JOURNAL OF THE PALAEONTOLOGICAL SOCIETY OF INDIA
VOL. 26, 1981, pp. 54—76.

EARLY-MIDDLE MIOCENE BENTHONIC FORAMINIFERA FROM THE VINJHAN-MIANI AREA OF KUTCH, WESTERN INDIA

A. K. JAUHARI

GEOLOGY DEPARTMENT, LUCKNOW UNIVERSITY, LUCKNOW-226 007

ABSTRACT

The present work relates to the study of benthic foraminiferal assemblage from a stream section of the Early-Middle Miocene succession near the village Vinjhan of the Vinjhan-Miani area of Kutch. There is a record of forty four species of benthonic foraminifera which have been illustrated with photomicrographs. Three informal biostratigraphic zones have been demarcated : namely, *Miogypsina globulina* zone, *Archaias malabarica* zone, and *Ammonia* zone. *M. globulina* zone represents deposits laid down in shallower part of inner neritic (near-shore) environment having fine grained substrates, whereas the strata characterized by *Archaias malabarica* were deposited in the shallow inner neritic environment of high-energy conditions and relatively coarser substrates. As compared to the above two zones, *Ammonia* zone shows a marked change in the environment of deposition characterized by depletion of fauna which can be related to further shallowing of the neritic sea. Palaeobiogeographic interpretations of the present foraminiferal assemblage suggest continuance of exchange of benthonic faunas between Indo-Mediterranean (Tethyan), Indo-Pacific, Caribbean-Antillean and Euramerican region not only upto the boundary of Early and Middle Miocene (as currently believed) but probably until early part of Middle Miocene. This exchange process appears to have been finally stopped by the Late Miocene Palaeogeographic changes.

INTRODUCTION

Tewari (1952, 1956) referred the rocks occurring in the vicinity of the village Vinjhan (Fig. 1) to Gaj (Lower Miocene) and Post-Gaj series of Sind. Later, Srivastava (1970) distinguished lower and upper Gaj beds disconformably overlying yellowish brown fossiliferous marl which he assigned to the Rupelian stage (Middle Oligocene). The Lower and Upper Gaj horizons, in his opinion on the basis of ostracodes, were considered of Aquitanian and Burdigalian ages respectively. Overlying the Lower and Upper Gaj strata are the unfossiliferous horizons of probable Pliocene age. The purpose of the paper is to study the biostratigraphy, palaeoecology and taxonomy of the benthonic fossil feraminifers from the fossilferous horizons of the succession.

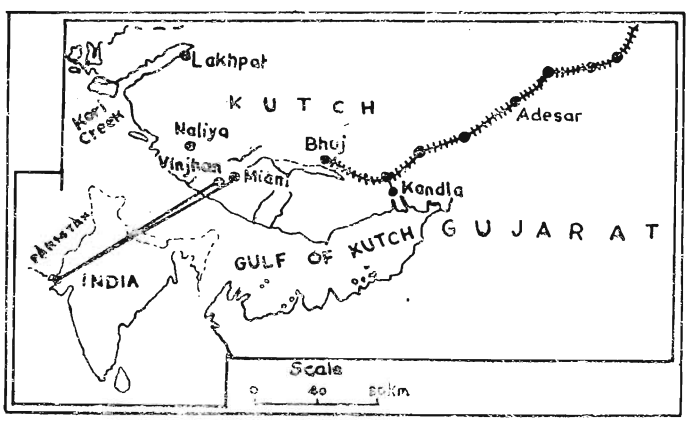


Fig. 1. Location Map.

STRATIGRAPHY

The sequence is well exposed in the Kankawati stream section extending SW—NE. It includes the rocks of Early—Middle Miocene age. At the base, the unfossiliferous grey shales are present. These are followed by yellow fossiliferous limestone containing macroinvertebrates in abundance. Then, there are unfossiliferous grey shales which are overlain by yellow hard fossiliferous limestone. This limestone is characterized by the abundant forms of *Archaias* referable to *A. malabarica* and by low taxonomic diversity of the macroinvertebrates. Overlying the limestone are unfossiliferous grey shales which are overlain by poorly fossiliferous greyish yellow shales containing specimens of *Ammonia*. These are followed by unfossiliferous horizons viz. yellow fine grained sandstone, red cherty bed, green coloured hard shales, and grey shales. The Early-Middle Miocene sequence later passes upwards into conglomerates, grits, and massive hard sandstones of probable Pliocene age. The lithologic sequnece is given in Table 1. Figure 2 shows the geological map of the area.

FAUNAL ANALYSIS

The sequence shows 3 fossiliferous horizons in alternation with unfossiliferous grey shales in the lower portion, and completely barren horizons in the upper portion. The grey shales at the base are unfossiliferous and have not yielded any microfauna. Biswas and Raju (1973) referred the similarly looking unfossiliferous/poorly fossiliferous beds to Aquitanian (Aida) stage in Khari river

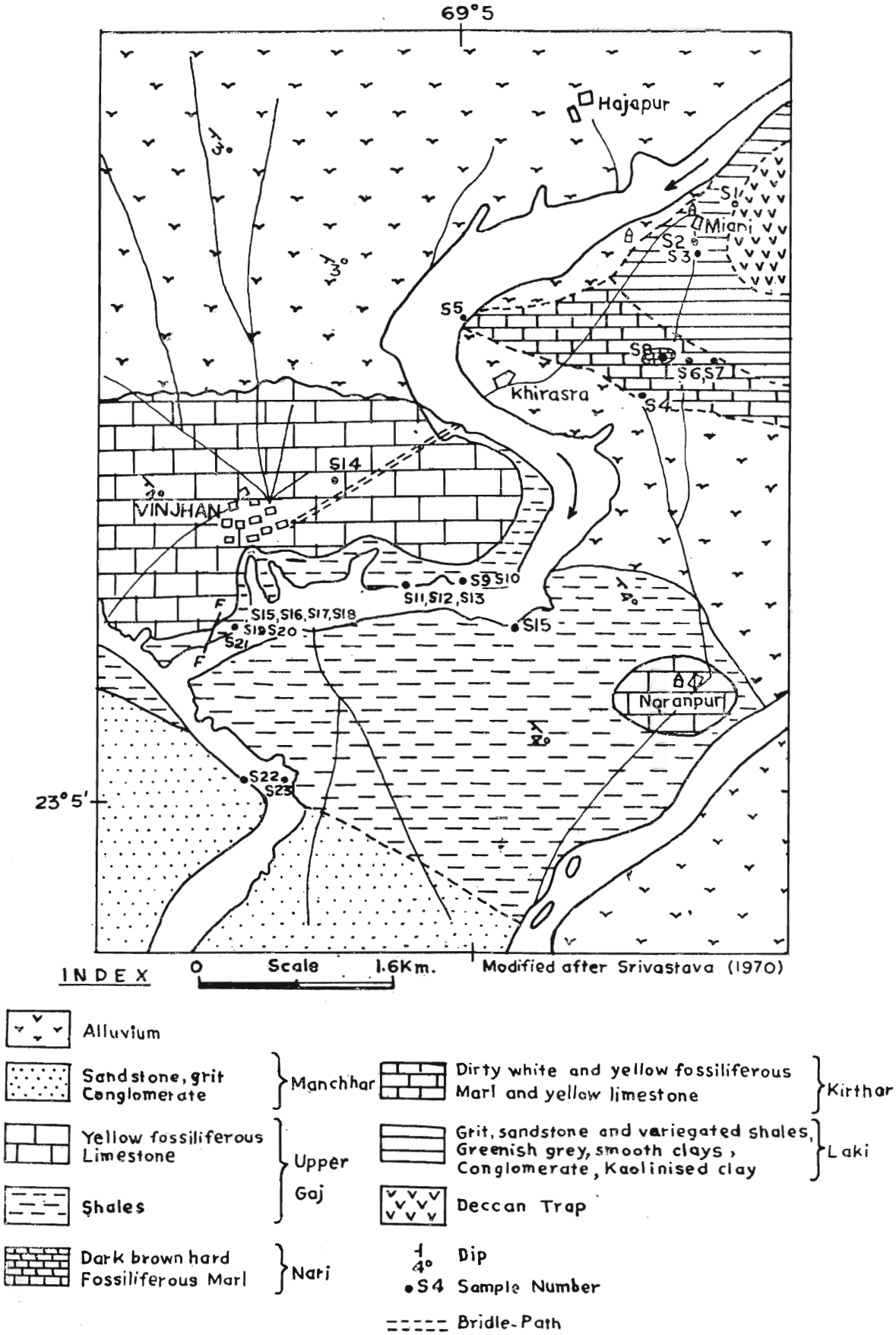


Fig. 2. Geological Map of the Vinjhan-Miani area, Southwestern Kutch.

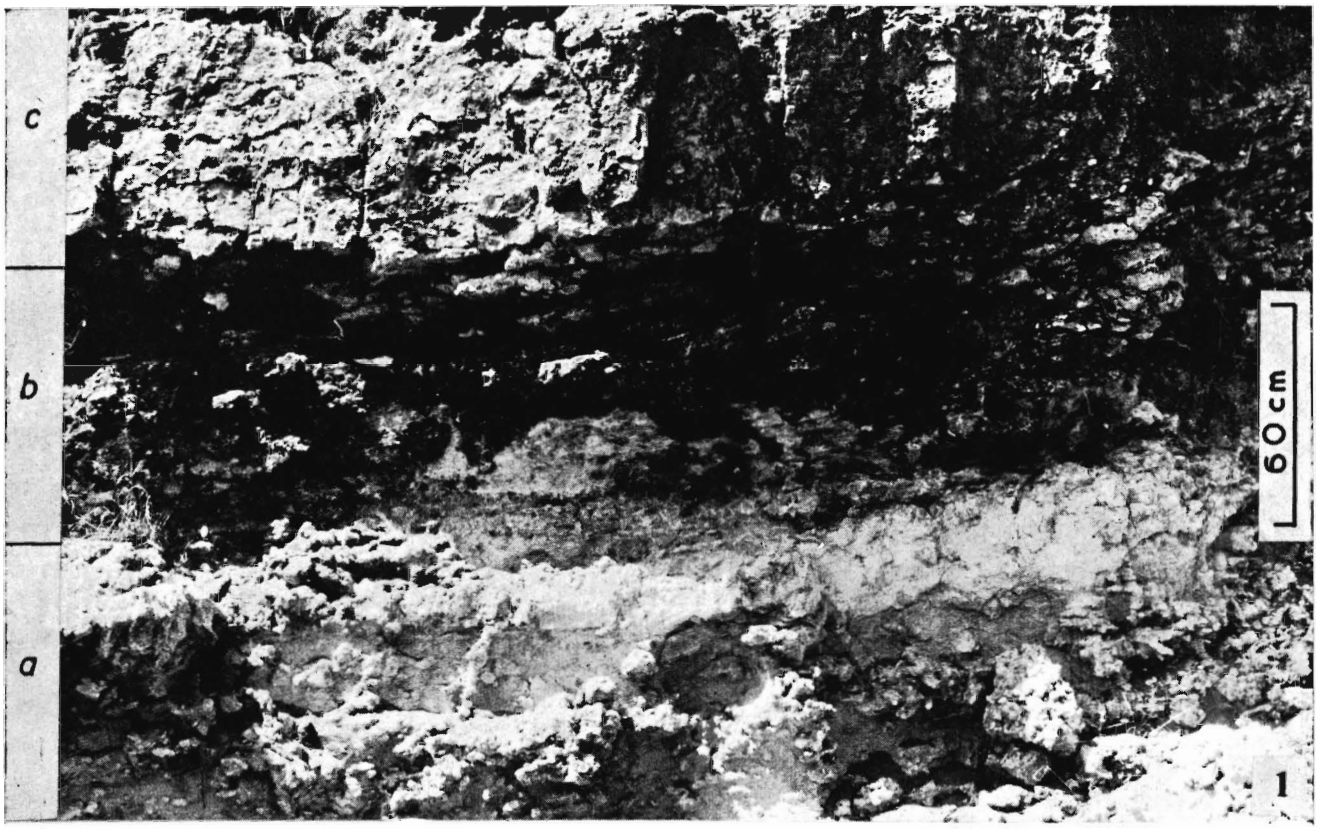
EPOCH	THICKNESS	LITHOLOGY	LITHOLOGICAL UNIT
PLIOCENE	14		SANDSTONE
	2		GRIT
	1		CONGLOMERATE
MIOCENE (MIDDLE)	2		GREY SHALES
	1		GREEN HARD SHALES
	1		RED CHERTY BED
	1		YELLOW FINE GRAINED SANDSTONE
	1		GREYISH YELLOW FOSSILIFEROUS SHALES
	1		GREY SHALES
	2		YELLOW FOSSILIFEROUS LIMESTONE
	4		GREY SHALES
MIOCENE (EARLY)	3		YELLOW FOSSILIFEROUS LIMESTONE WITH ABUNDANT GASTROPODS, BIVALVES, etc.
	5		GREY SHALES
LATE OLIGOCENE	1		DARK BROWN HARD FOSSILIFEROUS MARL

Table 1. Showing Lithological sequence at the Vinjhan-Miani area, Southwestern Kutch. (Thickness in metres).

section of Kutch on the basis of *Miogypsina tani*/*M. deharti*. So taking his unfossiliferous/poorly fossiliferous grey shales as analogous to the present unfossiliferous grey shales, it would appear that the latter is of Aquitanian age. These beds in both the cases lie below the *Miogypsina globulina* beds which are of Burdigalian age.

The unfossiliferous shales are overlain by lower fossiliferous yellow limestone rich in megainvertebrate and foraminiferal faunas. The foraminiferal fauna shows major representation of smaller foraminifers and limited occurrence of larger ones which are seen in thin sections only. The larger foraminiferal species are *Miogypsina globulina*, *Meandropsina* sp. and *Archaias* aff. *A. malabarica*. *M. globulina* is a marker species of Burdigalian. Its presence suggests a definite Burdigalian age for the lower limestone unit. Immediately next to lower limestone are unfossiliferous grey shales which are again overlain by upper fossiliferous yellow limestone. The upper limestone contains *Archaias malabarica* in great proliferation but shows much thinner occurrence of large-sized invertebrates like gastropods, lamellibranchs, echinoids, etc. *Archaias malabarica*, in the light of recent data (discussed later in this paper), indicates Langhian age for upper limestone. The upper limestone is followed by unfossiliferous grey shales, lying over which are poorly fossiliferous, greyish yellow shales. These have yielded only frequently occurring forms of *Ammonia*, most probably referable to *Ammonia annectens concinna* and *A. papillosus* also present in the lower and upper limestone units. *Ammonia* yielding shales are overlain by several thin, unfossiliferous horizons, namely, yellow fine-grained sandstone, red cherty bed, green hard shales and grey shales. Because of their unfossiliferous nature, all these horizons are here assigned to Langhian on the basis of their conformable position over Lanhghian horizons.

The uppermost layer of the Middle Miocene (the unfossiliferous grey shales) is overlain by 1 m. thick conglomerate bed which grades into 2 m. thick grit horizon. The grits are hard, compact and coarse-grained and do not reveal the presence of any fossil.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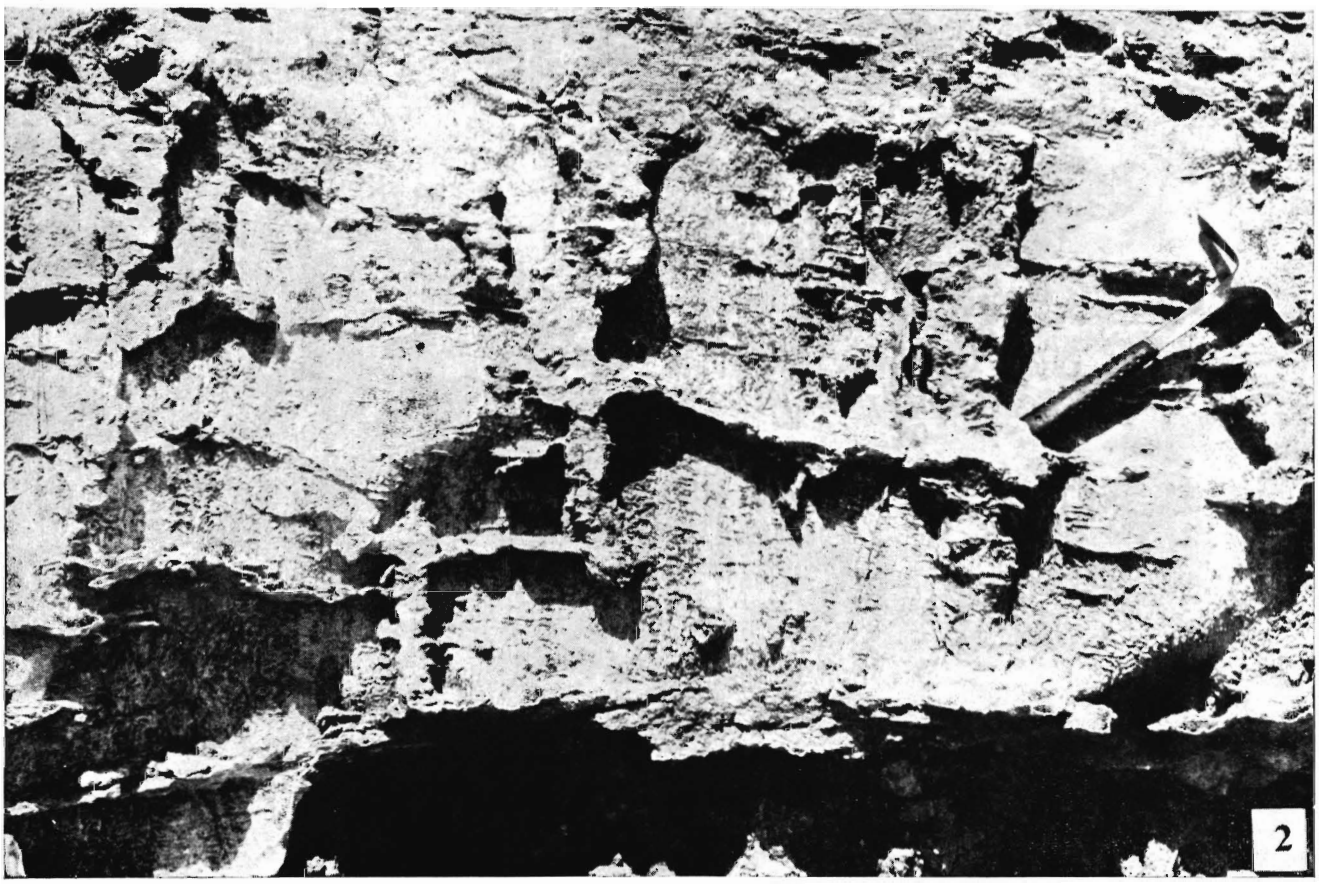
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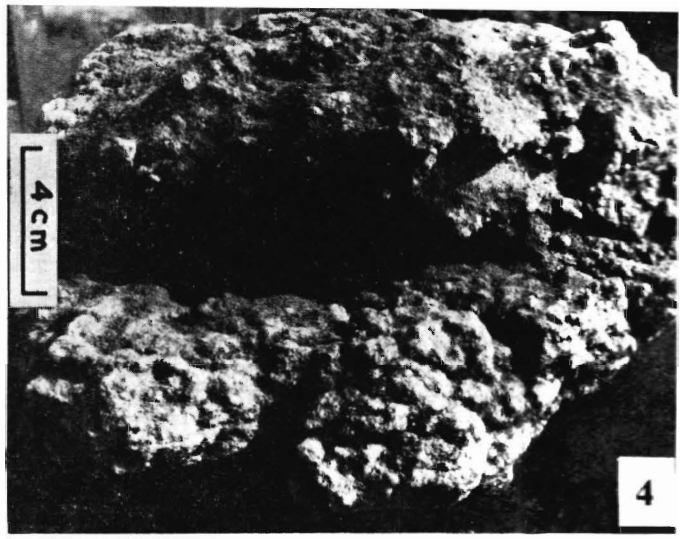
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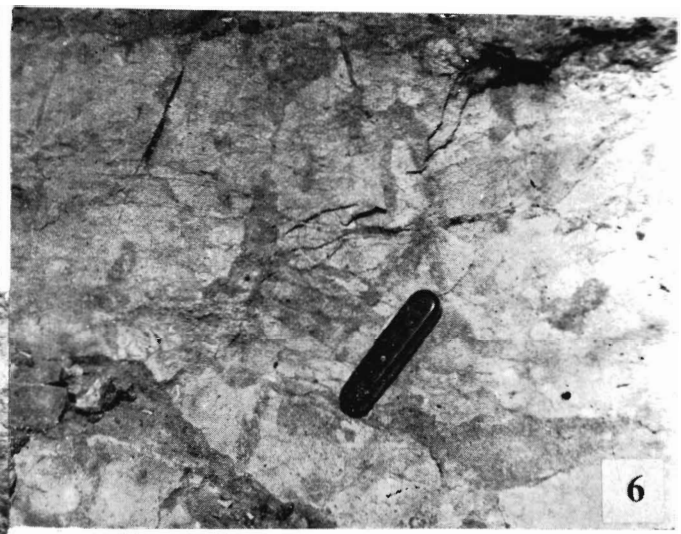
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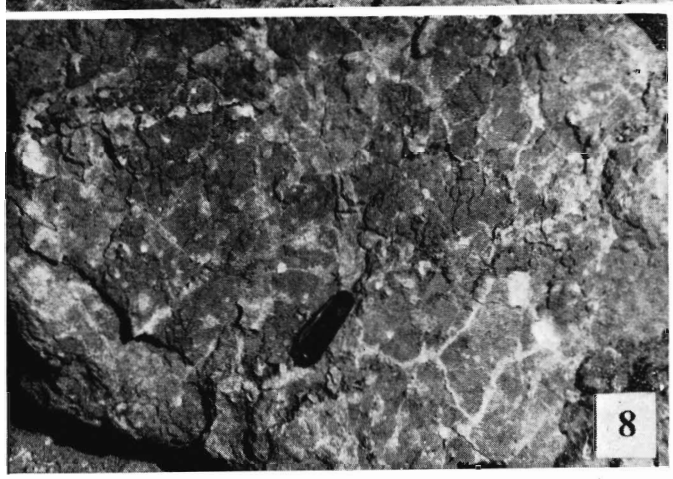
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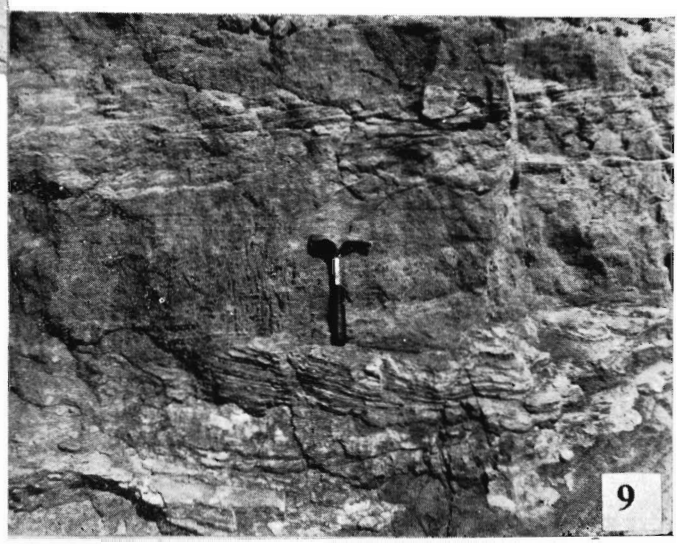
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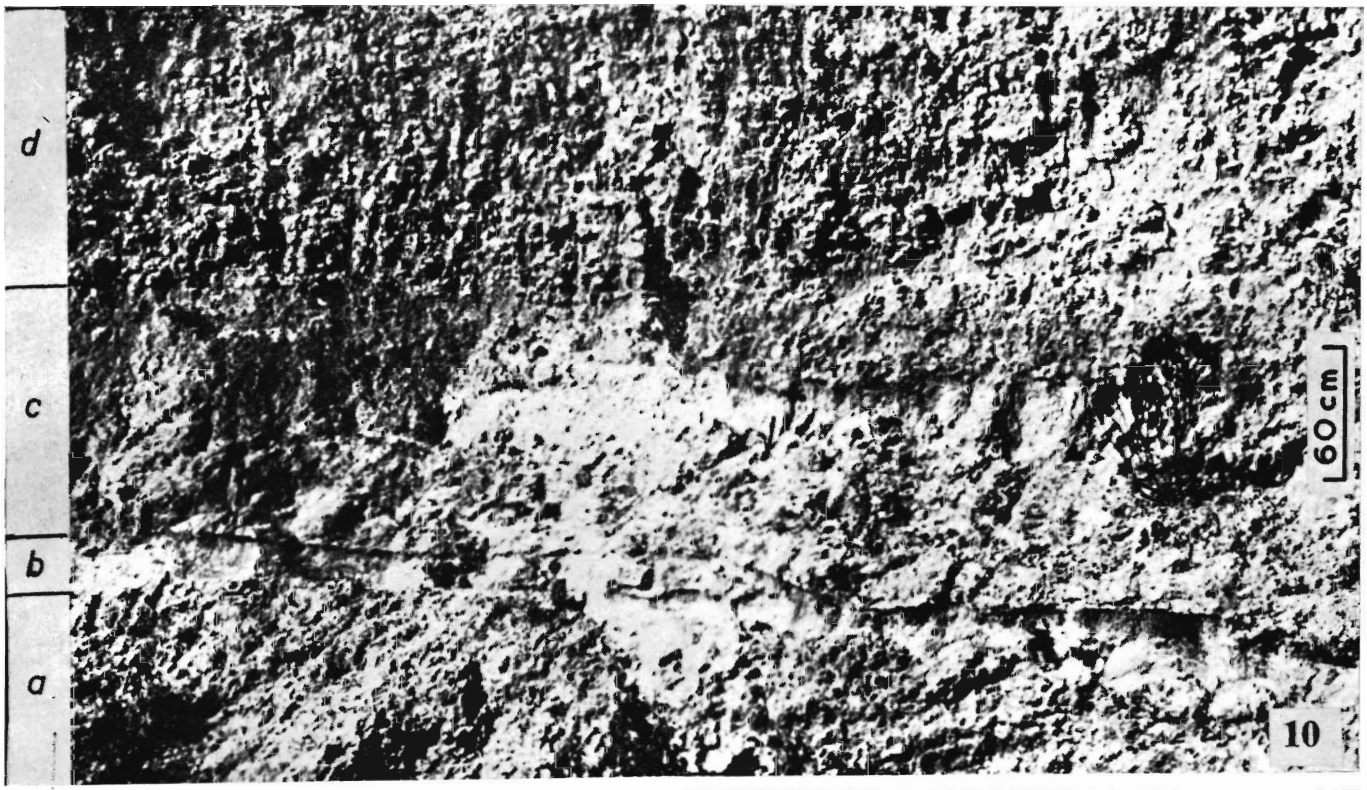
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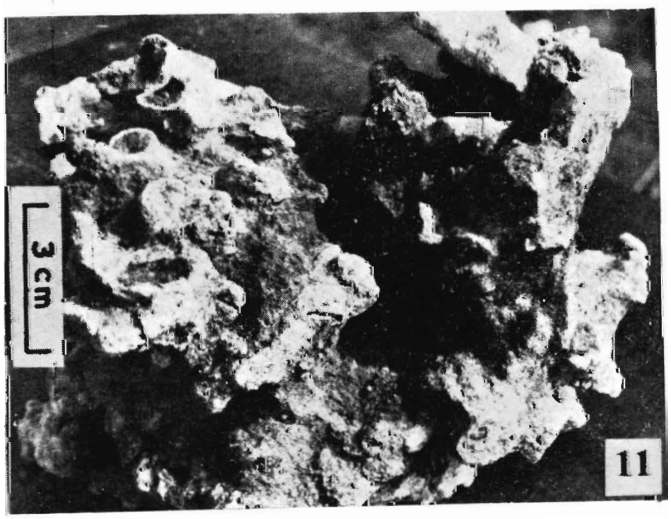
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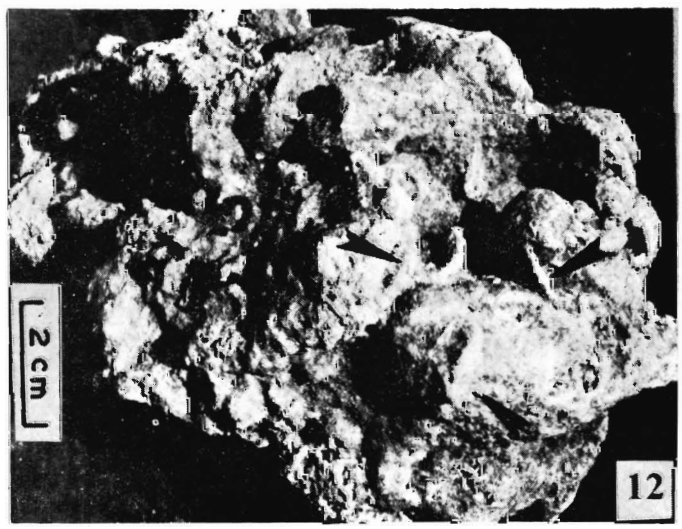
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13

14 cm
14

The grit bed is finally overlain by 14 m. thick, soft, coarse-grained, thickly bedded sandstone which does not show the presence of any fossil and sedimentary structure. Because of marked unconformity at the base, the overlying sequence comprising conglomerates, grits, and sandstones can be assigned to Pliocene epoch. In view of marked lithological similarity, Tewari (1952) and Srivastava (1970) have equated these beds with the Manchhars of Sind. The Manchhar beds are Pliocene in age and are believed to have been deposited in fresh to brackish water conditions.

BIOSTRATIGRAPHY

Lack of continuity of the fossiliferous strata in the sequence does not provide a very encouraging picture for biostratigraphy, and there is hardly any option for a formal biozonation. In the light of this difficulty, the alternative of proposing informal biozones seems appropriate. The criterion of presence or absence of fossils, which holds good in the cases like the present one, has been used as a basis for biozonation in this study. However, the correlation of these informal zones has been facilitated by the rich microfaunal assemblages which fortunately contain a few index species having widespread geographic distribution. These species have proved useful in assigning a relatively much precise age to these strata in the sequence. See Table 2.

The faunal assemblage is typical of tropical and subtropical belt. The three benthonic foraminiferal zones recognized in the present sequence are local in nature and do not cover the entire area of Kutch. The nominate species have been chosen either on the basis of their temporal value or on their abundance.

Miogypsina globulina Zone : Thickness—3 m.; Lithology—fossiliferous yellow limestone showing fine grained, hard, compact nature and containing a large number of shells of molluscs, echinoids, foraminifers, ostracodes, etc.

Characterization : Besides the nominate taxon, this zone is characterized by *Archaias* aff. *A. malabarica*, *Austrotrillina howchini*, etc. and a rich assemblage of smaller foraminifers. *M. globulina* is confined to this zone.

Age : The zonal species suggests early Miocene age (Burdigalian).

M. globulina zone is followed by a 4 m. thick barren zone of grey shales over which lie the highly fossiliferous limestone which is referable to *A. Malabarica* zone.

Archaias malabarica zone : Thickness—2 m.; Lithology—fine grained, highly fossiliferous, hard limestone having abundant *A. malabarica* and sparsely scattered macroinvertebrates.

Characterization : This zone is characterized by the two additional forms—definite *Archaias malabarica*, the nominate taxon of this zone, and *Archaias angulatus*. The assemblage of smaller benthonic foraminifers is broadly same as that of preceding zone.

Age : The zonal taxon suggests Middle Miocene age (Langhian).

Overlying the *A. malabarica* zone is another 1 m. thick barren zone of grey shales which is followed by *Ammonia zone*.

Ammonia Zone : Thickness—1 m., Lithology—Greyish yellow fossiliferous shales which have yielded few broken unidentifiable molluscs.

Characterization : The assemblage is solely composed of individuals of *Ammonia*, possibly referable to *A. concinna annectens* and *A. papillosus* which are also present in the underlying zones.

Age : Middle Miocene (Langhian).

AGE AND CORRELATION

The age assignments are here based on foraminifera. In the Vinjhan-Miani area, the unfossiliferous grey shales at the base are probably the extensions of the unfossiliferous or poorly fossiliferous rocks of the Khari Stream Section referred by Biswas and Raju (1973) to the Aida Stage (Aquitanian) on the basis of the presence of *Miogypsina tani*. However, in the present investigation, no microfauna could be ascertained from the samples belonging to these shales. Their lithological similarity with unfossiliferous horizons of the Khari Stream Section permits them to be doubtfully placed close to the Aida Stage (Aquitanian) of Biswas and Raju (1973). The remaining part of the Miocene is assignable to the Vinjhan Stage which is equivalent to both Burdigalian and Langhian Stages of Europe. The presence of *Miogypsina globulina* in the lower yellow fossiliferous limestone suggests a Burdigalian (Early Miocene) age for this horizon. *M. globulina* is not seen in the overlying horizons and is, therefore, taken to be restricted to the lower yellow fossiliferous limestone horizon. Due to this, the overlying horizons, one of which has yielded *Archaias malabarica* in abundance, have been considered of Langhian age (the Middle Miocene). *Archaias malabarica*, according to Clarke and Blow (1969), ranges from the zone N.10 to the zone N.11 (from the base to the middle of Langhian). Though some specimens showing affinity with *A. malabarica* occur with *M. globulina* in the lower yellow fossiliferous limestone, their maximum development is observed in the upper yellow fossiliferous limestone in which *M. globulina* is absent. In the absence of definite Burdigalian species, the upper limestone along with the underlying unfossiliferous shales and overlying poorly fossiliferous and unfossiliferous horizons can be tentatively dated as the Middle Miocene (Langhian).

According to Biswas and Raju (1973), the Langhian stage in the Vinjhan-Miani area is represented by

Ammonia bed and some unfossiliferous horizons. The present work shows that the *Ammonia* bed is underlain by the unfossiliferous grey shales, yellow fossiliferous limestone (referred to as upper limestone in the present study), unfossiliferous grey shales, and *M. globulina* horizons (Lower limestone). Since no typical Burdigalian species has been observed till now in the horizons overlying the *M. globulina* limestone, they have also been considered Middle Miocene (Langhian) in age.

The discussion presented in the following paragraphs is related to the age of *A. malabarica* and the presence of Middle and Late Miocene rocks (see Eames, 1950) in the Indian subcontinent. Though premature at the moment (data from many Indian areas are not available), this discussion might lead to some valid conclusion regarding age and correlation of the strata under study.

Age of Archaias malabarica and the presence of Middle-Late Miocene in the Indian region : Wayland and Davies (1923, p. 590) and Furon and Lemoine (1939) suggested a Middle to Late Miocene (Helvetian to Tortonian) age for *A. malabarica*. Considering its association with the upper Gaj type faunas, Eames (1950) restricted its age to the Early Miocene in the India-Pakistan-Ceylon region. He was of the opinion that the beds containing *A. malabarica* in Ceylon and Quilon are of Upper Gaj age (later part of Early Miocene) because of their time equivalence with the Upper Gaj horizons of Kutch and Sind. This led to the view that the Miocene deposits of India, Pakistan, and Ceylon belonged to the Early Miocene. The view appeared to gain momentum when he pointed out similarity between the Neogene geologic history of the Indian region and that of the East African coast. In the latter region, Eames found that the lower Miocene was succeeded by the Pliocene rocks. The similar stratigraphic relationship, he thought, might exist in the Neogene strata of the Indian subcontinent. However, when assessed in the light of the present-day micropalaeontological observations, such an opinion may not appear sound.

Henson (1950) recorded the occurrence of *A. malabarica* in the Middle East from : (i) the Lower Fars Limestone (Middle Miocene) of Persian Gulf in association with *Borelis melo*, *Sorites* sp., etc.; (ii) Lower Fars Limestone of southwest Iran, and the Middle Miocene Limestone of Syria in association with *Borelis melo* var. *curdica*, *Meandropsina anahensis*.

In the Far East region, its record has always been from the Middle Miocene rocks ranging from the zone N.10 to the zone N.11 (base to the middle part of the Langhian) (Clarke and Blow, 1969).

There is now a general consensus of opinion that the letter stage 'Tf' corresponds with European Langhian and Tortonian stages, with lower Tf (f1-f2) standing equal to Langhian and upper Tf (f3) lying at par with Tortonian. Clarke and Blow (1969) suggest that *Orbul* datum which occurs at the N8/N9 boundary is coincide with Te/Tf boundary. Incidentally, N8/N9 boundary also the Burdigalian/Langhian (early/middle Miocer boundary. According to this suggestion, Te/Tf bounda of the Far East region is in correspondence with N8/ boundary of the Planktonic scale and, hence, with Bur galian/Langhian boundary. The published data reve that the strata equal to Tf (f1-f2) in the Far East, Midc East and East Africa are characterized by *Flosculine bontangensis*, *Taberina malabarica* (=*Archaias malabaric* and *Borelis melo* (Berggren, 1971). Their occurren in Tf (f1-f2) stage which is equivalent of the Langhi stage of Europe is an obvious indication of the fact th these species are assignable to the Langhian Stage ar that *Archaias malabarica* is indicative of this stage in t Middle East, Far East, etc.

Clarke and Blow (1969) believe that though t specimens showing affinity with *A. malabarica* are know from the uppermost part of the Burdigalian (Early Mi cene), the true *A. malabarica* does not appear below N. (Langhian). Such a distinction might appear arbitrar but it becomes significant when considered in relati to the ecologic preferences of Peneroplids. Being a mer ber of Peneroplidae, *A. malabarica* must have inhabit shoals and reefs. As there was an extensive marine tran gression during Middle Miocene, the shoals and ree during that time had a wide geographic distributio providing the peneroplid group with optimum conditio of living. If this view is accepted, the chances of *malabarica* going up to the Middle Miocene and ev beyond in the Indian region are much higher ; and, a result, the possibility of the Middle Miocene tran gression in the Indian region is not far off.

Eames' (1950) view of the early Miocene age f the Miocene deposits of the India-Pakistan-Ceylon regi is again not supported by his own later work and t recent findings of some geologists of the Oil and Natur Gas Commission from the offshore areas of western Indi These geologists have recorded a complete mari sequence of the Miocene epoch. *A. malabarica*, accordi to them, appears with *Miogypsina globulina* in the low horizons and continues in the upper layers where it b comes associated with *Miogypsina cushmani* (an importa Middle Miocene species). But *M. globulina* does n extend into the upper horizons. Though there is a r cord of Late Miocene in this region (offshore), the d tribution of stratigraphically important foraminifers this part (Late Miocene) is not clearly known at t moment. Eames (1971, p. 332) agrees with the Midd Miocene age for Gaj Series in the Indian subcontiner *Archaias malabarica* (=*Pseudotaberina malabarica*), accordi to him (p. 334), is a characteristic Middle Miocene for minifer of the Indian Ocean region, the Middle East ar

TIME-UNITS		PLANKTONIC FORAMINIFERAL ZONES (After Blow, 1969)	FORAMINIFERAL ZONES PROPOSED IN THE PRESENT WORK*
PLEIST-OCENE	CALABRIAN	N.22	NOT PRESENT ?
PLIOCENE	ASTIAN ↕ ZANCLIAN	N.21	UNFOSSILIFEROUS
		N.20	
		N.19	
		N.18	
LATE MIOCENE	MESSINIAN	N.17	NOT PRESENT
	TORTONIAN	N.16	
OCENE	AN	N.15	
		N. 14	UNFOSSILIFEROUS
		N.13	AMMONIA ZONE

MIDDLE MI	LANGHI	N.12	UNFOSSILIFEROUS
		N.11	ARCHAIAS MALABARICA ZONE
		N.10	
		N.9	UNFOSSILIFEROUS
EARLY MIOCENE	BURDIGALIAN	N.8	MIOGYPSINA GLOBULINA ZONE
		N.7	
		N.6	UNFOSSILIFEROUS
	AQUITANIAN	N.5	
		N.4	
OCENE	BORMIDIAN	P.22 (N.3)	NOT PRESENT
		P.21 (N.2)	SPIROCLYPEUS RANJANAE ZONE
	IAN- N- N	P.20 (N.1)	

OLIG	LATTORF RUPELIA CHATTIA	P.19	NOT PRESENT
		P18	
LATE EOCENE	PRIABONIAN	P.17	
		P.16	
		P.15	
MIDDLE EOCENE	LUTETIAN	P.14	
		P.13	ORBULINOIDES BECKMANNI ZONE
		P.12	GLOBOROTALIA LEHNERI ZONE
			UNFOSSILIFEROUS

Table 2. Showing Relationship of present Foraminiferal zones with the Planktonic foraminiferal zones of Blow (1969).

North and East Africa. The exact range of *A. malabarica* will, however, become clear only when more detailed studies of the offshore region of western India have been made. Tentative conclusions which one can draw at the moment are :

(A) *A. malabarica* probably appeared a little earlier in the Indian subcontinent than in the Middle East and the Far East, i.e., the uppermost part of Burdigalian (N.7 or N.8), and continued up to the middle part of the Langhian (N.11) (Middle Miocene). Its maximum development was, however, attained only during Middle Miocene.

(B) The marine Miocene deposits of the subcontinent are not necessarily Early Miocene in age but extend even up to Late Miocene in certain cases.

Modern Foraminiferal species and their significance for the age of the Miocene sequence of Kutch, W. India : The concept that the present distribution pattern of foraminifera was attained during late Early-Middle Miocene, and many Recent species made their appearance by that time (Adams, 1973) might prove useful in the present discussion. The rocks under study contain large number of some smaller benthonic species which are widespread in the present-day oceans. The examples of *Archaias angulatus*, *Sortites marginalis*, *Elphidium indicum*, *E. advenum*, *E. crispum*, *Ammonia* spp., *Protelphidium profundifossatum*, etc. may be cited. These species, though appeared in the latter part of Lower Miocene, became well established only in the Middle Miocene. Since these species are present in both the limestones (though abundantly in upper limestone only) interbedded with poorly fossiliferous/unfossiliferous shales, an age ranging from the latter part of Early Miocene to the middle part of the Middle Miocene might seem much favourable for them. See Fig. 3.

Thus, taking the above observations as a whole, it can be said that the Miocene strata at Vinjhan-Miani range from the Early Miocene to the Middle Miocene (? Aquitanian, Burdigalian to Langhian). They correlate with the upper Te (Te 5) and Tf (f1-f2) stages of the Far East letter stage classification. When compared with planktonic foraminiferal zonation scheme, they would probably range from N.5/N.6 zone to N.11 zone.

PALAEOECOLOGY

The Early-Middle Miocene succession in the present area, though quite thick, shows only three fossiliferous horizons. These include lower yellow fossiliferous limestone with abundant invertebrate fauna (3 m.), upper yellow fossiliferous limestone with abundant *Archaias malabarica* (4 m.) and greyish yellow fossiliferous shales (1 m.). But their rich and varied fossil contents have enlarged the scope of this study by giving a wealth of information for making reasonable palaeoecologic observations. The palaeoecologic discussion that follows is the outcome of the interpretations of the fossil forms known from the fossil-yielding horizons mentioned as above. The interpretations are based on the available ecologic data on certain living taxa of groups which occur as fossils in the sequence under study. Because of purely palaeontological nature of the problem, the present interpretations are limited to fossiliferous horizons only.

(I) LOWER YELLOW FOSSILIFEROUS LIMESTONE

It is characterized by foraminifera, ostracoda, and macroinvertebrates. Smaller foraminifera are common

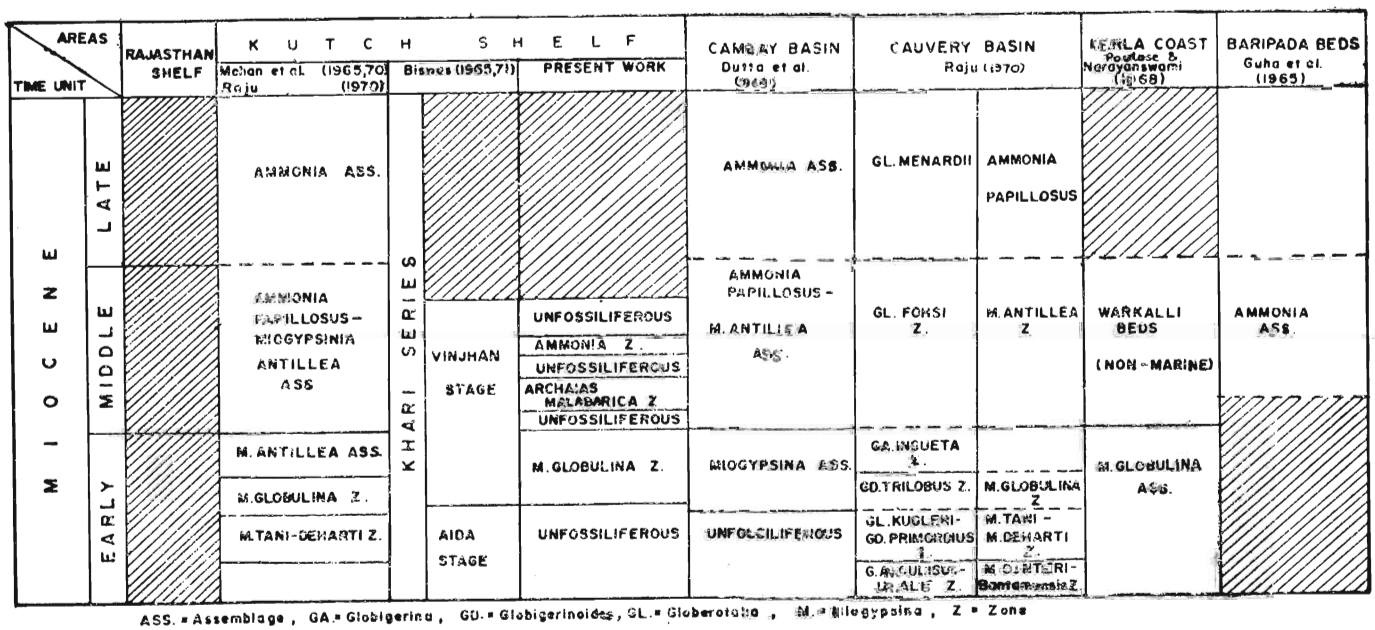

Fig. 3. Showing biostratigraphic correlation of the Miocene rocks of the Indian Region.

to frequent in different samples from this limestone. The macroinvertebrates are, however, richly distributed and represented by gastropods, lamellibranchs, echinoids, and bryozoans. The important taxa include *Cerithium*, *Conus*, *Cyprea*, *Gisortia*, *Pleurotomaria*, *Turritella*, *Trochus*, *Oliva* and *Xancus* among gastropods ; *Arca*, *Mytilus*, *Ostrea*, *Pecten*, *Spondylus* and *Venus* among lamellibranchs; *Breynia*, *Clypeaster* and *Hemicidaris* among echinoids ; and *Anoteropora* and *Nellia* among cheilostome bryozoa. Ostracode genera are *Actinocythereis*, *Aurila*, *Bronsteiniana*, *Cytheridea*, *Echinocythereis*, *Murrayina*, *Neomonoceratina*, and *Paijenborchella*. Except foraminifera, all these groups of fossils were recorded by Srivastava (1970).

This limestone is hard, compact, fine grained and impure in nature. In thin sections, it appears cryptocrystalline and contains clayey matter. It can be equated with modern substrates of fine sands or muds characterized by increased amount of organic matter. Such deposits are formed under low current velocities. The less turbulent currents increase the substrate stability, as a result of which non-shifting bottoms are formed. The bottoms so formed are much hospitable to micro and macroinvertebrates (see Purdy, 1964). Johnson (1965) observed that fine sands or muds containing complete valves or large fragments are a common feature of the level bottoms in depths of 10-30 ft. in Tomales Bay, California. Animal-sediment relationship as envisaged above is commonly revealed in the shallow water deposits.

Gastropods and lamellibranchs are by far the major groups represented among the macroinvertebrate fauna. The majority of macroinvertebrates live within the photic zone (neritic region) because of abundance of phytoplankton.

The ecologic data of the fossils present in this limestone have resulted in following interpretations :

(A) Evidence from foraminifera

The common genera are *Ammonia*, *Elphidium*, *Triloculina*, *Quinqueloculina*, *Discorbis*, *Miliola*, and *Protelphidium*. *Bolivina*, *Lagena*, *Pyrgo*, *Brizalina*, *Cibicides*, *Eponides*, etc. occur rarely. Populations of *Archaias* and other penerolplids are very limited. The dominance of genera varies from sample to sample. Mostly, the assemblage in these samples is dominated by *Ammonia*, *Elphidium*, and the members of Miliolidae (*quinqueloculina*, *Triloculina*, *Miliola*, etc.).

Ammonia dominated fauna is usually associated with marginal marine conditions prevailing at 10 fathoms (=20 m.) depth (Walton, 1964). Abundant miliolids suggest near-shore conditions of deposition. Ecological data on *Discorbis* indicate that it is a shallow, marine genus. *Protelphidium* is also a shallow water foraminifer. *Elphidium advenum* and *E. indicum*, which have numerous records from warm, shallow water sediments of Recent and older age, are present in much abundance. The overall evidence from smaller foraminifera is in favour of shallow, inner neritic environment.

(B) Evidence from macroinvertebrates

(*a*) *Molluscs* : Molluscs are most abundant. They indicate, shallow, marine environment. Gastropoda and Lamellibranchiata, well represented here, provide following ecological data :

(i) *Gastropods* : Because of wider ecological tolerance, they have very restricted use in environmental analysis. However, few forms are good indicators of environment. *Turritella* lives in the sediment (infaunal form) and feeds on suspension feeders by filtering sea water (Boekschoten, 1967). This mode of life suggests its preference for shallow, warm water on sandy bottom where suspension feeders are present in abundance. *Cerithium*, *Pleurotomaria*, etc. are of less value in environmental reconstruction because of their wider ecological ranges.

(ii) *Lamellibranchs* : The genera most frequently found are *Arca*, *Ostrea*, *Spondylus*, *Mytilus*, *Pecten* and *Venus*. They are epifaunal forms and are better adapted to stable bottoms of fine sands or muds. The presence of *Ostrea* and *Mytilus* together suggests a fairly high energy inner neritic environment. *Ostrea* is an important constituent of shallow-water pelecypod faunas. *Arca* and *Spondylus* are also common inhabitants of shallow seas. *Mytilus* is a marine form and mostly inhabits the zone from high-water to few fathoms. Pectinids also flourish in near-shore environment.

(iii) *Echinoids* : Though very little is known about the palaeoecology of echinoids, a few echinoids serve as good indicators of environment. *Clypeaster*, present in the lower limestone in good number, is commonly known from shallow marine regions and prefers to "live on or beneath the surface of sea floor, largely within the sublittoral and littoral zones" (Durham, 1966).

(iv) *Bryozoa* : The bryozoans have restricted distribution. Only two genera identified as *Anoteropora* and *Nellia* (cheilostome group) are recorded. Cheilostomes are found in marine water of normal salinity (30 to 40 parts per thousand ; Cheetham, 1963). They show preference for the photic zone and high energy conditions. But they are largely influenced by texture and consistency of substrates. Buge (1952) suggests that the fine grained substrates exercise lot of restraint on their growth. Their limited occurrence in the present assemblage of fossils is suggestive of bottoms of fine sands or muds.

The evidence from the macroinvertebrate faunas favours a shallow, inner neritic environment, as also indicated by foraminifera, and throws light on the nature

of sea bottoms on which these groups existed during deposition of this limestone unit. It was deposited in shallow marine environment at or near 20 m. depths, where the fine grained substrates and the invertebrate animals must have become an integral part of each other.

The grey shales which lie above are unfossiliferous. They are followed by upper yellow fossiliferous limestone.

(II) UPPER YELLOW FOSSILIFEROUS LIMESTONE :

It is characterized by an abundance of *Archaias*, which can be split into two species : *Archaias angulatus* and *Archaias malabarica*. *Archaias* dominates the whole foraminiferal fauna recovered from the upper limestone and shows maximum development in size and other characters. Other peneroplids like *Sorites* and *Meandropsina* are just common or even less than that. It is, however, striking to note that the abundant macroinvertebrates encountered in the Lower yellow fossiliferous limestones have become a rare feature in the Upper limestone. As a result, the palaeoecological interpretations are derived mainly from the ecological data on Peneroplidae, or rather *Archaias*.

Henson (1950) suggests that Peneroplidae thrive in a warm, shallow water (18.9°C—31.4°C) and are abundant up to 5 fathoms depth and rare below 60 fathoms. Their distribution is largely governed by sea weeds which grow near the reefs. Because they live attached to sea weeds, reef environments have great influence on them. Henson (1950) states, "....Peneroplidae, with larger Miliolidae are found characteristically in the back reef shoal facies, i.e., in limestones deposited in shallow lagoons between fringing—or barrier—reefs and the shore ; or in top-reef shoals of bank reefs—.... The shoal rocks themselves are typically....calcareous muds and sands derived from reef erosion". These rocks require shallow, warm, clear, disturbed water poor in carbon dioxide. Like Miliolidae and some other groups of foraminifera, they flourish in shallow shoal environments. Bandy (1964a) observes that the forms"....with pillars, such as *Archaias*, occur in greatest abundance at depths of 0-30 m." In the Gulf of Batabano, Cuba, Bandy (1964b) recognised large occurrences of *Archaias* group associated with high-energy environment characterized by coarse sediments, normal salinity, and high oxygen content.

More or less the same environmental conditions are indicated by the common distribution of other shallow inner-shelf forms like *Triloculina*, *Miliola*, *Quinqueloculina*, *Ammonia*, *Hauerina*, *Eoeponidella*, *Elphidium*, *Protelphidium*, etc.

Based on above discussion, it can be remarked that the warm, shallow, marine conditions with normal salinity and high oxygen content might have influenced the deposition of upper yellow fossiliferous limestone. The bathymetric range was most probably from 0 to 30 m. Paucity of macroinvertebrate fauna in the upper limestone may be ascribed to very high energy conditions (in comparison to those of lower limestone) and relatively coarser substrates (Bandy, 1964b).

Overlying the upper yellow fossiliferous limestone are found unfossiliferous grey shales. These are again followed by fine, greyish yellow, poorly fossiliferous shales which contain nothing except *Ammonia*. There is a record of rare molluscs from this bed (Srivastava, 1970). The change in the foraminiferal fauna is significant and marks a shift in depositional environment. It might result from oxygen deficient conditions or toxicity of the substrates (Purdy, 1964) or reduced salinity, or combined effect of these all. With the present study alone, it is very difficult to exactly suggest as to which of the above factors was most active in bringing about the observed change. Anyway, such conditions, when develop, usually restrict the growth of fauna and result in low population density and low taxonomic diversity. Whatever may be the cause, there is a high probability of a gradually receding sea, because these conditions are often associated with the shallowing of sea.

Unconformably overlying horizons put under Pliocene are unfossiliferous, and, hence, no palaeoecologic interpretation is possible for them.

PALAEOBIOGEOGRAPHIC CONSIDERATIONS

A look at the present foraminiferal fauna reveals that the species illustrated here are world-wide in distribution and have been described by the respective authors from various localities of the world which are widely separated. The present-day distribution shows that there is a remarkable degree of provincialism among Recent faunas, and each locality (in a broader sense) is now characterized by its own distinctive faunal assemblage. Against this background, the uniformity in the distribution of fossil species through major regions of the world seems surprising and needs to be explained with a reasoning. The works by Adams (1967), Berggren and Phillips (1971), etc. provide an explanation for this phenomenon, suggesting that these species can have widespread occurrence, provided that the necessary environmental conditions controlling the dispersal of organisms do exist. These workers concur on the proposal of dispersal through migration. In view of the wide acceptance of this proposal among majority of the workers, it is now believed that the extensive faunal migration could possibly be the cause of wide geographic distribution of the species reported herein. An attempt has been made in the following paragraphs to discuss the wide-ranging faunal affinities of the present foraminiferal assemblage in the light of faunal migration which is supposed to be a

key factor in the intermixing of marine faunas of different regions in the geological past. In this attempt, some existing views on faunal migration across the oceans of the world, distribution pattern of Middle Miocene planktonic foraminifera, and major palaeogeographic changes during Neogene times have been briefly discussed.

The present assemblage, though mainly Indo-Mediterranean (Tethyan) in character, shows the presence of faunal elements drawn from Euramerican region (north American and north European provinces), Caribbean-Antillean region and Indo-Pacific-Region. Indo-Mediterranean elements constitute 40% of the total assemblage, while the remaining elements belong to Euramerican, Caribbean-Antillean and Indo-Pacific regions. In the assemblage, there are certain species which are common to all the aforesaid regions. But the maximum degree of commonness is exhibited by Indo-Mediterranean and Indo-Pacific regions. This is followed by Carribbean-Antillean region and Euramerican region. Among the Euramerican faunal elements, the north American (Gulf—Atlantic coast areas) elements outnumber the north European elements having poor representation in the material.

While reviewing the Tertiary benthonic foraminiferal distribution, Berggren and Phillips (1971) suggested an affinity between the benthonic faunas of Caribbean-Antillean, Mediterranean, Euramerican and Indo-Pacific regions during Palaeogene. They believed that this affinity was the result of the intermixing of faunas through several seaways which had linked the major oceans of the world during those times. The mode of dispersal was mainly through the transportation of larvae of these faunas by oceanic currents. The larvae of benthonic invertebrates are known to be planktonic in habit and can be transported by water currents to distant areas, depending upon the duration of larval stage.

Berggren and Phillips (1971) visualise the above inter-regional marine connections for the whole of Palaeogene and early part of Neogene (up to the boundary of Early and Middle Miocene—about 16 m.y. ago). However, the faunal affinities expressed by the present foraminiferal assemblage (Early-Middle Miocene) indicate that the above conditions did exist, to some extent, even in the early part of Middle Miocene, facilitating the free inter-regional migration of benthonic faunas. The data from the studies of distribution pattern of Middle Miocene planktonic foraminifera, coupled with information from palaeogeographic and palaeoclimatic studies of Neogene times support this. The results of these studies are also suggestive of the possibility of persistence of palaeogene marine seaway connections that maintained a wide expanse of approximately uniform warm-water conditions during early part of Middle Miocene. The later disruption of the above uniform pattern, wh led to the geographic isolation of benthonic faunas sulting in higher level of faunal provinciality as se today, has been attributed by Berggren and Phill (1971) to the 'climatic deterioration' and changes in t Tethys sea.

It is generally believed that 'climatic deteriorati and changes in the extent of Tethys took place duri the Late Miocene and resulted in the closure of seve marine seaways that had earlier allowed bentho faunas to migrate frequently across various faunal regi of the world. Berggren and Phillips (1971) state th "the faunal migration between Mediterranean and Car bean regions was effectively cut off by the gradual count clockwise rotation of Spain which nearly closed the Stra of Gibralter in the Late Miocene (Messinian) ; a simi pattern may be seen in the gradual closing of the conn tion with the Indian Ocean to the east".

Evidence from the distribution of planktonic foran fers suggests that the warm-water species had an extensi distribution during Middle Miocene ; they were ev distributed to areas lying at high latitudes (as high 40°N) (Cifelli, 1976). This led Cifelli (1976) to conclu that the tropics had far greater latitudinal extensi during the Miocene (Early-Middle) than at present, a that there was a widespread geographic distributi of warm-water masses during then.

Because of existence of some marine seaways whi served to link the major oceans of the world, somewh similar marine conditions, as believed to have occurr in Palaeogene, also prevailed during early part of t Middle Miocene. Wider latitudinal extent of the trop of those times maintained the warm-climatic charact of the major world oceans, thereby preserving the h pitable conditions for the growth of warm-water spec over a wide geographic range.

An extensive faunal migration continued to occ between Indo-Mediterranean, Indo-Pacific, Caribbea Antillean, and Euramerican regions even up to early pa of Middle Miocene, i.e., well beyond the boundary Early and Middle Miocene. In view of the widely ava able hospitable conditions, the migrant benthonic spec from one region were easily accommodated in the oth

Major barriers to dispersal of organisms in sea see to have been introduced during the Late Miocene when t climatic cooling and disruption of Tethys sea occurre And it is probably then that the widespread inter-regio migration of marine faunas which had been going freely for millions of years came to standstill.

SYSTEMATIC DESCRIPTION

Genus *Textularia* DEFRANCE in DE BLAINVILL 1824

Textularia aff. *Textularia badensis* LALICKER
(Plate I—1-2)

Textularia badensis Lalicker, 1935, *Cushman Lab. Foram. Res., Contrib.*, Sharon, Mass., U.S.A., vol. II, pt. 2, p. 44, pl. 7, fig. 1a-c.

Dimensions (in mm) :

Specimen number	Length	Breadth	Thickness
Geol./LU/915	0.40	0.35	0.25

Remarks : This species is well represented in the present material. The Kutch specimens differ from the type species in their subacute periphery of early portion, smaller dimensions, and broader apertural end.

Horizon : Lower yellow hard fossiliferous limestone, and upper yellow, hard fossiliferous limestone.

Genus *Spiroloculina* D'ORBIGNY, 1826

Spiroloculina sp.
(Plate I—4)

Remarks : This rare form is characterised by strongly compressed, lanceolate test, flattened sides, slightly depressed central area, truncated, carinate periphery, narrow apertural end, absence of neck and a small rounded aperture at the end of the final chamber.

Dimensions :

Length 0.75 mm ; Breadth 0.30 mm ; Thickness 0.15 mm.

Horizon: Lower yellow, fossiliferous limestone, and upper yellow hard fossiliferous limestone.

Genus *Quinqueloculina* D'ORBIGNY, 1826

Quinqueloculina cf. *Quinqueloculina barkhana* Mohan and Bhatt (pl. I—3)

Quinqueloculina barkhana Mohan and Bhatt, 1968, *Natl. Inst. Sci.* India, *Proc.* vol. 34, pt. B, no. 4, p. 166, pl. 13, fig. 5a-c.

Dimensions (in mm) :

Specimen number	Length	Breadth	Thickness
Geol./LU/916	0.90	0.65	0.60

Remarks : This species is comparable with *Quinqueloculina barkhana* Mohan and Bhatt recorded from the Miocene rocks exposed along the Barkhan River, western Kutch, India.

Horizon : Lower yellow fossiliferous limestone, and upper yellow, hard fossiliferous limestone.

Quinqueloculina aff. *Q. norvangi* BOLTOVSKOY
(Plate I—9-10)

Quinqueloculina norvangi Boltovskoy, 1954, Buenos Aires, *Inst. Nac. Invest. Cienc. Nat. Rev.* Buenos Aires, *Geol.*, vol. 3, no. 3, p. 126, pl. 1, fig. 13a-c.

Dimensions (in mm) :

Specimen number	Length	Breadth	Thickness
Geol./LU/917	0.95	0.60	0.45

Remarks : The forms exhibiting a small compressed test having depressed sutures, inflated chambers and loosely agglutinated surface express affinity to the Boltovskoy's species recorded from the Gulf of San Jorge, southeast of Comodoro Rivadavia, Southwestern Argentina.

Horizon : Lower yellow fossiliferous limestone, and upper yellow hard fossiliferous limestone.

Genus *Triloculina* D'ORBIGNY, 1826

Triloculina brongniartiana D'ORBIGNY
(Plate I—7-8)

Triloculina brongniartiana d'Orbigny—Brooks, 1973, *Micropalaeontology*, vol. 19, no. 4, p. 406, pl. 6, figs. 3-4.

Dimensions (in mm) :

Specimen number	Length	Breadth	Thickness
Geol./LU/918	0.75	0.40	0.30

Remarks : This species, recorded both as fossil and living species from Castel Arquato, Plaisantin, Italy and les Antilles respectively, occurs in the present area in fairly good numbers. The Kutch specimens look very close to the photomicrographs of Brooks (1973) who recorded it from the Recent sediments of southern coast of Puerto Rico.

Horizons : Lower yellow, fossiliferous limestone, and upper yellow, hard, fossiliferous limestone.

Triloculina frederica LE CALVEZ
(Plate I—5-6)

Triloculina frederica Le Calvez, 1947, France, *Service, Carte Geol., Mem.*, Paris, p. 20, pl. 4, figs. 69-71.

Dimensions (in mm) :

Specimen number	Length	Breadth	Thickness
Geol./LU/919	0.70	0.45	0.30
Geol./LU/920	0.70	0.45	0.30

Remarks : Though smaller than the type species, the Kutch specimens agree with the species of Le Calvez. Some distinctive features include : elongate test ; truncated acute edges ; costate wall ; and circular aperture with rim-like margins and a small tooth.

Horizon : Lower yellow fossiliferous limestone, and upper yellow, hard, fossiliferous limestone.

Trilocuulina inflata D'ORBIGNY
(Plate II—1-2)

Triloculina inflata d' Orbigny, 1826, *Ann. Sci. Nat.*, Paris, France, Ser. 1 tome 7, p. 300—Mohan and Bhatt, 1968, *Proc. Natl. Inst. Sci.* India, vol. 34, pt. B, no. 4, p. 168, pl. XII, figs. 12a, b, c,

Dimensions (in mm) :

Specimen number	Length	Breadth	Thickness
Geol./LU/921	0.60	0.55	0.35

Remarks : The Kutch specimens recorded by the writer are larger than the type species.

The species was earlier recorded by Mohan and Bhatt (1968) from the Miocene rocks of Waghopadar—Cheropadi area of Kutch.

Horizon : Lower yellow, fossiliferous limestone, and upper yellow, hard, fossiliferous limestone.

Triloculina tricarinata D'ORBIGNY

(Plate II—3)

Triloculina tricarinata d'Orbigny—Mohan and Bhatt, 1968, *Proc. Natl. Inst. Sci.*, vol. 34, B, no. 4, p. 168, pl. XII, figs. 13a, b.

Dimensions (in mm) :

Specimen number	Length	Breadth
Geol./LU/922	0.55	0.30

Remarks : This smooth-walled species shows the typical tricarinate character. It was previously recorded by Mohan and Bhatt (1968) from the Miocene rocks of Waghopadar-Cheropadi area of Kutch.

Horizon : Lower yellow, fossiliferous limestone, and upper yellow, hard, fossiliferous limestone.

Triloculina turgida REUSS

(Plate II—4-5)

Triloculina turgida Reuss, 1851, *Deutsch. Geol. Ges.*, Zeitscher., Berlin, Deutschland, Bd. 3, p. 86, pl. 7, fig. 8.

Dimensions (in mm) :

Specimen number	Length	Breadth	Thickness
Geol./LU/923	0.45	0.35	0.25

Remarks : This Eocene species is represented in the Kutch material by small-sized specimens.

Horizon : Lower yellow, fossiliferous limestone, and upper yellow, hard, fossiliferous limestone.

Genus *Miliola* LAMARCK, 1804

Miliola aff. *Miliola rostrata* (TERQUEM)

(Plate II—17, 18)

Miliola rostrata (Terquem)—Le Calvez, 1947, France, *Service, Carte, Geol., Mem.*, Paris, p. 31, figs. 55-57.

Dimsions (in mm) :

Specimen number	Length	Breadth	Thickness
Geol./LU/924	0.65	0.30	0.15

Remarks : The specimens referable to *M. rostrata* show elongate, fusiform test, agglutinated surface, slightly produced apertural end, and a small rounded aperture with a trematophore.

Horizon : Lower yellow, fossiliferous limestone, and upper yellow, hard, fossiliferous limestone.

Miliola aff. *Miliola saxorum* (LAMARCK)

(Plate II—6-10)

Miliola saxorum (Lamarck), Cushman, 1927, *Contrib. Cushman Lab. Foram. Res.*, Sharon, Mass., vol. 3, pt. 2, p. 125, pl. 24.

Dimensions (in mm) :

Specimen number	Length	Breadth	Thickness
Geol./LU/925	0.80	0.35	0.25
Geol./LU/926	0.85	0.35	0.25

Remarks : The Miocene representatives of this species from Kutch exhibit elliptical test which does not possess longitudinal striations of the type species. The last chamber is broader near the base and tapering at the apertural end.

Horizon : Lower yellow, fossiliferous limestone and upper yellow, hard, fossiliferous limestone.

Genus *Ammomassilina* CUSHMAN, 1933

Ammomassilina alveoliniformis (MILLETT)

(Plate II—13, 16)

Ammomassilina alveoliniformis (Millett)—Cushman, 1933, *Cushman Lab. Foram. Res., Contrib.*, vol. 9, pt. 2, p. 32—Barker, 1960, *Soc. Econ. Palaeontologists* and *Mineralogists, Spec. Publ.*, Tulsa, Oklahoma, U.S.A., no. 9, p. 16, pl. VIII, figs. 11, 13, 14.

Dimensions (in mm.) :

Specimen number	Length	Breadth	Thickness
Geol./LU/928	0.60	0.50	0.10
Geol./LU/929	0.85	0.65	0.10

Remarks : These specimens conform to the type description of *Ammomassilina alveoliniformis* (Millett) recorded from the Recent sediments of Malay Archipelago.

Horizon : Lower yellow, fossiliferous limestone, and upper yellow, hard, fossiliferous limestone.

Genus *Hauerina* D'ORBIGNY in DE LA SARGA, 1839

Hauerina orientalis (CUSHMAN)

(Plate II-11-12)

Hauerina orientalis Cushman, 1946, *Cushman Lab. Foram. Res., contrib., Saron, Mass.*, vol. 22, p. 12, pl. 2, figs. 22-24—Brady, 1881, *Rept. Voy. H. M. S. Challenger, Zoology*, vol. 9, p. 192, pl. 7, figs. 18-20.

Dimensions (in mm) :

Specimen number	Diameter	Thickness
Geol./LU/930	0.30	0.10
Geol./LU/931	0.35	0.10

Remarks : The specimens show strongly crenulated periphery and highly ornamented wall. The wall ornamentation consists of radial ridges having mild development of transverse striae. The present specimens are relatively smaller in dimensions and appear more close to the figures (18, 19, pl. 7) of Brady. The species is common in warm, shallow waters of the tropical Pacific.

Horizon : Upper yellow, hard, fossiliferous limestone, and upper yellow, hard, fossiliferous limestone.

Hauerina ornatissima (KARRER)

(Plate II—14)

Quinqueloculina ornatissima Karrer, 1868, *K. Akad. Wiss Wien, Math.—Naturw.* Cl., *Sitzber.*, Wien, Osterreich, 13rd. 58, Abt. 1, p. 151, pl.3, fig. 2.

Dimensions (in mm) :

Specimen number	Diameter	Thickness
Specimen number		
Geol. LU/932	0.30	0.10

Remarks : This compressed, subcircular species is characterized by plicated periphery and highly ornamented surface. The surface ornamentation consists of numerous, radial ridges and several series of transversely arranged conspicuous knobs.

There are numerous records of this species from the Recent sediments of Pacific ; it is also known from the Miocene of Kostej in Banat, Rumania.

Horizon : Lower yellow, fossiliferous limestone, and upper yellow, hard, fossiliferous limestone.

Genus Austrotrillina PARR, 1942

Austrotrillina howchini (SCHLUMBERGER)

(Plate II—15)

Austrotrillina howchini (Schlumberger), Mohan and Bhatt, 1968, *Natl. Inst. Sci.* India, vol. 34, pt. B, no. 4, p. 169, pl. XIII, fig. 18.

Dimensions (in mm) :

Specimen number	Length	Breadth	Thickness
Geol./LU/933	0.675	0.55	0.40
Geol./LU/934	0.35	0.55	0.35

Remarks : The present forms are referable to *Austrotrillina howchini* (Schlumberger), a well-known species of Miocene, originally recorded from Australia. The species is known to range from the bsae of the Aquitanian to the middle of the Langhian. See Clarke and Blow (1969).

Horizon : Lower yellow, fossliferous limestone, and upper yellow, hard, fossiliferous limestone.

Genus Archaias MONTFORT, 1808

Archaias angulatus (FICHTEL AND MOLL)

(Plate III—5)

Archaias angulatus (Fichtel and Moll), Brooks, 1973, *Micropalaeontology*, vol. 19, no. 4, pl. 9, figs. 16-20.

Remarks : The species, referred here to *Archaias angulatus* (Fichtel and Moll), may probably belong to the *angulatus* and the related group. The test is much compressed, circular. The spire has about 4 whorls, the first being closely coiled ; the later ones become loose. The last whorl forms a flare.

Cushman (1930) states, "This species is very abundant in the West Indian region, and very much less so in the Indo-Pacific. In the western tropical Atlantic, it is often the dominant species in comparatively shallow water". Smout and Eames (1958) observe, "In spite of published statements, the only reliable records of the species are from the Recent material from the Caribbean sea, Gulf of Mexico, and adjacent parts of the western Atlantic Ocean". The species recorded here is not the flabelliform one but of cyclical nature, agreeing with the figures 2, 3 of Smout and Eames (1958, p. 212, pl. 39). It is visible in thin sections only.

Horizon : Rare in lower yellow, fossiliferous limestone, and common in upper yellow, hard, fossiliferous limestone.

Archaias (= *Taberina*, *Pseudotaberina*) *malabarica* (CARTER)

(Plate III—1-2)

Orbitolites malabarica Carter, 1853, *Ann. Mag. Nat. Hist.* vol. 2, no. 11, p. 425, pl. 16b, figs. 1-4. *Orbiculina malabarica* Carter, 1857, *Jour. Bombay Br. R. Asiatic Soc.*, 5, p. 634.

Taberina malabarica (Carter), Henson, 1950, Middle Eastern *Tertiary Peneroplidae* (Foraminifera), with remarks on the Phylogeny and Taxonomy of the family p. 50, pl. 3, figs. 7, 11-12, Tewari, 1952, *Curr. Sci.*, vol. 21, no. 8, pp. 217-218 ; Smout and Eames, 1958, *Palaeontology*, vol.. 1, pt. 3, p. 222.

Taberina malabarica (Carter), Eames, Banner Blow, and Clarke, 1962, Fundamentals of Mid-Tertiary Stratigraphic correlation. pl. VI, figs. A, B, pl. VII, figs. A, B.

Pseudotaberina malabarica (Carter), Eames, 1971, In : *Revised Tertiary Faunas* by Morley Davies, vol. 1, p. 36, fig. 52.

Remarks : Henson (1950) expanded the genus *Taberina* to include species having the similar essential chamber structure, but showing a range of variation in the form of test and chamber arrangement, as found in other Peneroplinids, viz., "Spiral throughout, compressed or lenticular, involute or evolute, or cyclical in the adult". The genus also includes some Tertiary and Recent species which are compressed—spiral types and have sub-epidermal partitions.

Eames (1971, In : Tertiary Faunas by Morley Davies) renamed it as *Pseudotaberina malabarica* to differentiate it from *Taberina* which is known to range from Cretaceous to Palaeocene.

The writer has carefully reviewed the previously published records about this species. He assigns this species to *Archaias*, defining it as an ecotype of *Archaias* with sub-epidermal partitions which may be regarded as a slight modification of pillars of the pillared species. In the present case, the true pillars have gradually become transformed into partial partitions. With other things being same, the rudimentary partitions of later stages alone would not justify the placement of this species in a genus other than *Archaias*. Henson's (1950) extension of the genus *Taberina* to include those Tertiary and Recent species which have sub-epidermal partitions and compressed-spiral tests with cyclical arrangement of chambers in the adult stage may not hold good in the case of *malabarica*.

The sections under study show compressed, spiral forms becoming cyclical in the adult ; the sub-epidermal

partitions observed in the later chambers alternate from one chamber to the next ; the interseptal pillars are confined to the central zone of chambers ; the megalosphere is oval and prominent.

The species was originally reported from the late Tertiary (Pliocene)—Bluish green limestone of Malabar coast of India. But such beds were later assigned to Miocene ; Morley Davies (1935) recorded *A. malabarica* (Carter) from the Miocene of Travancore and Ceylon (Lower to Middle Miocene). Henson (1950) recorded it from the Middle Miocene of the Middle East. Tewari (1952) reported it from the Middle Miocene of the Vinjhan-Miani area. Clarke and Blow (1969) record that it (as *Pseudotaberina malabarica*) ranges from the zone N.10 to the lower part of zone N.11 (within Langhian, Lower part of the Middle Miocene) in Far Eastern countries —Indonesia, Melania, and Malaysia. The forms expressing affinity to *malabarica* have been seen even in older strata, equivalent to the zone N.7 and N.8 (Burdigalian) (see Clarke and Blow, 1969). In the letter stage classification of the Far East, it ranges from Tf_1 to Tf_2, having doubtful occurrence in upper e' (Upper Burdigalian).

Horizon : Rare forms having affinity with *A. malabarica* are seen in Lower yellow, fossiliferous limestone ; true *A. malabarica* is abundantly represented in the upper yellow, hard, fossiliferous limestone.

Genus *Sorites* EHRENBERG, 1839

Sorites marginalis (LAMARCK)

(Plate III—3-4)

Sorites marginalis (Lamarck), Brooks, 1973, *Micropalaeontology*, vol. 19, no. 4, p. 410, pl. 8, figs. 13-16.

Dimensions (in mm) :

Specimen number	Diameter	Thickness
Geol./LU/935	0.77	0.10
Geol./LU/936	0.90	0.125

Remarks : Though less than common, the specimens from Kutch agree with the type description. *S. marginalis* has been earlier reported from the Dominican area, Cuba and Atlantic.

Horizon : Lower yellow, fossiliferous limetsone, and upper yellow, hard, fossiliferous limestone.

Genus *Lagena* WALKER & JACOB in KANMACHER, 1798

Lagena laevis (MONTAGU)

(Plate III—11-12)

Lagena laevis (Montagu), Bhatt, 1968, *Proc. Natl. Inst. Sci.* India, vol. 34, B, no. 4, p. 171, pl. XIII, fig. 23.

Dimensions (in mm) :

Specimen number	Diameter
Geol./L.U./937	0.17
Geol./L.U./938	0.17

Remarks : Rare forms of this species occur in the Kutch material.

Horizon : Lower yellow, fossiliferous limestone, and upper yellow, hard, fossiliferous limestone.

Lagena cf. *Lagena lisbonensis* CUSHMAN

(Plate III—10)

Lagena lisbonensis Cushman and Todd, 1948, *Cushman Lab. Foram. Res., Contr.*, Sharon, Mass., vol. 24, p. 30, pl. 5, fig. 22.

Dimensions (in mm) :

Specimen number	Length	Breadth
Geol./LU/939	0.375	0.125

Remarks : The single specimen showing an elongate test, broad base, tapering apertural end, costate wall, short neck, and a rounded, radiate aperture is comparable with *Lagena lisbonensis* Cushman and Todd recorded from the Eocene, Claiborne, Cook Mountain formation of Mississippi.

Horizon : Upper yellow, hard, fossiliferous limestone.

Lagena phialaeformis CRESPIN

(Plate III—8-9)

Lagena apiculata (Reuss) var. *phialaeformis* Crespin, 1953, *Cushman Found. Foram. Res. Contrib.*, Washington, D. C., vol. 4, pt. 1, p. 34, pl. 6 fig. 9.

Dimensions (in mm) :

Specimen number	Length	Breadth
Geol./LU/940	0.225	0.10
Geol./LU/941	0.225	0.10

Remarks : The forms from Kutch agree with the type description. The characteristic features include small, bottle-shaped test, broad, angular basal end, gradually tapering apertural end, a short eccentric spine at the base, and radiate, terminal aperture.

Horizon : Upper yellow, hard, fossiliferous limestone.

Genus *Pseudonodosaria* BOOMGART, 1949

Pseudonodosaria cf. *Pesudonodosaria tenuistriata* (BERMUDEZ)

(Plate III—13-14)

Pseudoglandulina tenuistriata Bermudez, 1949, *Cushman Lab. Foram. Res.*, Spec. Publ., Sharon, Mass., no. 25, p. 163, pl. 10, fig. 45.

Dimensions (in mm) :

Specimen number	Length	Thickness
Geol./LU/942	0.50	0.30
Geol./LU/ 943	0.40	0.35
Geol./LU/944	0.45	0.325

Remarks : The specimens from Kutch exhibit embracing chambers in the early portion, highly inflated last chamber, horizontal sutures, and radiate, terminal aperture.

Horizon : Lower yellow, fossiliferous limestone, and upper yellow, hard, fossiliferous limestone.

Genus *Bolivinella* CUSHMAN, 1927

Bolivinella folia (PARKER AND JONES)

(Plate III—6-7)

Bolivinella folia (Parker and Jones), Cushman, 1927, *Cushman Lab. Foram. Res.*, Sharon, Mass., U.S.A., vol. 2, pt. A, p. 79, pl. 11 fig.

Dimensions (*in mm*) :

Specimen number	Length	Breadth	Thickness
Geol./LU/945	0.275	0.225	0.075
Geol./LU/946	0.35	0.30	0.10
Geol./LU/947	0.30	0.225	0.075
Geol./LU/948	0.425	0.30	0.10

Remarks : This compressed, biserial species with elongate chambers commonly occurs in the present material. It is characterized by the raised, limbate sutures, the markedly raised median line, and a stout spine on each side. The sutures are typically characterized by beads.

Horizon : Upper yellow, hard, fossiliferous limestone.

Genus *Glandulina* D'ORBIGNY in DE LA SAGRA, 1839

Glandulina nipponica ASANO

(Plate IV—5-6)

Glandulina nipponica Asano, 1951, Part 8 : Polymorphinidae. In : Stach, L. W. (ed.), *Illustrated catalogue of Japanese Tertiary smaller foraminifera*. Tokyo : Hosokawa Printing Co., p. 14, tfs. 71- 72.

Dimensions (*in mm*) :

Specimen number	Length	Breadth
Geol./LU/949	0.40	0.25

Remarks : Broadly fusiform specimens with highly inflated, overlapping chambers, flush sutures, and terminal, radiate aperture have been assigned to *Glandulina nipponica* Asano. These are, however, smaller in dimensions than the type species.

Horizon : Upper yellow, hard, fossiliferous limestone.

Genus *Bolivina* D'ORBIGNY, 1839

Bolivina cf. *Bolivina quasiplicata* SUBBOTINA

(Plate IV—1-2)

Bolivina quasiplicta Subbotina, 1953, Leningrad : *Vses. Neft. Nauchnoissled. Geol.-Razved. Inst.* (VNIGRI) (All-Union Petroleum Scientific Research) Geological Prospecting Institute), Microfauna of the U.S.S.R., Trudy, n.s., shornik, 6, 0.220, pl. 10, fig. 4.

Dimensions (*in mm*) :

Specimen number	Length	Breadth	Thickness
Geol./LU/950	0.45	0.25	0.15

Remarks : This wedge-shaped, strongly inflated species described from the Oligocene and late Eocene of southern U.S.S.R. occurs in the present material in fairly good numbers. The distinct, depressed, meandrine sutures, oval-shaped aperture with a thin lip, and two longitudinal costae in the lower part of the test are the characteristic features of the Kutch specimens.

Horizon : Lower yellow, fossiliferous limestone, and upper yellow, hard, fossiliferous limestone.

Genus *Brizalina* COSTA, 1856

Brizalina petterssoni (PARKER)

(Plate IV—3-4)

Bolivina petterssoni Parker, 1953, In : North Atlantic Foraminifera (Phleger, F. B., Parker, F. L., and Prrson, J. F.) *Swedish Deep Sea Exped.* 1947-1948, Repts., Geteborg, Sweden, vol. 7, no. 1, 0.36, pl. 7, figs. 15-17.

Dimensions (*in mm*) :

Specimen number	Length	Breadth	Thickness
Geol./LU/951	0.45	0.20	0.10
Geol./LU/952	0.40	0.15	0.10

Remarks : Although sharing many characteristic features of Parker's species, the Kutch specimens differ from the type species in their less number of chambers, weakly carinate periphery (in initial portion), and very fine longitudinal costae at the basal end.

Horizon : Lower yellow, fossiliferous limestone, and the upper yellow, hard, fossiliferous limestone.

Genus *Tubulogenerina* CUSHMAN, 1927

Tubulogenerina tubulifera (PARKER AND JONES)

(Plate IV—7)

Tubulogenerina tubulifera (Parker and Jones)—Mohan and Bhatt, 1968, *Proc. Natl.* Inst. Sci. India, vol. 34, B. no. 4, p. 179, pl. XIV, fig. 18.

Dimensions (*in mm*) :

Specimen number	Length	Breadth	Thickness
Geol./LU/953	0.32	0.25	0.20

Remarks : This form agrees well with type species recorded from the Eocene of Grignon, France. Mohan and Bhatt (1968) recorded it from the Miocene rocks of Waghopadar-Cheropadi area of Kutch.

Horizon : Upper yellow, hard, fossiliferous limestone.

Genus *Eoeponidella* WICKENDEN, 1949

(*Eoeponidella multisecta* (GALLOWAY AND HEMINWAY)

(Plate IV—8-9)

Discorbis multisectus Galloway and Heminway, 1941, New York *Acad. Sci.*, Sci. Surv. Puerto Rico and Virgin Islands, New York, U.S.A. vol. 3, pt. 4, p. 384, pl. 20, fig. 4a-c.

Dimensions (*in mm.*) :

Specimen number	Diameter	Thickness
Geol./LU/954	0.45	0.15

Remarks : Originally recorded from the Miocene of Puerto Rico, this species is common in the present ma-

terial. The distinguishing features include : planoconvex test ; centrally depressed umbilical side ; strongly convex, evolute spiral side ; supplementary chambers ; coarsely perforate wall ; faintly developed sigmoid secondary sutures ; and a large, open arched aperture.

The Kutch specimens differ from the type species in their acute, carinate periphery, 5 chambers in the last whorl, early limbate sutures on spiral side, faint secondary sutures, and large open aperture.

Horizon : Lower yellow, fossiliferous limestone, and upper yellow, hard, fossiliferous limestone.

Eoeponidella hemisphaerica (CUSHMAN)

(Plate IV—11-12)

Discorbis hemisphaerica Cushman, 1931, *Contr. Cushman Lab. Foram. Res.* Sharon, Mass., U.S.A., vol. 7, pt. 3, p. 59, 01.7, fig. 14a-c.

Dimensions (in mm.) :

Specimen number	Diameter	Thickness
Geol./LU/955	0.25	0.15
Geol./LU/956	0.25	0.10
Geol./LU/957	0.275	0.125

Remarks : This species is common in the present material and ranges here from late Oligocene to Middle Miocene.

The recorded specimens conform to the type species in almost all the characters.

Horizon : Lower yellow, fossilferous limestone, and upper yellow, hard, fossiliferous limestone.

Genus *Spirillina* EHRENBERG, 1843

Spirillina arenacea WILLIAMSON

(Plate IV—10)

Spirillina arenacea Williamson, 1858, on the Recent foraminifera of Great Britain. Roy. Soc., London. England, p. 93, pl. 7, fig. 203.

Dimensions (in mm.) :

Specimen number	Diameter	Thickness
Geol./LU/958	0.275	0.05
Geol./LU/959	0.20	0.05

Remarks : The present specimens are referable to *Spirillina arenacea* Williamson recorded originally from the Recent sediments of Great Britain.

Horizon : Lower yellow, fossiliferous limestone, and upper yellow, hard, fossiliferous limestone.

Genus *Ammonia* BRUNNICH, 1972

Ammonia annectens concinna MILLET

(Plate IV—13-16)

Ammonia annectens concinna Millet, 1904, Report on the Recent foraminifera of the Malay Archipelago collected by Mr. A. Durant. Pt. XVI, *Roy, Micr. Soc.* London, *Jour.* London, England, p. 505, pl. 10, fig. 7a-c.

Dimensions (in mm) :

Specimen number	Diameter	Thickness
Geol./LU/960	0.55	0.35
Geol./LU/961	0.60	0.40
Geol./LU/962	0.65	0.35
Geol./LU/963	0.75	0.40

Remarks : Originally described from the Recent sediments of Malay Archipelago, this species is one of the main components of the Kutch assemblage and has the maximum representation in the material.

The specimens show an acute, carinate periphery, 11-11½ chambers in the last whorl, elevated, smooth, slightly curved sutures on spiral side, and open fissures in the umbilicus. Sutures on unbilical side are deeply excavated, each having two rows of beads.

Horizon : Lower yellow, fossiliferous limestone ; upper yellow, hard, fossiliferous limestone ; and greyish yellow fossiliferous shales.

Genus *Elphidium* DE MONTFORT, 1808

Elphidium advenum (CUSHMAN)

(Plate V—1-3)

Elphidium advenum (Cushman), Mohan and Bhatt, 1968, *Proc. Natl. Inst.* Sci. India, vol. 34, B, no. 4, p. 172-173, pl. XIV, fig. 3a, b.

Dimensions (in mm) :

Specimen number	Diameter	Thickness
Geol./LU/964	0.45	0.20
Geol./LU/965	0.45	0.20

Remarks : This species is common in the present assemblage. It is characterized by a small, compressed test, acute, lobulate, slightly carinate periphery, inflated chambers, and a series of small rounded pores at the base of the apertural face. The umbilical regions are marked with a small central boss of clear shell material.

Horizon : Lower yellow, fossiliferous, limestone, and upper yellow, hard, fossiliferous limestone.

Elphidium indicum CUSHMAN

(Plate V—5-7)

Elphidium indicum Cushman—Mohan and Bhatt, 1968, *Proc. Natl. Inst. Sci. India*, vol. 34, B, no. 4, p. 173, pl. XIV, figs. 4a, b.

Dimensions (in(mm) :

Specimen number	Diameter	Thickness
Geol./LU/966	0.85	0.50
Geol./LU/967	0.70	0.40

Remarks : Specimens from Kutch exhibit large number of chambers, curved retral processes, and costate wall.

The type species was originally recorded from the Recent shore sands of Bombay, India. Mohan and Bhatt (1968) earlier recorded it from the Miocene of Waghopadar-Cheropadi area of Kutch.

Horizon : Lower yellow, fossiliferous limestone, and upper yellow, hard, fossiliferous limestone.

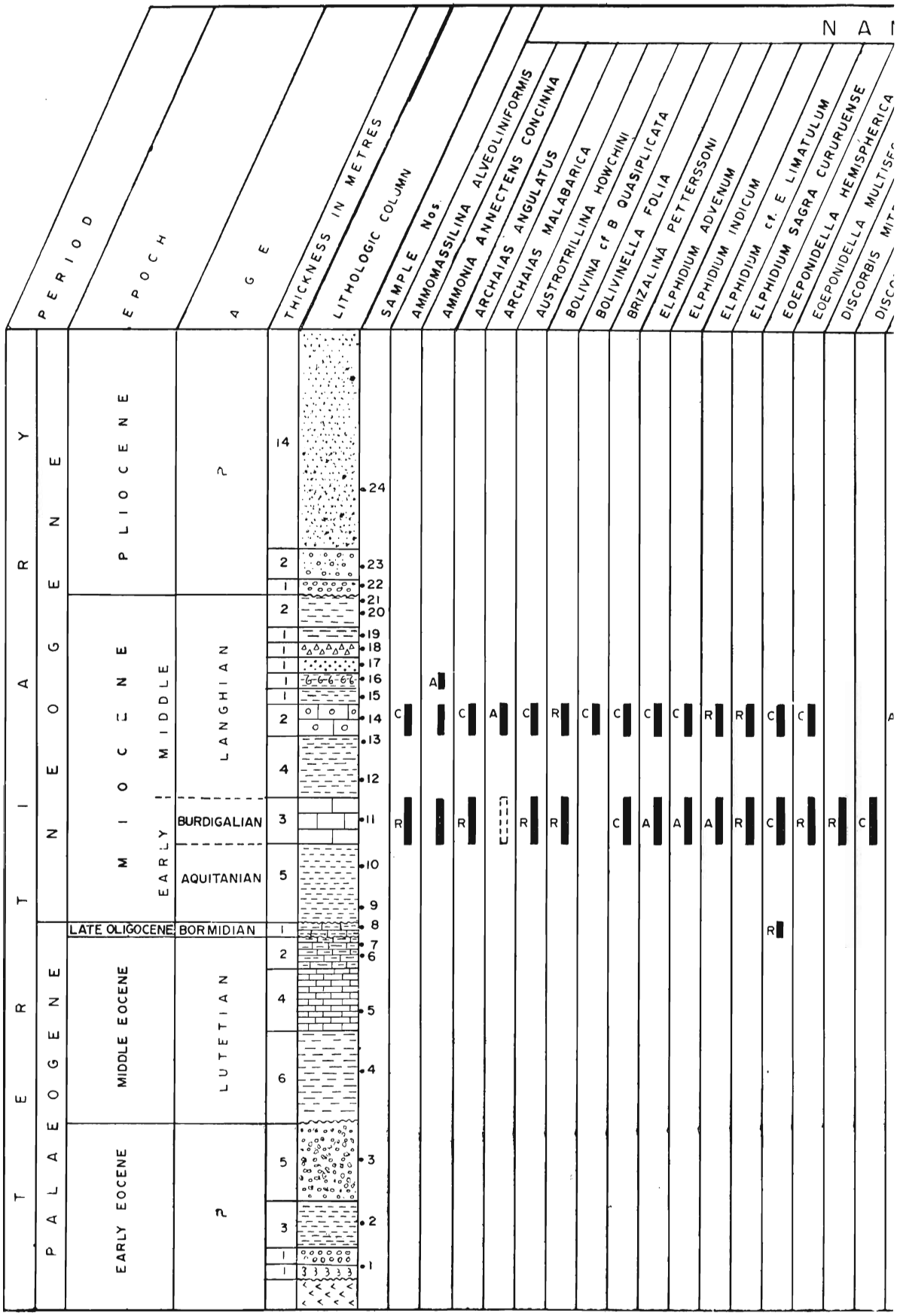
PERIOD
EPOCH
AGE
THICKNESS IN METRES
LITHOLOGIC COLUMN
SAMPLE Nos.
AMMOMASSILINA ALVEOLINIFORMIS
AMMONIA ANNECTENS CONCINNA
ARCHAIAS ANGULATUS
ARCHAIAS MALABARICA
AUSTROTRILLINA HOWCHINI
BOLIVINA cf B QUASIPLICATA
BOLIVINELLA FOLIA
BRIZALINA PETTERSSONI
ELPHIDIUM ADVENUM
ELPHIDIUM INDICUM
ELPHIDIUM cf. E LIMATULUM
ELPHIDIUM SAGRA CURURUENSE
EOEPONIDELLA HEMISPHERICA
EOEPONIDELLA
DISCORBIS
TERTIARY
PALAEOGENE
NEOGENE
PLIOCENE
MIOCENE
EARLY
MIDDLE
LANGHIAN
BURDIGALIAN
AQUITANIAN
LATE OLIGOCENE
BORMIDIAN
MIDDLE EOCENE
LUTETIAN
EARLY EOCENE

Fig. 4. Show

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FLORILUS cf F BOUEANUM																														
FLORILUS SCAPHUM																														
GLANDULINA aff G. NIPPONICA																														
HAUERINA ORIENTALIS																														
HAUERINA ORNATISSIMA																														
LAGENA LAEVIS																														
LAGENA cf L LISBONENSIS																														
LAGENA PHIALAEFORMIS																														
MELONIS aff M. DANVILLENSE																														
MELONIS GUADALUPAE																														
MIOGYPSINA GLOBULINA																														
MILIOLA aff M ROSTRATA																														
MILIOLA aff M SAXORUM																														
PROTELPHIDIUM PROFUNDIFOSSATUM																														
PSEUDONODOSARIA cf P TENUISTRIATA																														
QUINQUELOCULINA cf Q BARKHANA																														
QUINQUELOCULINA aff Q NORVANGI																														
SORITES MARGINALIS																														
SPIRILLINA ARENACEA																														
SPIROLOCULINA sp																														
TEXTULARIA aff T BADENSIS																														
TRILOCULINA BRONGNIARTIANA																														
TRILOCULINA FREDERICA																														
TRILOCULINA INFLAT...																														
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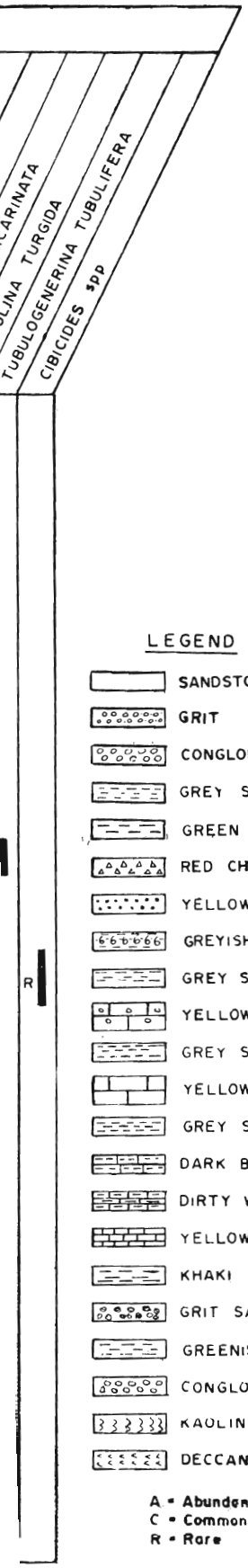
ing frequency distribution of Early-Middle Miocene Benthonic Foraminifera.



LEGEND

- SANDSTONE
- GRIT
- CONGLOMERATE
- GREY SHALES
- GREEN HARD SHALES
- RED CHERTY BED
- YELLOW FINE GRAINED SANDSTONE
- GREYISH YELLOW SHALES (Fossiliferous)
- GREY SHALES
- YELLOW LIMESTONE (Fossiliferous)
- GREY SHALES
- YELLOW HARD LIMESTONE (Macroinvertebrates)
- GREY SHALES
- DARK BROWN HARD MARL (Fossiliferous)
- DIRTY WHITE AND YELLOW SOFT MARL (Fossiliferous)
- YELLOW HARD LIMESTONE (Fossiliferous)
- KHAKI SHALES
- GRIT SANDSTONE AND VARIEGATED SHALES
- GREENISH GREY SMOOTH CLAYS
- CONGLOMERATE
- KAOLINISED CLAY
- DECCAN TRAP

A = Abundant (More than 25 specimens)
C = Common (6 - 10 specimens)
R = Rare (1 - 5 specimens)

Elphidium cf. *Elphidium limatulum* COPELAND
(Plate V—8-9)

Elphidium limatulum Copeland, 1964, Bull. Amer. Pal., Ithaca, N.Y. vol. 47, no. 215, pp. 263-264, pl. 37, fig. 5a-b.

Dimensions (in mm) :

Specimen number	Diameter	Thickness
Geol./LU/968	0.275	0.15

Remarks : Specimens from the present area differ from the type species in the large, highly inflated last chamber, expanded apertural face, absence of clear shell material in the umbilici, and the smaller dimensions. A similar form was described by Mohan and Bhatt (1968) from the Miocene of Kutch with only generic status.

The type species was recorded from the upper Miocene, Duplin Marl, of Duplin County, North Carolina.

Horizon : Lower yellow, fossiliferous limestone, and upper yellow, hard, fossiliferous limestone.

Elphidium sagra cururuense PETRI
(Plate V—4)

Elphidium sagra (d'Orbigny) var. *cururuense* Petri, 1954 *Sao Poulo, Univ. Fac. Filos. Cienc. Let., Bol.*, Sao Paulo, Brazil, no. 176 (Geol., no. 11), 0.80, pl. 5, figs. 13-16.

Dimensions (in mm) :

Specimen number	Diameter	Thickness
Geol./LU/969	0.20	0.15

Remarks : Although rare in the Kutch material, specimens are in accord with the Brazil Miocene species described by Petri.

Horizon : Lower yellow, fossiliferous limestone, and upper yellow, fossiliferous limestone.

Genus Protelphidium HAYNES, 1956

Protelphidium profundifossatum POAG
(Plate V—10-11)

Protelphidium profundifossatum Poag, 1966, *Micropalaeont.*, vol. 12, no. 4, p. 416, pl. 7, figs. 13-14.

Dimensions (in mm) :

Specimen number	Diameter	Thickness
Geol./LU/970	0.325	0.175

Remarks : Kutch specimens agree well with the description and figures of Poag (1966), who reported it from the base of Paynes Hammock Formation (Lower Miocene ?) of Alabama and Mississippi. The species occurs abundantly in the material of Kutch.

Horizon : Lower yellow, fossiliferous limestone (abundant), and upper yellow, hard, fossiliferous limestone.

Genus Florilus DE MONTFORT, 1808

Florilus cf. *Florilus boueanum* (D'ORBIGNY)
(Plate V—12-14)

Florilus boueanum (d'Orbigny)—Hada, 1931, *Tohoku Imp. Univ. Sci. Rept.*, Ser. 4, Biol., vol. 6, p. 117, tf. 76, *Nonionina boueana* d'Orbigny, 1846, Foraminifers fossiles du bassin tertiare de Vienne, p. 108, pl. 5, figs. 11, 12.

Dimensions (in mm) :

Specimen number	Diameter	Thickness
Geol./LU/971	0.30	0.15
Geol./LU/972	0.25	0.10

Remarks : The specimens referable to *F. boueanum* exhibit small compressed test, depressed umbilical areas filled with papillate secondary material, limbate, depressed sutures, inflated last chamber, and an arched, aperture at the base of the apertural face.

The type species was recorded from the Miocene of Nussdorf in the Vienna Basin. The species is also known from the Oligocene to Pliocene of central and southern Europe. It occurs less commonly in the Kutch material.

Horizon : Upper yellow, hard, fossiliferous limestone.

Florilus scaphum (FICHTEL AND MOLL)
(Plate V—15-16)

Nonion scaphum (Fichtel and Moll), Cushman, 1930, *U. S. Natl. Musc., Bull.*, 104, pt. 7, p. 5, pl. 2, figs. 3, 4—Marks, 1951, Contr. Cushman Found. Foram. Res., vol. 2, no. 4, p. 677, pl. 66, figs. 3a, b —Brady, 1884, in Barker; Taxon. Notes on Rept. H. M. S. challenger Exped. *Soc. Econ. Palaeont.* and *Mineral*, Spec. Publ., 9, p. 114, pl. 56, figs. 7-9.

Florilus communis (d'Orbigny), Singh *et al.*, 1975 *Jour. Pal. Soc. India*, vol. 18, p. 34, pl. 4, figs. 6, 10 (1973).

Dimensions (in mm) :

Specimen number	Length	Breadth	Thickness
Geol./LU/973	0.325	0.20	0.15
Geol./LU/974	0.275	0.20	0.10

Remarks : Bilaterally symmetrical, compressed specimens with unormented umbilici and depressed, non-limbate sutures have been referred to *F. scaphum* (Fichtel and Moll.) The specimens are close to the figures of Brady (1884) and Cushman (1930). The species is abundantly represented in the Kutch material.

Horizon : Lower yellow, fossiliferous limestone, and upper yellow, hard, fossiliferous limestone.

Genus Melonis DE MONTFORT, 1808

Melonis aff. *Melonis danvillense* (HOWE AND WALLACE)
(Plate VI—1-2)

Nonion danvillense Howe and Wallace—Cushman, 1939, *U. S. Geol. Survey Prof.* no. 191, p. 5, pl. 1, fig. 19a, b.

Dimensions (in mm) :

Specimen number	Diameter	Thickness
Geol./LU/975	0.15	0.10
Geol./LU/976	0.25	0.125

Remarks : Though rare in the present material, the specimens having affinity with the species of Howe and Wallace are easily recognized.

They differ from the type species in their highly flaring, broad apertural face and less curved apertural slit. The Kutch forms are, however, much akin to the topotype figures of the species illustrated by Cushman (1939).

Horizm : Upper yellow, hard, fossiliferous limestone.

Melonis guadalupae PARKER

(Plate VI—3-6)

Melonis guadalupae Parker, 1964, Jour. Pal., Tulsa, Okla., vol. 38, no. 4, p. 633, pl. 100, figs. 13-14.

Dimensions (in mm) :

Specimen number	Diameter	Thickness
Geol./LU/977	0.225	0.15
Geol./LU/978	0.25	0.10

Remarks : This species is rare in Kutch material. The Kutch specimens reveal depressed sutures, smaller dimensions, and the absence of the last chamber expansion down over the umbilical regions.

Horizon : Upper yellow, hard, fossiliferous limestone.

Genus Miogypsina SACCO, 1893

Miogypsina cf. *Miogypsina globulina* (MICHELOTTI)

(Plate V I—7)

Miogypsina globulina (Michelotti), 1847, Holland, Maatsch. Wetensch. Haarlem, Natuurk, Verh., Haarlem, Netherlands, Verz. 2, dl. 3, stuk. 2, pp. 1-408, pl. 1, figs. 11-12—Drooger and Socin, 1959, Micropalaeontology, vol. 5, no. 4, pp. 415-426, pl. 1, figs. 5-6—Raju, 1972, study of Indian Miogypsinidae, Ph.D. Thesis, State University of Utrecht, Utrecht, Ther Netherlands.

Remarks : The form in the thin section is comparable with *Miogypsina globulina* (Michelotti) ; it has much resemblance with the axial section figured by Drooger and Socin (1959), who recorded it from the Miocene (Burdigalian) of Rosignano, northern Italy. Raju (1974) described it from the Indian region from the strata equal to Burdigalian age. The species was first reported from Turin, Italy. It is reported from the American, the Mediterranean, and the Indo-Pacific provinces.

Horizon : Lower yellow, fossiliferous limestone.

ACKNOWLEDGEMENT

The writer expresses his deep sense of gratitude to the late Prof. S. N. Singh for encouragement and library and laboratory facilites, and to Prof. K. P. Vimal for able guidance and suggestions.

Gratitude is extended to Dr. W.A. Berggren of Woods Hole Oceanographic Institution, Mass., U.S.A., who read through the manuscript in spite of his busy schedule of time and made many important suggestions towards the improvement of this paper.

This work constitutes a part of the writer's doctoral thesis at Lucknow University, which was partly written at the Institute of Petroleum Exploration, Dehra Dun during the session 1975-76. Gratitude is expressed to Mr. S. N. Talukdar, Director, I.P.E., and Mr. V. V. Sastri, Director, Research & Development Wing, I.P.E. for the cordial facilities extended to the writer during his stay there. He is indebted to Dr. Pratap Singh, Senior Geologist, I.P.E. for sustained help and valuable suggestions. The writer wishes to thank Mr. Madan Mohan, Mr. K. S. Soodan, Mr. P. Kumar, Mr. M. L. Bhatia and Dr. V. Narayanan, the distinguished scientists of I.P.E. for their critical review of the work as well as meaningful advice. Sincere thanks are extendet to Dr. I. P. Srivastava of Directorate of Geology & Mining, U. P. for giving the writer some relevant data on macro-invertebrate fauna. Dr. Arun Kumar of Kumaun University, who critically read the manuscript, is gratefully acknowledged. State Council of Science & Technology, U.P., supported this research (Grant No. SCSIR/1883/LKO (45)/72).

REFERENCES

ADAMS, C. G. 1967. Tertiary foraminifera in the Tethyan, American and Indo-Pacific provinces. *Syst. Assoc. Pub.* **7** : 195-219.

ADAMS, C. G. 1973. *Some Tertiary Foraminifera.* In : Atlas of Palaeobiogeography, Ed. A Hallam, Elsevier Scientific Publishing Company. 453-468.

BANDY, O. L. 1964a. Cenozoic planktonic foraminiferal zonation. *Micropaleontology.* **10**(1) : 1-17.

BANDY, O. L. 1964b. Foraminiferal biofacies in sediments of the Gulf of Batabano, Cuba, and their geologic significance. *Bull. Amer. Assoc. Petrol. Geol.* **48**(10) : 1666-1679.

BERGGREN, W. A., 1971. Tertiary boundaries and correlations : In Funnel, B. M. and Riedel, W. R. (Eds.), *Micropalaeontology of Oceans*, London (Cambridge Univ. Press) : 693-809.

BERGGREN, W. A., AND PHILLIPS, J. D. 1971. The influence of continental drift on the distribution of Cenozoic benthonic foraminifera in the Mediterranean and Caribbean regions. *Symp. Geology of Libya* (Tripoli, 1969), *Catholic Press, Beirut.* : 263-299.

BISWAS, S. K. 1971. Note on the Geology of Kutch. *Quart. Jour. Geol. Min. Met. Soc. India.* **43** (4) : 223-235.

BISWAS, S. K. AND RAJU, D. S. N. 1973. The Rock-Stratigraphic classification of the Tertiary sediments of Kutch : *Bull. O.N.G.C.* **10** (1-2) 37-45

BLOW, W. H. 1969. Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy : *Proc. First Int. Conf. Plankt. Microf.* **1** : 199-422.

BOEKSCHOTEN, G. J. 1967. Palaeoecology of some Mollusca from the Tielrode Sands (Pliocene of Belgium). *Palaeog. Palaeoclim. Palaeoecol.* **3** (3) : 331-362.

BRADY, H. B. 1884. In Barker, R. W., 1960, Taxonomic Notes on the species figured by H. B. Brady in his report on the Foraminifera dredged by H. M. S. *Challenger* during the years 1873-1876 : *Soc. Econ. Paleont. Miner., Spl. Publ.* **9** : 2-240.

BROOKS, W. W. 1973. Distribution of Recent foraminifera from the southern coast of Puerto Rico: *Micropaleontology.* **19** (4) : 385-416.

BUGE, EMIL 1952. Classe des Bryozoaires, in Piveteau Jean, Ed., *Traite de Paleontologie*, tome **1** : Paris, Masson : 688-749.

CHEETHAM, A. H. 1963. Late Eocene Zoogeography of the Eastern Gulf coast Region. *Mem. Geol. Soc. Amer.* **91** : 1-109.

CIFELLI, R. 1976. Evolution of Ocean climate and the record of planktonic foraminifera. *Nature.* **264** : 431-432.

CLARKE, W. J. AND BLOW, W. H., 1969. The inter-relationship of some late Eocene, Oligocene and Miocene Larger foraminifera and planktonic Biostratigraphic indices. *Proc. First. Inter. Conf. Plankt.* Microf. (Geneva, 1967). **II** : 82-97.

CUSHMAN, J. A. 1939. A monograph of the foraminiferal family Nonionidae : *U.S. Geol. Survey Prof. Paper.* **191** : 1-191.

CUSHMAN, J. A. 1930. The foraminifera of the Atlantic Ocean Pt. 7. Nonionidae, Camerinidae, Peneroplidae and Alveolinidae : *U.S. Nat. Mus. Bull. Smithsonian Institution, Washington, D. C.* **104** : 1-77.

DATTA, A. K., BANNERJI, R. K. AND SOODAN, K. S., 1969. A review of Recent contributions to the Meso-Cenozoic foraminiferal biostratigraphy of India : *ECAFE, Symposium on the development of Petroleum Resources of Asia and the Far East, 4h. Session, Canberra, Australia.* : 1-14.

DAVIES, M., 1935. *Tertiary faunas.* Murby, London. **1** : 1-406.

DROOGER, C. W. AND SOCIN, C. 1959. Miocene foraminifera from Rosignano, northern Italy. *Micropaleontology.* **5** (4) : 415-426.

DURHAM, J. W. 1966. Clypeasteroid : In *Treatise on Invertebrate Palaeontology.* Ed. R. C. Moore, Pt. 4 (Echinodermata 3). **2** : 450.

EAMES, F. E. 1950. On the ages of certain upper Tertiary beds of Peninsular India and Ceylon. *Geol. Mag.* **87** (4) : 233-252.

EAMES, F. E. 1971. *Tertiary Faunas* (revised edition of *Tertiary faunas* by A. Morley Davies in 1935). George Allen and Unwin, London. **1** : 19-563.

FURON, R., AND LAMOINE, P. 1939. Sur la presence du Nummulitique a Pondicherry (Inde francaise). C. R. *AC. Sci. Parise.* **207** : 1424-6.

GUHA, D. K., MOHAN, M., KUMAR, P., IYENGAR, R. (KM.), AND RAJU, D. S. N. 1965. Marine Neogene microfauna from Karaikal, South India : *Bull. Geol. Min. Met. Soc. India.* **34** : 1-13.

HENSON, F. R. S. 1950. *Middle Eastern Tertiary Peneroplidae (Foraminifera) with remarks on the phylogeny and Taxonomy of the family.* The West Yorkshire Printing Co. Ltd., Wakefield, England. : 1-70.

JOHNSON, R. G. 1965. Pelecypod Death Assemblages in Tomales Bay, California. *Jour. Pal.* **39** (1) : 80-85.

MOHAN, M. AND BHATT, D. K., 1968. Burdigalian Foraminifera from Kutch, India. *Proc. Nat. Inst. Sci. India.* **34B** (4) : 160-190.

POAG, C. W. 1966. Paynes Hammock (Lower Miocene ?) foraminifera of Alabama and Mississippi. *Micropalentology.* **12** (4) : 393-440.

POULOSE, K. V. AND NARAYANSWAMI, S. 1968. The Tertiaries of Kerala coast. *Mem. Geol. Soc. India.* **2** : 300-398.

PURDY, E. G. 1964. Sediments as substrates : In *Approaches to Palaeoecology*, Ed. John Imbrie and Norman Newell. 238-269.

RAJU, D. S. N. 1970. Zonal distribution of Selected foraminifera in the Cretaceous and Cenozoic sediments of Cauvery basin and some problems of Indian biostratigraphic classification. *Publ. Cent. Adv. Stud. Geol., Panjab Univ., Chandigarh.* **7** : 85-110.

SMOUT, A. H., AND EAMES, F. E. 1958. The genus *Archaias* and its stratigraphical distribution. *Palaeontology.* **1** (3) : 207-225.

SOUAYA, F. J. 1963. On the foraminifera of Gebel Ghara (Cairo-Suez road) and some other Miocene samples. *Jour. Pal.* **37** : 433-457.

SOUAYA, F. J. 1966. Miocene foraminifera of the Gulf of Suez region, U. A. R., Pt. 3—Biostratigraphy. *Micropaleontology.* **12** (2) : 183-202.

SOUAYA, F. J. 1966. Miocene foraminifera of the Gulf of Suez region, U. A. R., Pt. 4—Paleoecology and Age. *Micropaleontology.* **12** (4) : 493-504.

SRIVASTAVA, I. P. 1970. Geology and Micropalaeontology of the Miani-Vinjhan area, southwestern Kutch, Gujarat (with special reference to the study of Ostracoda). *Unpublished Ph.D. Thesis, Luck. Univ. Lucknow.*

TEWARI, B. S. 1952. The Tertiary beds of Vinjhan-Miani area, southwestern Cutch, India. *Curr. Sci.* **21** : 217-218.

TEWARI, B. S. 1956. The genus *Spiroclypeus* from Kutch, western India. *Curr. Sci.* **25** : 217-218.

WALTON, W. R. 1964. Recent foraminiferal Ecology and Paleoecology. In *Approaches to Paleoecology*, J. Imbrie and N. D. Newell (Eds.), John Wiley and Sons, New York : 151-237.

WAYLAND, E. J., AND DAVIES, A. M. 1923. The Miocene of Ceylon. *Quart. Jour. Geol. Soc.* **79** : 577-602.

EXPLANATION OF PLATES

PLATE I

1, 2. *Textularia* aff. *Textularia badensis* Lalicker, 1, side view, 2, apertural view, × 140.
3. *Quinqueloculina* cf. *Quinqueloculina barkhana* Mohan and Bhatt, 3, side view × 66.
4. *Spiroloculina* sp., 4 side view, × 77.
5-6. *Triloculina frederica* Le Calvez, side views, × 77.
7-8. *Triloculina brongniartiana* d'Orbigny side views, × 66.
9-10. *Quinqueloculina* aff. *Quinqueloculina norvangi* Boltovskoy, side views, × 77.

PLATE II

1-2. *Triloculina inflata* d'Orbigny, side views, × 77.
3. *Triloculina tricarinata* d'Orbigny, side view, × 66.
4-5. *Triloculina turgida* Reuss, side views, × 77.
17-18. *Miliola* aff. *Miliola rostrata* (Terquem), emend. Le Calvez, side views, × 66.
6-10. *Miliola* aff. *Miliola saxorum* (Lamarck), 6-10 side views; × 66.
13-16. *Ammomassilina alveoliniformis* (Millett), 13, side view, × 66; 16, side view, × 66.
14. *Hauerina ornatissima* (Karrer), side view, × 66.
11-12. *Hauerina orientalis* Cushman, side views, × 66.
15. *Austrotrillina howchini* (Schlumberger), side view, × 66.

PLATE III

1-2. *Archaias malabarica* (Carter), 1, equatorial section, × 35; 2, axial section, × 35.
3-4. *Sorites marginalis* (Lamarck), side views, × 66.
5. *Archaias angulatus* (Fichtel and Moll), 5, Equatorial section, × 25.
6-7. *Bolivinella folia* (Parker and Jones), side views, × 108.
8-9. *Lagena phialaeformis* Crespin, side views, × 116.
10. *Lagena* cf. *Lagena lisbonensis* Cushman, side view, × 116.
11-12. *Lagena laevis* (Montagu), 11, side view; 12, apertural view, × 116.
13-14. *Pseudonodosaria* cf. *Pseudonodosaria tenuistriata* (Bermudez), side views, × 77.

PLATE IV

1-2. *Bolivina* cf. *Bolivina quasiplicata* Subbotina, 1, side view, 2, apertural view, × 140.
3-4. *Brizalina petterssoni* Parker, side views, × 140.
5-6. *Glandulina* aff. *Glandulina nipponica* Asano, 5, apertural view, 6, side view, × 77.
7. *Tubulogenerina tubulifera* (Parker and Jones), side view, × 116.
8-9. *Eoeponidella multisecta* (Galloway and Heminway) 8, spiral view, 9, umbilical view, × 77.
10. *Spirillina arenaceae* Williamson, 10 spiral view, × 108.
11-12. *Eoeponidella hemisphaerica* (Cushman), 11, spiral view, 12, umbilical view, × 77.
13-16. *Ammonia annectens concinna* Millet, 13 umbilical view, × 77; 14, spiral view, 15, umbilical view, 16, apertural view, × 77.

PLATE V

1-3. *Elphidium advenum* (Cushman), 1, side view, 2, apertural view, × 77; 3, side view, × 77.
4. *Elphidium sagra cururuense* Petri, side view, × 108.
5-7. *Elphidium indicum* Cushman, 5, side view, 6, apertural view, × 66; 7, side view, × 66.
8-9. *Elphidium* cf. *Elphidium limatulum* Copeland, 8, side view, 9, apertural view, × 108.
10-11. *Protelphidium profundifossatum* Poag, 10, side view, 11, apertural view, × 108.
12-14. *Florilus* cf. *Florilus boueanum* (d'Orbigny) 12, side view, 13, apertural view, × 108; 14, side view, × 108.
15-16. *Florilus scaphum* (Fichtel and Moll), 15, side view, × 108; 16, apertural view, × 108.

PLATE VI

1-2. *Melonis danvillense* (Howe and Wallace), side views, 1, × 16; 2, × 160.
3-6. *Melonis* aff. *Melonis guadalupae* Parker, 3, side view, × 160; 4-5, side views, 6, apertural view, × 160.
7. *Miogypsina globulina* (Michelotti), axial section, × 49.
8. A portion of an indeterminate algae, × 16.

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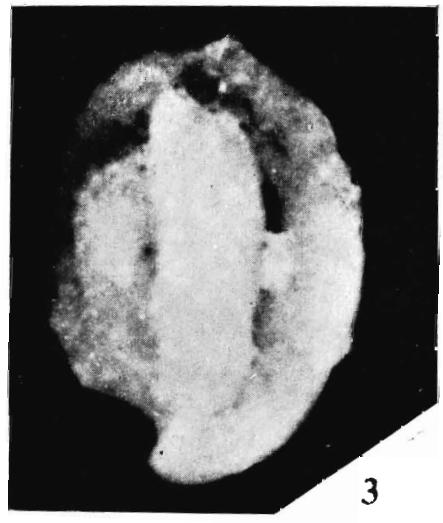
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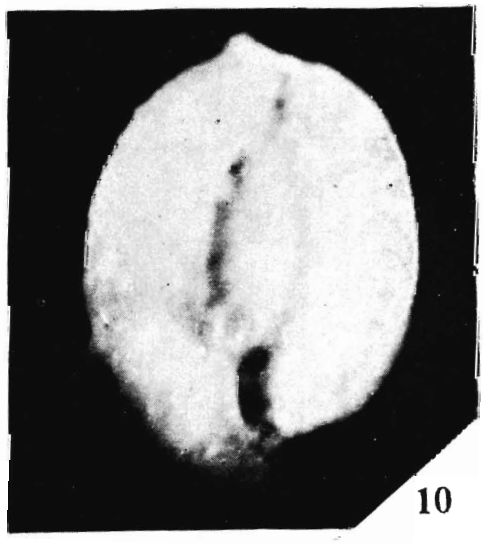
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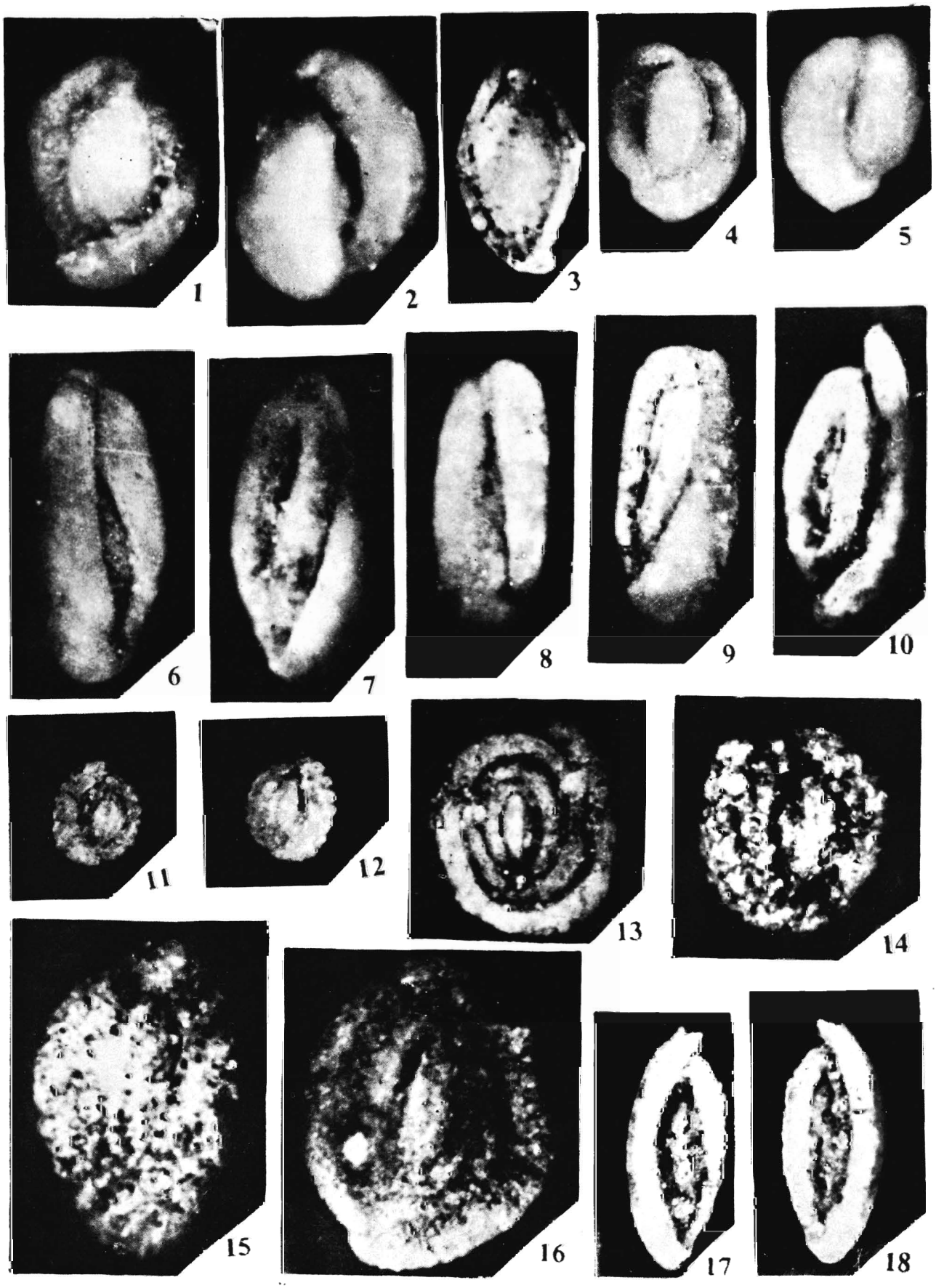
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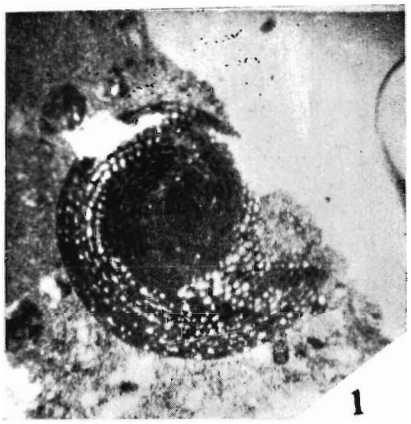
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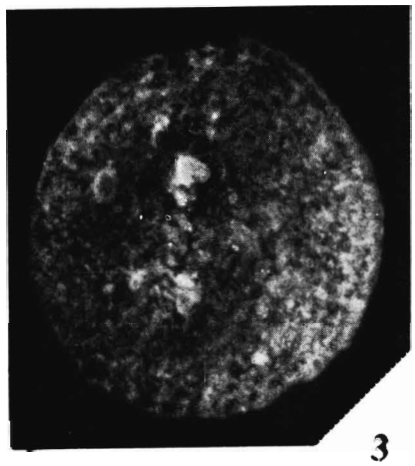
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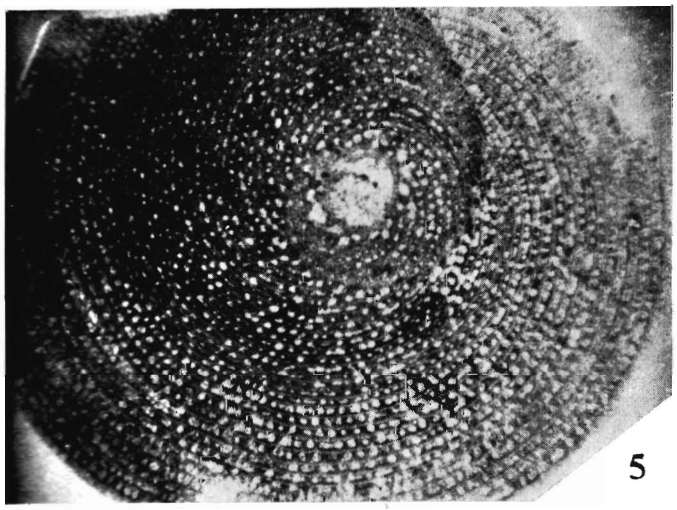
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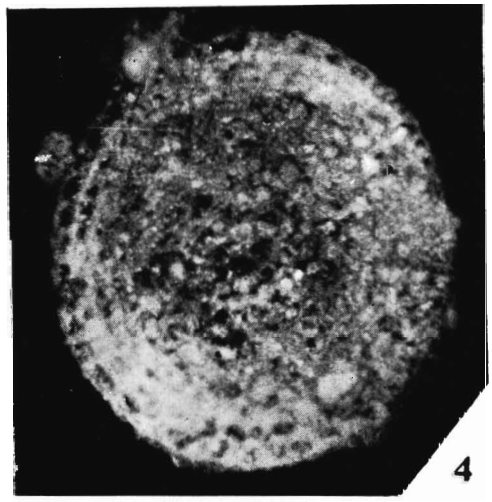
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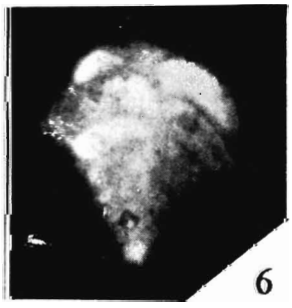
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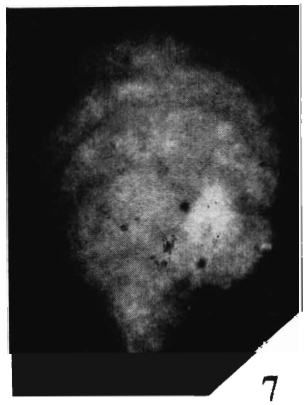
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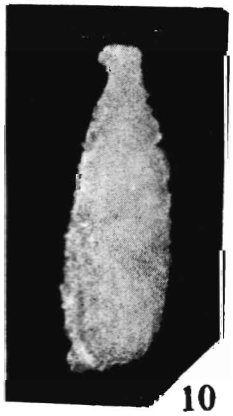
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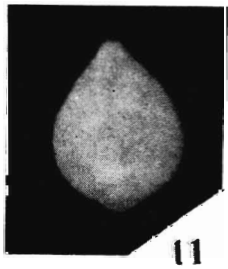
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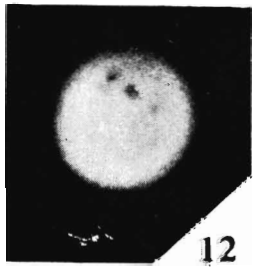
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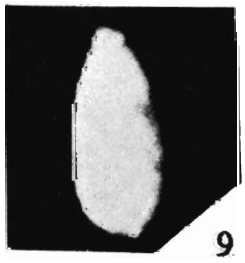
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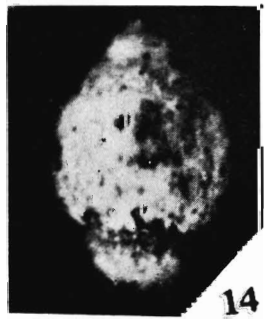
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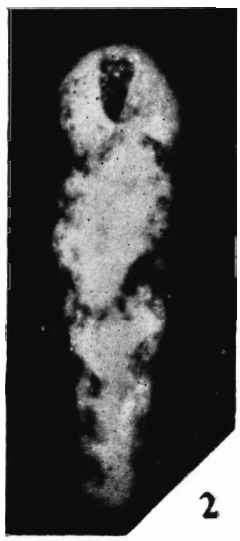
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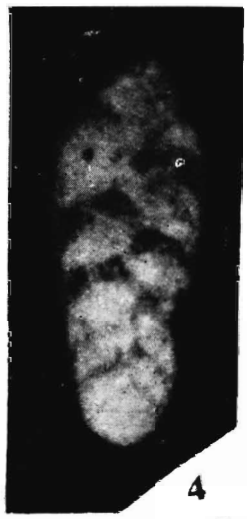
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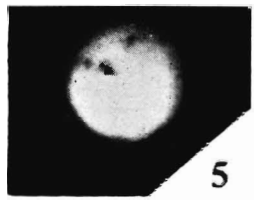
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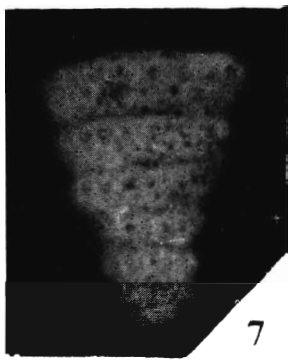
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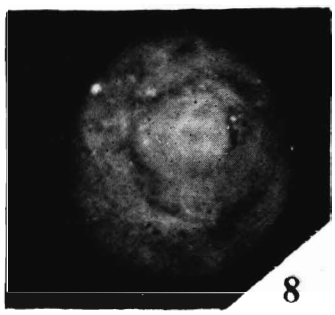
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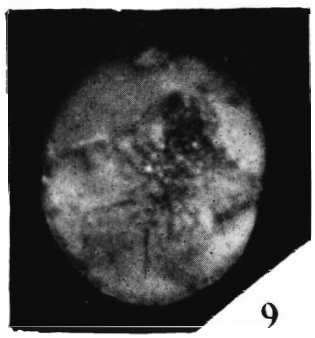
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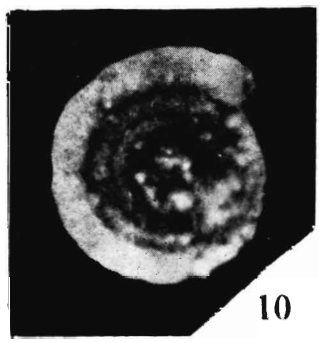
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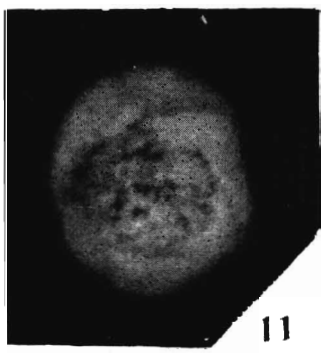
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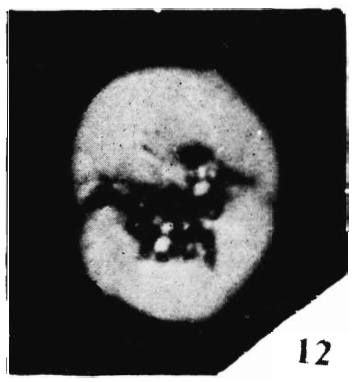
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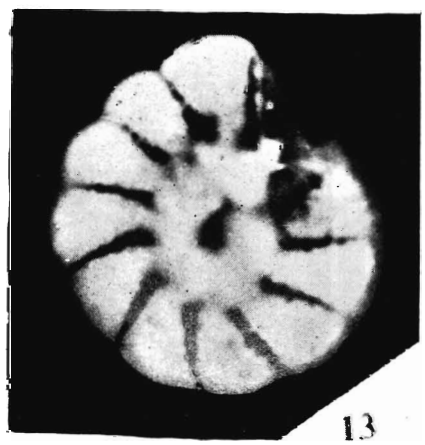
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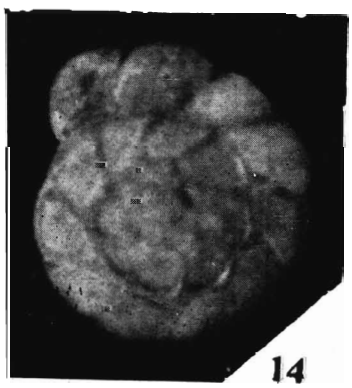
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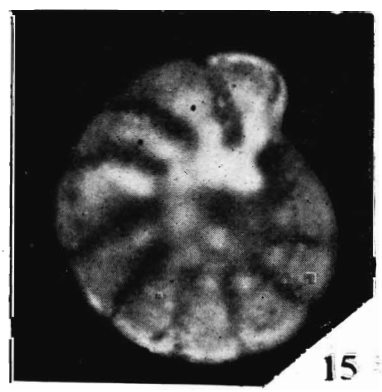
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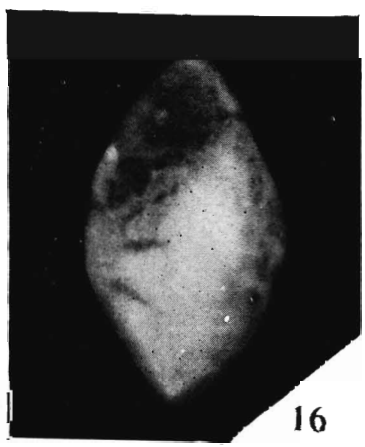
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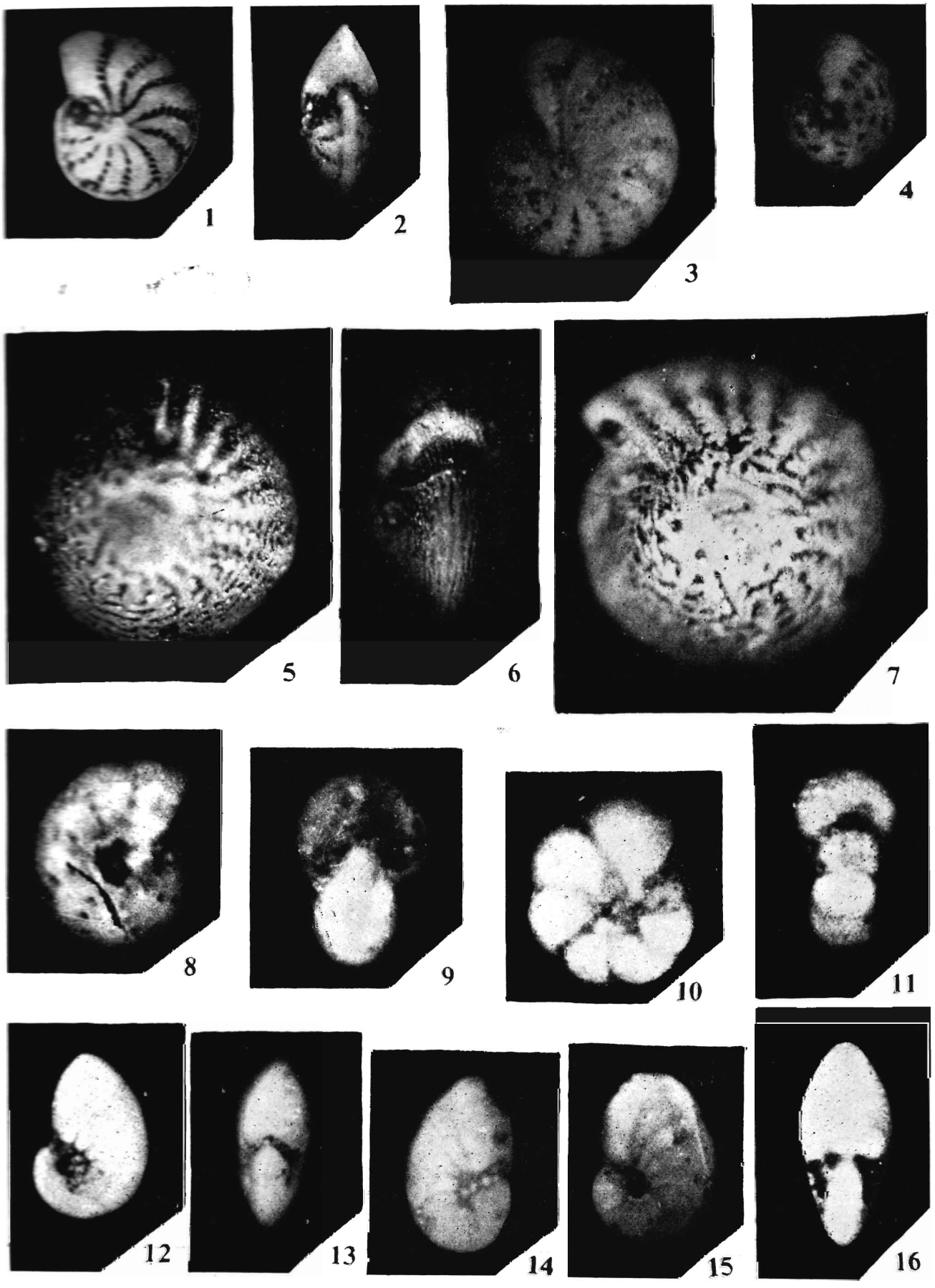

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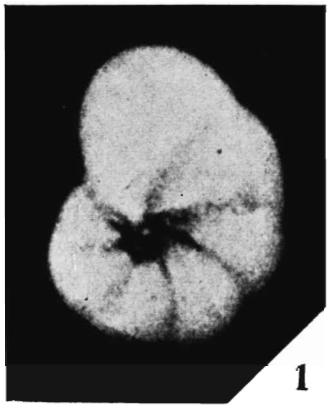
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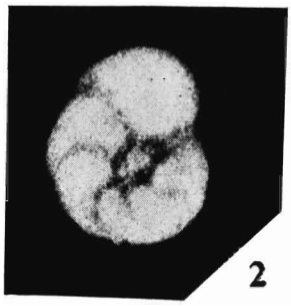
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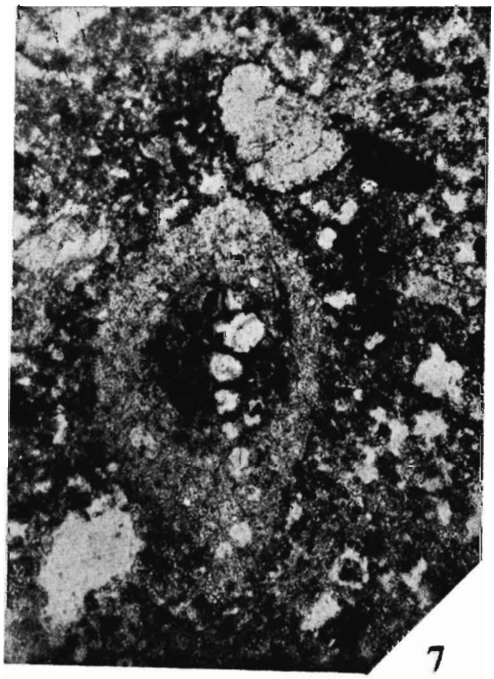
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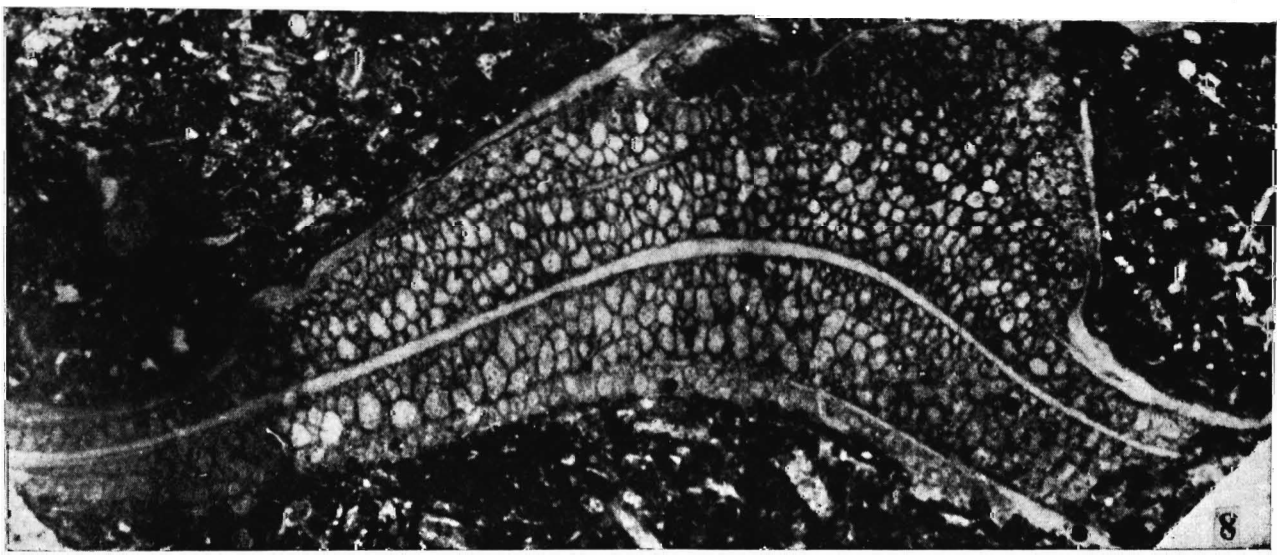
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