, western Rajasthan.

Etymology: The species is named after the state of Rajasthan, India.

Singhamina jaisalmerensis n. sp.

(Pl. I—7-13; Pl. II—5-6)

Holotype: LUGM JF 693; Pl. I—7-9.

Paratypes: LUGM JF 694 to 697.

Material: 23 specimens, only a few well preserved.

Description: Test free, low trochospiral, tightly coiled, compressed; spiral side slightly convex, evolute, umbilical side flat to slightly concave, involute; umbilicus closed, depressed; axial periphery subrounded to subacute, equatorial periphery almost circular to faintly lobulate. Chambers compressed subangular, rhomboid to subtriangular, with simple interiors; sixteen to twenty chambers coiled in about two to two and a half whorls, increasing regularly in size as added, seven to nine chambers in the final whorl; last chamber, broad elongate to subtriangular, swollen on umbilical side, with a narrow to rather wide flap extending from its inner margin to the umbilical region which commonly shows the development of an obscure umbilical disc. Sutures depressed; curved on spiral side; radial to slightly curved on umbilical side, rarely becoming sigmoid in the last few chambers. Wall thick, calcareous non-lamellar, granular, imperforate, with some agglutinated foreign matter; surface smooth, opaque. Aperture interiomarginal, low-arched slit about midway between periphery and umbilicus.

Dimensions:

	Holotype	*Range* (Based on 10 specimens)
Max. diameter of test	0.32 mm	0.25 mm to 0.36 mm
Min. diameter of test	0.27 mm	0.21 mm to 0.3 mm
Thickness of test	0.1 mm	0.08 mm to 0.12 mm

Variation: Slight variation is observed in the size and compression of the test. The spiral side is only broadly raised in nearly all the specimens while the umbilical side varies from flat to slightly depressed or concave. The development and extent of umbilical disc varies noticeably from specimen to specimen. Number of volutions in the test and number of chambers range within rather narrow limits in the entire population.

Both sinistrally and dextrally coiled specimens occur in the assemblage but the former predominate.

Remarks: This species is distinguished by the rather regular increase in size of the chambers with growth, only slightly curved sutures on both spiral and umbilical sides and development of an obscure umbilical disc. It lacks the rapidly increasing, elongate and low later chambers, strongly curved to sigmoid sutures and occasionally excavated umbilical side of *S. rajasthanensis* n. sp. which is also slightly larger in overall size than the present species.

Variation in shape and size of the last couple of chambers and shape of the sutures separating them, makes some individuals of *S. jaisalmerensis* n. sp. (Pl. I-12) quite similar in umbilical view to *S. rajasthanensis* n. sp. The two species, however, do not appear to completely intergrade and are distinguished on the basis of a combination of other morphological characters.

Type horizon and distribution: Sample J15. soft oolitic marl, Amarsagar Limestone Member, Jaisalmer Formation; Bathonian.

Type Locality: Scarp section facing the railway station, about 1.6 km north of the Fort, Jaisalmer, western Rajasthan.

Etymology: The species is named after the town of Jaisalmer, Rajasthan, India.

Genus *Tandonina* n. gen.

Type species: Tandonina paula gen. et n. sp.

Diagnosis: Test small, compressed low trochospiral, tightly coiled both sinistrally and dextrally, spiral side slightly convex, evolute; umbilical side flat to slightly concave, involute; umbilicus closed, depressed, obscured; axial periphery subacute to subrounded; equatorial periphery almost circular to subcircular, entire to faintly lobulate. Chambers compressed, subangular, rhomboid to subtriangular, arranged in about two whorls, ten to twelve chambers in final whorl gradually increasing in size; last chamber may be larger and swollen on the umbilical side forming a small flap. Sutures on both spiral and umbilical sides gently to moderately curved, faintly depressed. Wall thick, calcareous, non-lamellar, granular, very finely perforate; surface smooth, hyaline. Aperture interiomarginal, a low-arched slit near periphery.

Remarks: Morphologically *Tandonina* n. gen. is similar to *Singhamina* n. gen. but is distinguished due to its smaller size, finely perforate hyaline test, relatively more tightly coiled chambers, and an obscure, depressed umbilical region with a narrow umbilical flap.

Type horizon and distribution: Amarsagar Limestone Member, Jaisalmer Formation; Bathonian.

Type Locality: Jaisalmer, Western Rajasthan, India.

Etymology: The genus is named for the Late Dr. K.K. Tandon of the Department of Geology, Lucknow University, as a tribute to his valuable contributions to the Tertiary stratigraphy and palaentology of Kutch, western India.

Tandonina paula n. sp.

(Pl. I—14-18)

Holotype: LUGM JF 698; Pl. I—14-16.

Paratypes: LUGM JF 699 to 700.

Material: 18 specimens, a few well preserved.

Description: Only a single species of the genus is known to date. The test is characteristically small with about nineteen to twentytwo chambers, tightly coiled trochospirally in nearly two to two and a half whorls. The final whorl partially covers the earlier one which shows through the transluscent, hyaline test wall. Other morphological characters are outlined in the generic description.

Dimensions:

	Holotype	*Range* (Based on 10 specimens)
Max. length of test	0.25 mm	0.22 mm to 0.26 mm
Max. breadth of test	0.18 mm	0.16 mm to 0.22 mm
Thickness of test	0.07 mm	0.06 mm to 0.8 mm

Variation: Only slight variation is observed in the depression of the umbilical side and the equatorial outline of the test which varies from almost circular to subcircular and may be entire to faintly lobulate. The size of the test as well as the number of chambers in final whorl range within very narrow limits. The shape and inflation of the last chamber may also vary slightly.

Type horizon and distribution: Sample J14, sandy marl rich in rhynchonellids, Amarsagar Limestone Member, Jaisalmer Formation; Bathonian.

Type Locality: Scarp section facing the railway station, about 1.6 km north of the Fort, Jaisalmer, western Rajasthan.

Etymology: The species is named after its small size (Latin: *paula*—small)

PHYLOGENETIC RELATIONS OF DUOSTOMINIDAE

A major difference between the foraminiferal assemblages of the Palaeozoic and Mesozoic Eras outlined by Brotzen (1963) is the absence of rotalioid Foraminifera in the former and appearance of the same in the latter. This group of smaller calcareous Foraminifera generally dominates the benthic microfaunas of the Late Mesozoic and the Cenozoic. However, the earliest known rotaliform Foraminifera from the Early Mesozoic, originally attributed to Rotaliidea by Kristan-Tollmann (1960), differ from the true rotalioid Foraminifera of the younger periods primarily in the structure of their test walls and apertural features. Because of the primitive nature of their wall structure, Brotzen (1963) termed these early rotaliform Foraminifera as Praerotalioids.

Evidences by way of basic similarities in the test morphology and change in the wall structure corresponding to the known trends in foraminiferal evolution, suggest that at least three lineages might have originated from the duostominid praerotalioid stock. These are the discorbid stock, ceratobuliminid-epistominid stock and buliminid stock of the younger smaller calcareous Foraminifera. The ancestry of these praerotalioids is not clear at present but it should be found probably among Lituolid or Endothyrid Foraminifera as suggested by Brotzen (1963) and Loeblich and Tappan (1974).

The homologous correspondance of the test morphology of Triassic duostominid genera with Jurassic and Cretaceous ceratobuliminid and buliminid genera is discussed in meticulous details by Brotzen (1963). Influenced by the similarities in the structure of their trochospiral tests as well as by the dissimilarities in test wall and apertures that could clearly be demonstrated as a consequence of the natural course of evolution, Brotzen (1963) traced the origin of the younger rotaliid and buliminid Foraminifera among the few known Duostominids (e.g. *Duostomina, Diplotrema* and *Variostoma*) recorded by Kristan-Tollmann (1960) from the Triassic of Alps.

Among Rotalioids, the ceratobuliminid and epistominid Foraminifera are characterised by a highly specialised apertural apparatus. Their lineage from the ancestral duostominid stock should naturally be different from the ones which give rise to the other groups of hyaline, lamellar Foraminifera like Discorbiacea and Buliminacea. The newly discovered Praerotalioids *Singhamina* nov. and *Tandonina* nov. from the Middle Jurassic of Jaisalmer, apparently provide the links to the origin of the discorbid Foraminifera. The various aspects of these lineages are discussed below in detail.

CERATOBULIMINID—EPISTOMINID LINEAGE

Brotzen (1963, p. 73, fig. 3) draws a close similarity in the test shape and apertures of the Triassic *Duostomina* Kristan-Tollmann and certain species of the Jurassic Ceratobuliminid *Reinholdella* Brotzen, viz. *R. macfadyeni* (Ten Dam) Hofker, and *R. brandi* Hofker. Both the genera have a more or less biconvex test with closed umbilicus. The tongue-like projection of the frontal chamber wall between the two openings, called 'tenon' by Brotzen, separates the main umbilical aperture from the interior lateral aperture. In *Duostomina* and related Triassic genera, however, both apertures in the final chamber open to the exterior, while among ceratobuliminid Foraminifera presence of the second external opening in the tests (interior lateral aperture of Brotzen, 1963; internal intercameral foramen of Pazdro, 1969), is rarely noted. According to Brotzen (1963, p. 73) it does not exist in all *Reinholdella* specimens and seems to occur at a certain stage of growth. In fact, in Ceratobuliminids and Epistominids there is essentially a single opening out of the test, which performs the function of aperture. The second opening, the internal intercameral foramen, originates on the septum through resorption only during addition of subsequent chambers and remains separated by an internal chamber partition on its umbilical side from the main aperture (Uhlig, 1883; Troelsen, 1954; Pazdro, 1969; and Grigelis, 1978).

Based on the shape of their tests and apertures, certain other ceratobuliminid genera viz. *Ceratobulimina* Toula, *Ceratolamarckina* Troelsen and perhaps *Conorboides* Hofker also, may be regarded as having arisen out of *Diplotrema*-like ancestor (e.g. *D. astrofimbriata* Kristan-Tollmann and *D. subangulata* Kristan-Tollmann). All these genera have more or less convex tests with deep, open umbilicus and share the same system or two apertures in the sense of Brotzen (1963). However, as suggested by Brotzen (1963), until the internal structure of the Triassic *Diplotrema* is known, a detailed comparison with *Ceratobulimina*-like forms will be difficult.

Praelamarckina Kaptarenko-Chernousova, a Lower-Middle Jurassic ceratobuliminid Foraminifer, also deserves to be mentioned due to its biconvex umbonate test with closed umbilicus and interiomarginal slit-like aperture. It lacks the diagnostic internal chamber partition but shows presence of internal foramen on septal wall (Antonova, 1969). It is supposed to be the most primitive genus of Ceratobuliminidae but data on its wall structure are lacking (Grigelis, 1978). The nature of its wall structure may further reveal its true affinities with praerotalioids.

The internal structure and apertural characteristics of Triassic Duostominidae are imperfectly known. In spite of this, the evolutionary lineage drawn by Brotzen (1963) between Triassic *Duostomina* and *Reinholdella* species from Lias and Dogger appears quite justified in the present state of our knowledge. In such a case, the earliest *Reinholdella* species might logically be expected to retain the double apertures of the ancestral duostominid stock, though losing their frilled lobate character but developing a complex inner apertural apparatus and radial, lamellar wall through geologic time. The close morphological similarity of the trochospiral, rotaliform tests of Duostominidae with Epistominidae has also been emphasised by Grigelis (1978) who remarked that the interiomarginal apertures of the Triassic genera have not yet developed a complex apertural apparatus.

BULIMINID LINEAGE According to Brotzen (1963) this lineage is supposed to have originated from Triassic species like *Variostoma prolongense* Kristan-Tollmann through *Buliminella*-like forms of the Cretaceous, in view of their close similarity in test shape and aperture but distinct change in wall structure. Presumably, species of *Praebulimina* Hofker, known from the Middle Jurassic, might also have fallen on the same course of evolution.

DISCORBID LINEAGE

Just as *Reinholdella* provides some clues to ancestry of ceratobuliminids among Duostominids, *Singhamina* nov. and *Tandonina* nov. from the Middle Jurassic help in drawing similar evolutionary lineage between the ancestral praerotalioid stock and Cretaceous and younger genera of Discorbidae. It is not difficult to homologize the test morphology of *Singhamina* nov. with *Discorbis* Lamarck and *Rosalina* d'Orbigny. All the three genera have a low trochospiral plano-convex test having flattened to slightly depressed umbilical side which shows chambers of the final whorl only. They also share an apparently similar flap extending from the basal part of the chamber towards umbilical region which, however, differs in morphological details in these genera. The umbilicus is closed in *Discorbis* and *Singhamina* nov. but *Rosalina* has an open umbilicus. The umbilical alar projections of chambers in *Discorbis* form a secondary mass varying from small plug-like to more extensive disc-like structure, while in *Singhamina* nov. small secondary masses, which may form an obscure umbilical disc, occur around umbilicus. As compared to the interiomarginal low-arched, slit-like aperture of *Singhamina* nov., the interiomarginal aperture in *Discorbis* is more extensively developed and freely communicates from beneath the umbilical flap with the accessory sutural apertures.

Another genus which is morphologically close to Jurassic duostominids as to test morphology is *Conorbina* Brotzen, 1936, recorded from the Lower Santonian of Sweden. Like *Singhamina* nov. it also lacks the umbilical apparatus of *Discorbis*. All chambers of the final whorl in *Conorbina* extend over the closed umbilicus which appears homologus with *Tandonina* nov.

As compared to the morphological similarities that could be drawn between the Jurassic duostominid Praerotalioids and the younger Discorbids, it appears difficult, however, to find detailed affinities of *Singhamina* nov. and *Tandonina* nov. with the biconvex, either umbilicate or umbonate tests and double apertures of the Triassic *Diplotrema* and *Duostomina*. The Jurassic forms differ in being characterized by planoconvex to concavoconvex tests having a close depressed umbilicus and a single interiomarginal aperture.

Besides apparent modifications in test morphology, the primary change that took place from the Middle Jurassic Duostominids to the Cretaceous and younger Discorbids is in the structure of the calcareous wall. The non-lamellar, granular, imperforate or very finely perforate wall of the older group (e.g. *Singhamina* and *Tandonina*) evolved through geologic time to hyaline, lamellar and distinctly perforate walls in the younger genera, viz. *Conorobina* and *Discorbis*. The earlier Jurassic genera are further characterised by thick and heavy walls, especially the septal walls. The tendency to agglutinate some foreign matter and lack of distinct perforations also indicate their primitive character. However, the earlier Praerotalioids from the Triassic are known to have perforate calcareous test wall. Apparently, perforations in the foraminiferal tests, though a characteristic feature of the more advanced groups viz. Rotaliids in this lineage, have appeared at different times in their long evolutionary history.

From the above discussion, it is apparent that one line of evolution among Duostominidae advanced through *Singhamina, Tandonina* to *Conorbina, Discorbis, Rosalina*-like genera of Late Mesozoic and Tertiary Discorbidae (Discorbiacea). Another line of evolution, as postulated earlier by Brotzen (1963), led from *Duostomina* and *Diplotrema* to Ceratobuliminidae and Epistominidae through *Reinholdella*, while yet another line through certain high-conical species of the Triassic *Variostoma* Kristan-Tollmann (e.g. *V. prolongense*) might have given rise to the calcareous *Praebulimina, Buliminella* like forms of the Late Mesozoic and younger Turrilinidae (Buliminacea).

According to Grigelis (1978), during the Middle Mesozoic strong divergence of ceratobulinimid and epistominid stocks through complication of the apertural apparatus and internal partition, took place along blind phylogenetic branches. On the other hand, the remaining two stocks of calcareous perforate Foraminifera viz. Discorbids and Buliminellids, arising out of evolution of the Early and Middle Mesozoic Duostominids were destined to be more successful as they became leading elements in the benthonic foraminiferal assemblages of the Late Mesozoic and Tertiary times.

It is significant to note that origin of the other hyaline, lamellar Foraminifera e.g. Nonioniacea, as well as of the planktic Globigerinacea has been traced among Asymmetrinidae Brotzen and Oberhauserellidae Fuchs respectively (Fuchs, 1970; Loeblich and Tappan, 1974), which alongwith Duostominidae constitute the superfamily Duostominacea. In fact, Fuchs (1970) considered Oberhauserellidae (whose representatives have earlier been known as the 'Jurassic Globigerinids' according to Loeblich and Tappan, 1974) to have derived from *Diplotrema* (Dusotominidae) and to have given rise variously to the trochospiral planktic Globigerinacea, to the aragonitic Ceratobuliminidae and Epistominidae, and also to the calcareous, hyaline, lamellar Discorbidae.

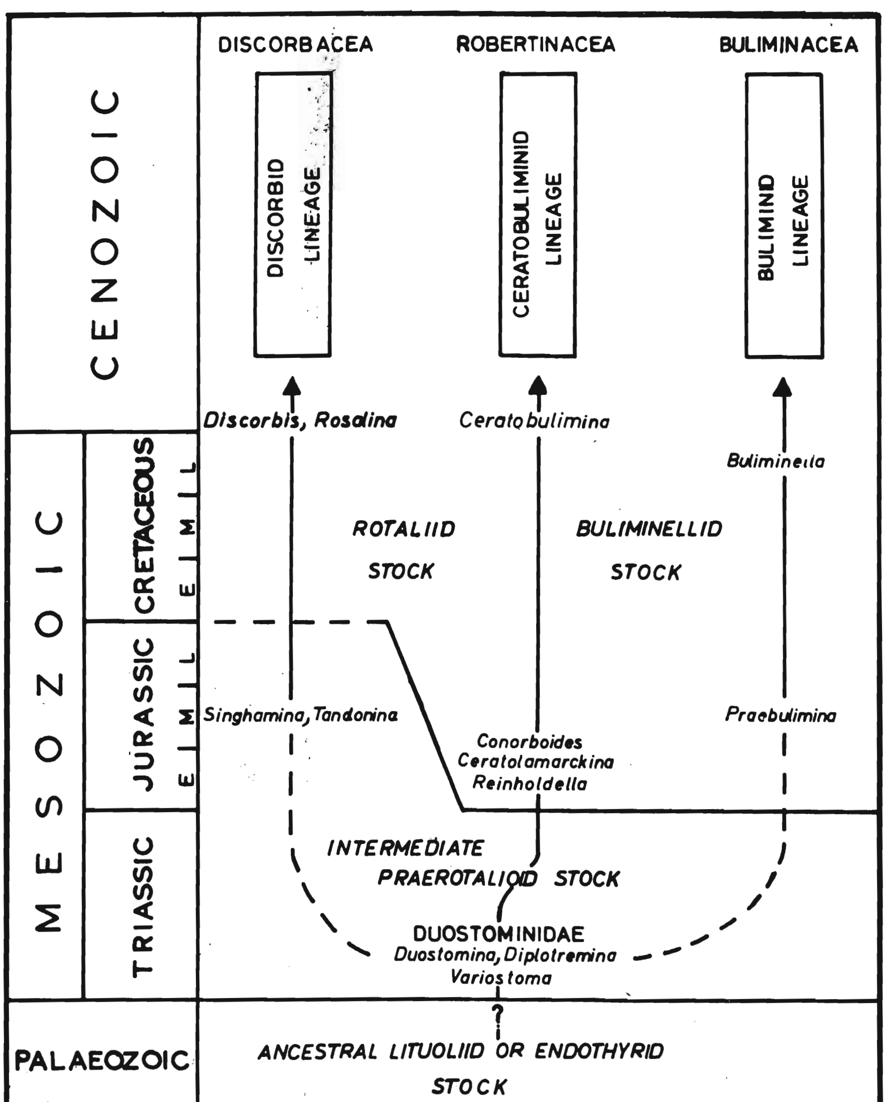
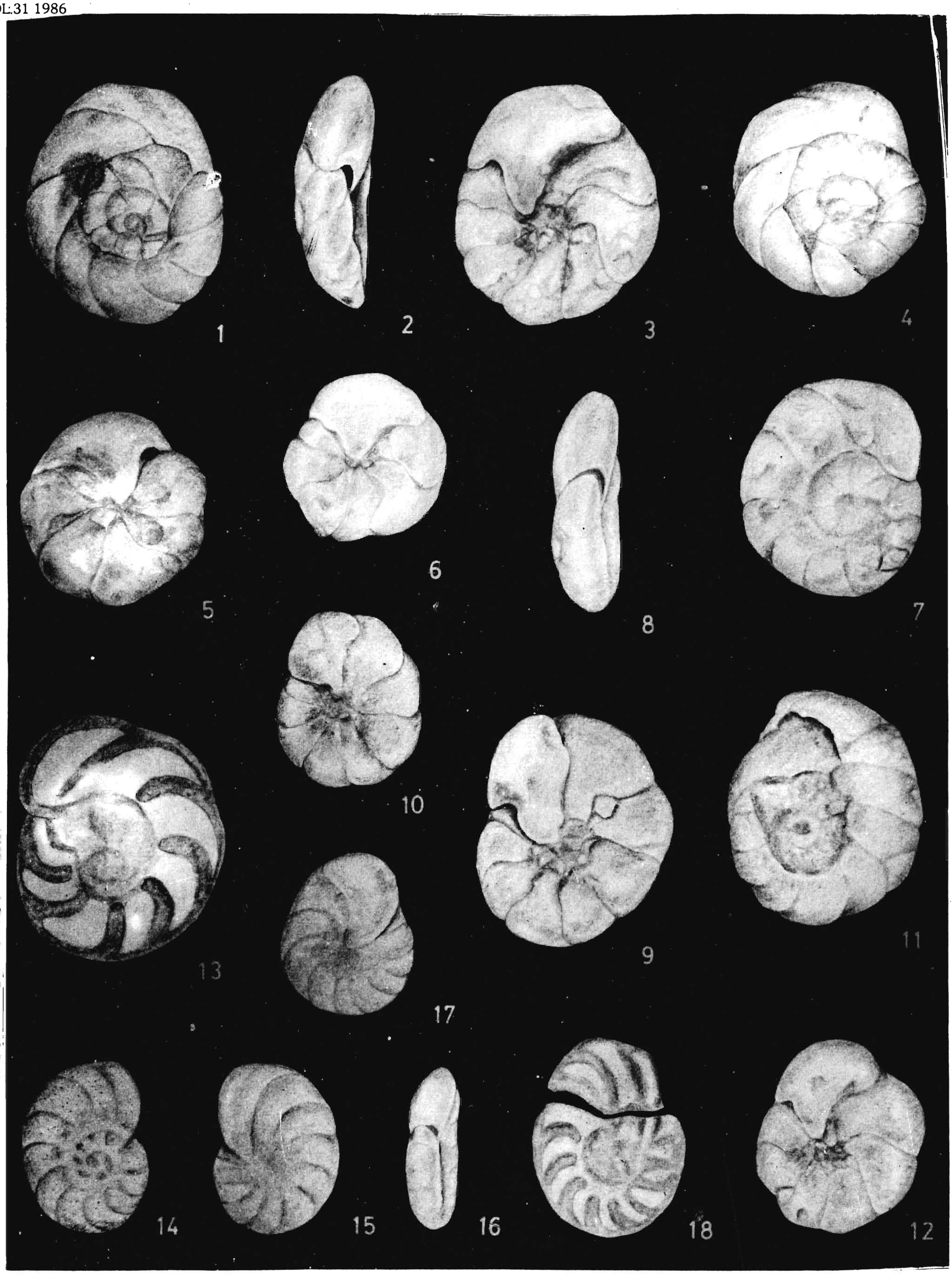
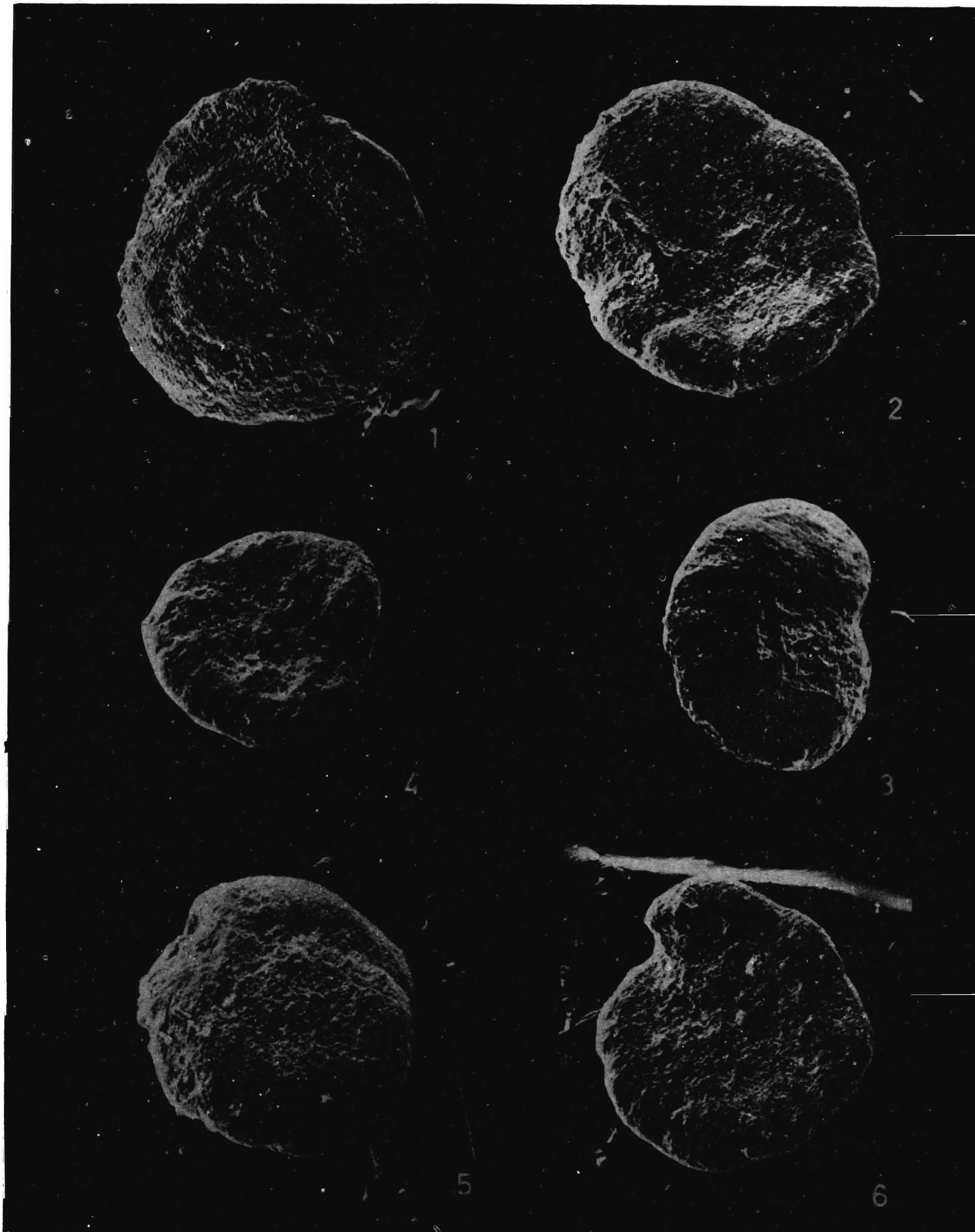


Fig. 4. Some evolutionary trends of Duostominid Foraminifera (modified after Brotzen, 1963).

PLATE I



GARG AND SINGH



GARG AND SINGH

Among Duostominacea, we are obviously dealing with a group which represents one of the most vital stages in foraminiferal evolution and diversification. Because of the rather sketchy state of our present knowledge of this group, important clues to the missing links in the evolutionary trends of smaller calcareous Foraminifera remain obscured. The low-spired rotaliform type of tests, which is the commonest among calcareous, lamellar, perforate Foraminifera, occurs only in Trochamminidae among the primitive stock of agglutinated Lituoliids (Glaessner, 1948). It seems logical, indeed, then to trace the ancestry of younger rotaliid Foraminifera among Praerotalioid-like dusotominids from which they appear to have evolved primarily through change in the wall structure.

The wall structure of the praerotalioid Foraminifera, as pointed out by Brotzen (1963), evolved from a simple or compound calcareous test wall (calcareous aggultinated with organic calcareous cement) in their Palaeozoic ancestors to the imperforate or perforate non lamellar, calcareous granular wall in the Triassic and Jurassic Duostominidae and Asymmetrinidae. Through these, subsequently have developed the hyaline, lamellar, distinctly perforate test walls of the smaller calcareous Foraminifera which, except for the aragonitic radial test walls, appeared for the first time in the Middle or Late Mesozoics. The development of aragonitic test walls in some descendants of the Praerotalioids in Early and Middle Mesozoic represents only a specific course of evolution among smaller calcareous Foraminifera.

The supposed evolutionary trends in duostominid Foraminifera discussed above, are shown in the Fig. 4.

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REFERENCES

ANTONOVA, Z.A. 1969. A voprosu ob evolineii niekotorych predstavitelei epistominid na primere razvitija ich v jurskoje I nizhnemielovoje vremia na severnom kavkare. *Akad. Nauk. SSR. Vop. Micropalaeont.* **11**: 61-69. (In Russian).

BROTZEN, F. 1963. Evolutionary trends in certain calcareous Foraminifera on the Palaeozoic-Mesozoic boundary. *In Evolutionary trends in Foraminifera*, von Koeningswald, G.H.R. *et al.* eds., Elsevier: 66-78.

DUTTA, A.K. 1983. Geological evolution and Hydrocarbon prospects of Rajasthan Basin. *In Petroliferous Basin of India*, KDMIPE, ONGC; *Petroleum Asia Jour.* **6**(4): 93-100.

FUCHS, W. 1970. Eine alpine, tiefliasslche Foraminiferenfauna von gerstein in Niederosterreich. *Verh. Geol. Bundesanst., Wien.* **1**: 66-145.

GARG, RAHUL 1983. *Stratigraphy* and *Micropalaeontology of the Mesozoic rocks exposed around Jaisalmer, Rajasthan*. Ph.D. Thesis, unpublished, Lucknow University: 1-489.

GLAESSNER, M.F. 1945. *Principles of Micropaleontology*. Melbourne Univ. Press, Australia: 1-296.

GRIGELIS, A.A. 1978. Morphology and classification of the *Ceratobuliminacea. Jour. Foram. Res.*, **8**(4): 275-285.

KRISTAN-TOLLMAN, E. 1960. Rotaliidea (Foraminifera) aus der Trias der Ostalpen. *Jb. geol. Bundesanst.*, Wien, Spl. vol., **5**: 47-78.

LOEBLICH, A.R. JR. & TAPPAN, H. 1974. Recent advances in classification of Foraminifera. In *Foraminifera* (Hedley, R.H. & Adams, C.G., eds.), Academic Press. **1**: 1-53.

PAZDRO, O. 1969. Middle Jurassic Epistominidae (Foraminifera) of Poland. *Stud. Geol. Polonica.* **27**: 1-92.

TROELSEN, J.C. 1954. Studies on Coratobuliminidae (Foraminifera). *Medd. Fra. Dansk. Geol. Forening.* Copenhagen. **12**: 448-472.

UHLIG, V. 1883. Ueber Foraminiferen aus dem rjasan'schen Ornatenthone. *K.K. Geol. Reichsanst. Wein, Jahrb.* **33**(4): 753-774.

EXPLANATION OF PLATES

PLATE I

1-6 *Singhamina rajasthanensis* gen. et n. sp.,
1—Spiral view, 2—Edge view, 3—Umbilical view, LUGM JF688 (Holotype), X 100; 4—Spiral view, LUGM JF 689, X 100; 5—Umbilical view, LUGM JF 690, X 100; 6—Umbilical view, LUGM JF691, X 95 (Paratypes).

7-13 *Singhamina jaisalmerensis* gen. et n. sp.,
7—Spiral view, 8—Edge view, 9—Umbilical view, KLUGM JF692 (Holotype), X 135; 10—Umbilical view, LUGM JF695, X 135; 11—Spiral view, LUGM JF694, X 135; 12—Umbilical view, LUGM JF696, X 135; 13—Equatorial section, LUGM JF697, X 135; (Paratypes).

14-18 *Tandonina paula* gen. et n. sp.,
14—Spiral view, 15—Umbilical view, 16—Edge view, LUGM JF698 (Holotype), X 135; 17—Umbilical view, LUGM JF699, X 130; 18—Equatorial section, LUGM JF700, X 130 (Paratypes).

(All figures are photographic reductions of camera lucida sketches drawn by Rahul Garg)

PLATE II

Scan Electron Micrographs

1-2 *Singhamina rajasthanensis* gen. et n. sp.,
1—Spiral view, LUGM JF 691A, X 150;
2—Umbilical view, LUGM JF 691B, X 170.

3-4 *Tandonina paula* gen. et n. sp.,
3—Oblique spiral view, LUGM JF700A, X 250;
4—Oblique umbilical view, LUGM JF700B, X 250.

5-6 *Singhamina jaisalmerensis* gen. et n. sp.,
5—Spiral view, LUGM JF697A, X 170;
6—Umbilical view, LUGM JF697B, X 150.