

**UTRECHT  
MICROPALAEONTOLOGICAL  
BULLETINS**

D. S. N. RAJU

STUDY OF INDIAN MIOGYPSINIDAE

**9**

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STUDY OF INDIAN MIOGYPSINIDAE

D. S. N. RAJU

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## ABSTRACT

The succession of Indian Miogypsinidae from three closely sampled sections in Kutch, from core and cutting samples of some deep wells in Cauvery Basin, and from two samples from Saurashtra, has been investigated in order to evaluate its value in biostratigraphic classification and correlation of the Oligo-Miocene sections.

Fourteen specific units of *Miogypsina*, belonging to three subgenera – *Miogypsinoides*, *Miogypsina* s.s. and *Lepidosemicyclina* – are recognized on the basis of the  $\bar{X}$  –  $\bar{V}$  scale, in combination with a few other features.

Very primitive species, *M. cf. bermudezi* and *M. complanata*, and highly advanced ones, such as *M. excentrica* and *M. antillea*, are present. As a whole the evolutionary trends in Indian Miogypsinidae are in accordance with the principle of nepionic acceleration, but there is a major contradiction in the case of early *Miogypsinoides*. The development trend in younger *Miogypsinoides* – from *M. bantamensis* via *M. dehaartii* to *M. indica* – is parallel to that of the succession of *Miogypsina* s.s., from *M. gunteri* via *M. tani* to *M. globulina*. Subconical *cupulaeformis* forms come into the picture at about the middle part of the range of *M. dehaartii*.

The evolution in the Indian *Lepidosemicyclina* lineage, from *M. thecideaeformis* to *M. excentrica* via *M. droogeri*, took place within the range of *M. globulina*. *M. globulina* assemblages from India present a case of very slow or arrested evolution.

Seven range zones (= lineage zones) could be based on the succession known from India. Study of associated planktonic foraminifera suggests that the rate of evolution in the *Miogypsina* s.s. – *Lepidosemicyclina* lineage, at least in the interval from *M. tani* to *M. excentrica*, is much higher than it is in planktonic foraminifera. The advantages and limitations of using Miogypsinidae in time-stratigraphic correlations are discussed.

## Chapter I

### INTRODUCTION

For more than thirty years assemblages of larger foraminifera have been widely used in age determinations and correlations of Oligo-Miocene sedimentary successions of the Indian sub-continent. Following the development after the introduction of the "letter stage" classification of the Indonesian Tertiary succession (Van der Vlerk & Umbgrove, 1927), some of the genera and species of larger foraminifera, such as *Miogypsina*, *Lepidocyclina* and *Taberina*, gained high index value in age determinations and correlations. For some of these markers it was taken for granted, that their presence gives definite proof of an age equivalence to some particular stage in Europe or a "letter stage" in Indonesia. Most of the controversies in the literature regarding age determinations centre around the evaluation of such specific and/or generic names. However, as most of the specialists working in India accepted and followed typological species concepts, with rather variable ideas on splitting and lumping, the ranges of the marker species, which paradoxically form the basis for defining a "stage", remained uncertain. The ranges given by many authors are vague or controversial, and as a consequence unreliable for any detailed correlation.

The presence of Miogypsinidae is known from several regions in India: Kutch, Saurashtra (Kathiawar), the southern part of Cambay basin, Quilon area, Cauvery basin, Bengal basin, and the Andaman Islands (fig. 1). Apart from Mohan's thesis (1958) on a short stratigraphical interval in Western India, no serious attempt was made so far to investigate the Indian Miogypsinidae systematically. Such a study would be highly desirable since there is ample evidence from other parts of the world that Miogypsinidae underwent a rapid evolution. Successive stages of the evolutionary sequence are thought to offer a good basis for refined time-stratigraphic correlations.

The original aim of this study, which started some four years ago, was to investigate the Miogypsinidae from some of its localities in India in an attempt to obtain a more detailed correlation of various outcrop and subsurface sections. In the predominantly shallow marine sediments Miogypsinidae are widely distributed, whereas planktonic foraminifera,

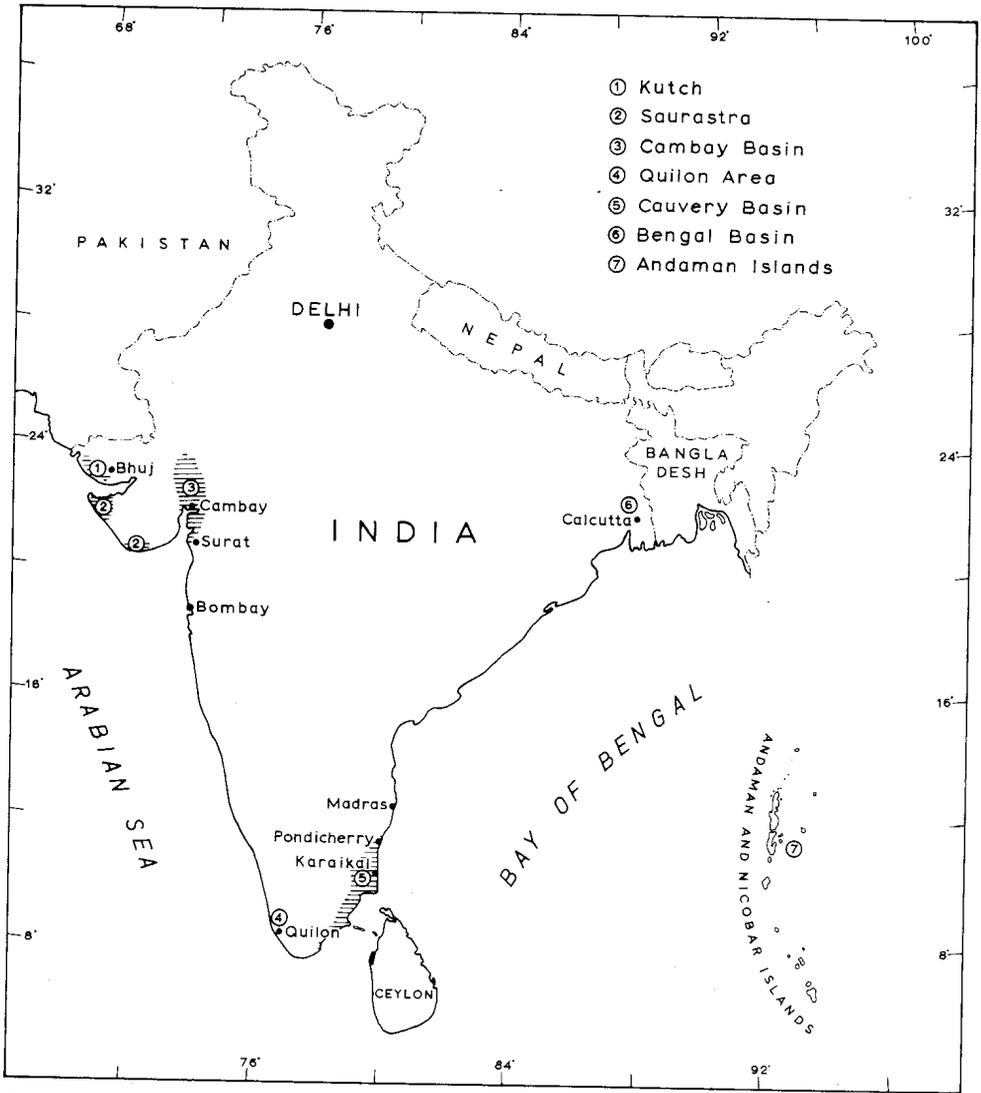


Fig. 1 Schematic map showing the location of sections with Miogypsinidae in India.

which gained importance in interregional correlation, are rare or non-diagnostic. The actual study was initiated during a short stay in Utrecht in 1968. Later on, several samples from measured sections in Kutch were collected by the author in January, 1969, and again in January-February, 1970. A few samples were collected by Mr. D. K. Guha and the author in Saurashtra in March 1970. In addition to this outcrop material Miogypsinidae were available from deep exploration wells drilled by the Oil & Natural Gas Commission in Cauvery basin during the last seven years.

A preliminary study of some of the samples from sections in Kutch and Cauvery basin revealed the presence of several specific units of the Miogypsinidae that were hitherto unrecorded from any of the Indian localities, but which had originally been described from other areas in the Indo-Pacific province, or from America. Interpretation of these data in terms of chronostratigraphy appeared uncertain because phylogenetic trends in the Miogypsinidae in the Indo-Pacific province are not well understood, in spite of the classical investigations as early as 1936–37 by Tan Sin Hok. With these and other problems before us, the present investigation had to incorporate, at successive steps of work, several more general aspects of the history of the Miogypsinidae. Some of the associated planktonic foraminifera have also been investigated in an attempt to tie up some of the stages of the Miogypsinidae development with the planktonic zones.

In the successive parts of this paper the reader will find a brief review of the previous literature, an account on methods of investigation, details of stratigraphic sections and samples, a description of morphological characteristics for each of the *Miogypsina* samples from Kutch, Saurashtra, and Cauvery basin and a discussion of phylogenetic trends, paleoecology, and biostratigraphy with an emphasis on the value of Miogypsinidae in zonal classification and in interregional correlation.

The paper is published with the permission of the Director of Geology, Oil & Natural Gas Commission, Dehradun, India.

## Review of previous research on the Miogypsinidae

Since the introduction of the taxonomic name *Miogypsina* in 1893, by Sacco, with an earlier described form *Nummulites irregularis* Michelotti 1841, as the type species, some fifty five names of species, subspecies and varieties of Miogypsinidae have crept into the vast literature. A detailed review of all previous publications is beyond the scope of this paper. Between 1893 and 1936 representatives of the Miogypsinidae were described, often with introduction of new species, by several authors, amongst whom Schlumberger (1900), Rutten (1911, 1912), Cushman (1918, 1919), Van der Vlerk (1924), Vaughan (1924, 1928) and Yabe & Hanzawa (1927, 1930). Little attention was paid to phylogenetic trends.

A theoretical background for a better understanding of the phylogenetic trends in the Miogypsinidae, was offered by Tan Sin Hok (1936, 1937) when he emphasized the significance of successive ontogenetic stages. Based on the study of Indonesian Miogypsinidae, he recognized five fundamental

types of nepionic chamber arrangement (*complanata*, *borneensis*, *ecuadorensis*, *bifida* and *indonesiensis* types). He recognized on a typological basis a rather large number of species, based on these nepionic types, in such a way that often several species occurred within a single sample. Although Tan's principle of nepionic acceleration and the significance of the nepionic stage in classification have been widely accepted, his methods of investigation were modified in different ways by subsequent authors.

Drooger (1952) in his study on American Miogypsinidae modified the methods of Tan Sin Hok and Bronnimann (1940) by applying the population concept, based on the assumption that in each sample the *Miogypsina* individuals had been part of a single, homogeneous population, unless it could be proved on the basis of a discontinuous variation of the data that this is not true. He introduced several counts and measurements to express the observations on the morphological features numerically and he used statistical methods in discriminating morphologically adjacent specific units in the Miogypsinidae succession. Later on, through several investigations on Miogypsinidae from Europe and from a small number of occurrences in Indonesia (Drooger, 1953–1966) considerable progress was made in deciphering the phylogenetic trends. Closely comparable methods were employed by Mohan (1958) and Souaya (1961) in their studies of Indian and Egyptian Miogypsinidae respectively. As a consequence the group became more important in intercontinental correlations of the Oligo-Miocene succession.

Although other specialists accept that Drooger's statistical approach "seems to be sound" (Cole, 1957) and his measurements usually show progressive change with geological age, thus confirming Tan's nepionic acceleration hypothesis, there are objections against following his methods. One is that they are "very time consuming and unsatisfactory" (Barker, 1965, p. 307), another that the industrial paleontologist has no time for statistical investigation or insufficient numbers of specimens to do so (Cole, 1957, p. 318), and also " . . . since it rests on a stratigraphic assumption that has never been proved" (Adams, 1970, p. 126). Unfortunately, none of the critics of Drooger's approach presented sound evidence, either numerical or stratigraphic, in support of their arguments.

Cole (1938–1969) published the results of a series of investigations on Miogypsinidae from America and west Pacific Islands. He followed a typological species concept and progressively changed the concept of several of his species in course of his research. In 1967 Cole clarified at length the changes in his approach and classifications during the last three decades. In 1957, he reduced the large number of species of Miogypsinidae from

America to five, and later (1964, 1967) even to three. His justification to do so, is said to be biological and stratigraphical, and also to facilitate work in applied paleontology. Although Cole (1957–1967) apparently favoured a biological species concept, even his latest reduction of the number of American species to three, is still based on a typological approach, as it leads in certain cases to the inevitable splitting of a homogeneous population from a single sample.

Hanzawa (1940–1965) developed a quite different typological approach in his studies of the Miogypsinidae, mainly those of west Pacific regions. Hanzawa (1957, 1962) made use of some measurements and counts, viz. A-P angle, number of juvenile whorls, number of septa in each whorl, and the ranking number of the peri-prolocular chambers found at the apical point of the test, in combination with Tan's types of juvenarium, in discriminating some 46 species of Miogypsinidae. Thus he may split homogeneous populations into several species based on the characteristics of such types.

Cole (1957–1969) and Hanzawa (1940–1965) advocated two extreme approaches of typological species concept, with "lumping" and "splitting" results respectively.

Other authors, including Barker (1965), Coleman (1963) and Adams (1965, 1970) adhered to different lines of typological species concept, though they apparently followed a somewhat middle course between the extremes of lumping and splitting.

Ujii and Oshima (1960), and Ujii (1966) attempted a new statistical approach, expressed as the "evolutionary line". This approach is considered unsatisfactory since it implies splitting of seemingly homogeneous populations.

### Previous literature on Indian Miogypsinidae

Rao (1939, 1941) was the first to report the presence of *Miogypsina* from western India. The only published systematic work on Indian Miogypsinidae is that of Mohan (1958), who described *Miogypsina (Miogypsina) irregularis* (Michelotti) and *M. (Lepidosemicyclina) droogeri* Mohan & Tewari from Kutch; *M. (M.) irregularis*, *M. (M.) boghotaensis* Mohan, *M. (L.) polymorpha* (Rutten) and *M. (L.) thecideaeformis* (Rutten) from Kathiawar (in this paper referred to as Saurashtra), and *M. (M.) irregularis* and *M. (L.) cf. thecideaeformis* from Surat-Broach, all areas in western India. Unfortunately, Mohan provided very little information on the exact stratigraphic position of

some of the samples, such as the one with the new species *M. droogeri*. He mentioned that the type level of this new species was bed no. 4 of the Vinjhan-Miani area, but the details of the locality and the limits of his so-called bed no. 4 are not documented.

Both prior to and after the publication of Mohan (1958), several papers dealing with micropaleontology and/or stratigraphy of Oligo-Miocene sediments in India, mentioned the occurrence of one or more species of the Miogypsinidae. These publications do not contain systematic descriptions, illustrations or details of exact localities. As a consequence most of these reported occurrences cannot be properly evaluated. Some of the species reported from Western India and Cauvery basin are mentioned below.

The presence of *M. (Miogypsinoides) dehaartii* in Kutch was reported by several authors, including Tewari (1957), Rao et al. (1957), Chatterjee & Mathur (1966), Mohan & Soodan (1970). But none of the authors really described their material. Mohan & Soodan (1970) wrote that *M. dehaartii* occurs in the Waior Stage, whereas Tewari (1957) and others reported the species from strata much younger than the so-called Waior Stage. Mohan & Bhatt (1968) reported the occurrence of *M. panamensis* and *M. antillea* from the Barkhan River section in Kutch. Here again details concerning specific determination and exact localities were not documented by the authors. These and other publications have added a great deal of confusion to the literature on stratigraphic distribution and taxonomy of the Miogypsinidae in India.

In short notes, Raju (1970, 1971) reported from Kutch the presence of *M. (Miogypsinoides) complanata* and *M. (M.) cf. bermudezi* from Waior Stage, *M. (Miogypsina) tani*, *M. (M.) borneensis*, *M. (Miogypsinoides) dehaartii* and its var. *cupulaeformis* from Aida Stage, and *M. (Lepidosemicyclina) excentrica* from Vinjhan Stage. Apart from some details on  $\bar{X}$  and  $\bar{\gamma}$ , these new findings have not yet been described. These assemblages are dealt with in the present study.

In Cauvery basin definite Oligo-Miocene marine sediments are known from deep exploration wells drilled since 1964. Guha et al. (1965) reported the presence of *M. antillea* and *M. panamensis* from Karaikal well No.1, but without any details regarding the specific determination. On the basis of  $\bar{X}$  or  $\bar{V}$  on small numbers of observations, Raju (1970) recognized *M. gunteribantamensis*, *M. tani*, *M. cf. globulina*, *M. dehaartii*, *M. cf. mediterranea* and *M. antillea* from deep wells of Cauvery basin. These assemblages form another part of the material for the present investigation. The determination of *M. cf. mediterranea* now appears to be erroneous.

## Areas studied

*Miogypsina* from Kutch, Saurashtra and Cauvery basin have been investigated for this study. The location of these three regions and also other areas in which *Miogypsina* was recognized, are shown in fig. 1.

Details of the different stratigraphic sections in each of the three regions are given in later parts of this paper.

## Methods of investigation

Individual specimens of the Miogypsinidae were sorted from the sieved residues, obtained by conventional methods of washing the samples. Well preserved specimens were obtained from most of the samples. However, poorly preserved assemblages were found in a few of them. Details on the state of preservation are given under the descriptions.

Whenever some morphological gap in respect of the external features was suspected, the individuals of a sample were separated into groups. As a further check on differences a number of oriented thin sections (in some cases half-sections) was made, to cover the widest possible range of external variation within each group.

Counts and measurements were carried out on a number of characteristics as outlined by Drooger (1952, 1963) and Souaya (1961). The angles were measured either directly by using crosshairs and a graduated revolving stage of the microscope, or from outline drawings of the embryonic-nepionic stage and the circumference of the test, drawn with the help of camera lucida using a plastic ruler and protractor. Linear measurements such as the diameter of the protoconch, were made by means of an ocular micrometer.

The symbols and the definitions of the corresponding parameters used are given below:

X= the total number of spirally coiled, nepionic chambers excluding both embryonic chambers.

Y= the number of spirally coiled, nepionic chambers up to, and not including the first one with a distal stoloniferous opening and excluding the embryonic chambers; hence up to the beginning of equatorial growth ascertained from the first distinct equatorial chamber. In case of doubt as to the counting of Y, because of isolated equatorial chambers, (e.g. Y= 3 or 4), the mean value is taken for further calculations.

Z= the number of nepionic chambers in the initial spiral up to and including the largest one in the section, and excluding the embryonic chambers.

$\gamma$  was originally defined (Drooger, 1952) as the angle, lying in the median section, and formed by the apical-frontal line through the centre of the protoconch and the line connecting the centres of the embryonic chambers. Later Amato & Drooger (1969) discussed in detail the procedure for measuring the  $\gamma$  angle. Some of the criteria used in defining the

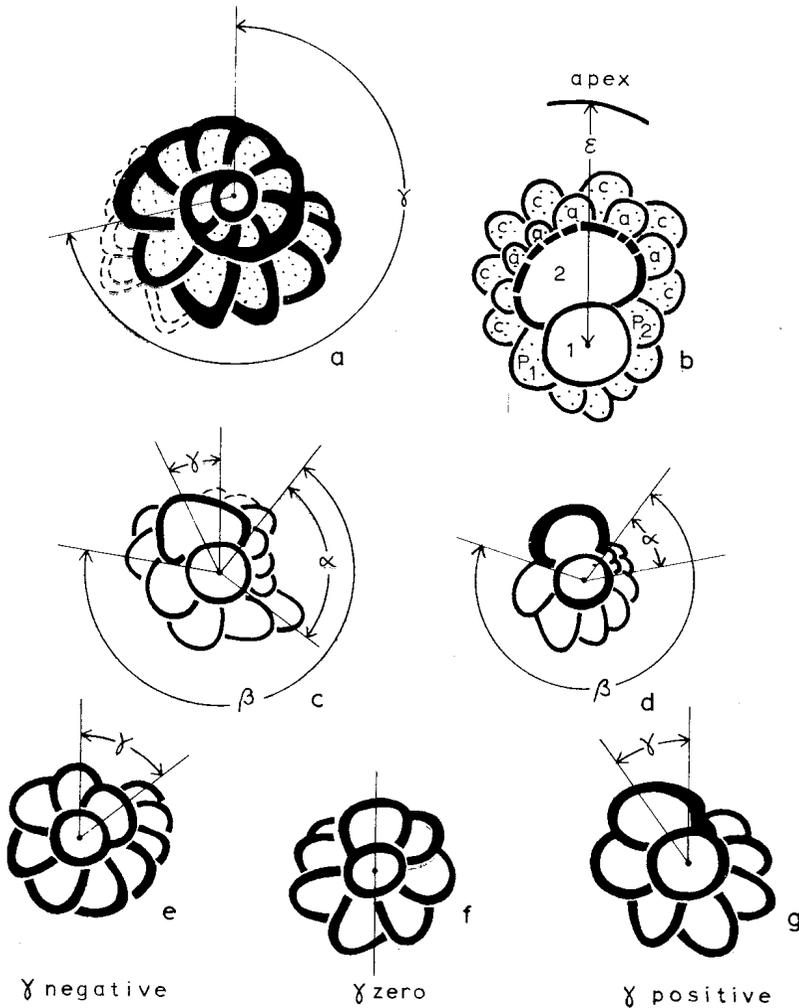


Fig. 2 Schematic drawings of median sections of the embryonic — nepionic stages of Miogypsiniidae, illustrating the derivation of  $\alpha$ ,  $\beta$ ,  $\gamma$  and  $\epsilon$ . 1= protoconch, 2= deuteroconch; 1 and 2 constitute the embryonic stage; chambers around the embryonic stage (dotted in figs. a, b) constitute the nepionic stage. P1 = first principal auxiliary chamber, P2 = second principal auxiliary chamber; a = accessory auxiliary chamber, c = closing chamber.

$\gamma$  scale are: 1) The scale has been fixed by setting the zero point where both lines that form the angle  $\gamma$  coincide in apical direction with a spiral length of one whorl or less, 2) the position of the third chamber has been taken as a further aid in defining the  $\gamma$  scale. In shorter spirals or in the case of two spirals,  $\gamma$  ( $0^\circ - 180^\circ$ ) is taken as positive if the first (or the larger one of the subequal) principal auxiliary chamber (also referred to as third chamber) is directed towards the frontal margin. For  $\gamma$  values of  $-1^\circ$  to  $-180^\circ$  this third chamber is directed towards the apex.

For longer spirals this rule is no longer true and the values are always taken as negative. A proper explanation of the actual value of  $\gamma$  for longer spirals appears to be as follows: the angle  $\gamma$  is obtained by rotation of the line connecting the centres of protoconch and deuterioconch (the centre of rotation being the centre of protoconch) along the direction indicated by the position of the third chamber, to the position in which the line coincides with the assumed zero position.

$V = 200 \alpha/\beta$  gives the degree of symmetry of the protoconchal nepionic spirals. The scale ranges from zero to 100.

$\alpha$  = the arc length of the circumference of the protoconch section underlying the smaller spiral.

$\beta$  = the arc length of the circumference of the protoconch underlying both protoconchal spirals.

$C$  = the number of accessory auxiliary chambers. If no choice could be made between adjacent numbers, e.g. 5 or 6, the mean value was taken for calculations.

DI (or simply I) = diameter of the protoconch, and

DII (or simply II) = diameter of the deuterioconch, both diameters including half of the thickness of the walls, and both taken at right angles to the line connecting the centres of these embryonic chambers. Both diameters are measured in  $\mu$ .

$\epsilon$  = the distance in  $\mu$  from the centre of the protoconch to the apex (Souaya, 1961).

Length and width: the maximum length of the test is measured along the apical-frontal line, the maximum width of the test is measured along a line at right angles to the apical-frontal line. The terms length and width are used in descriptions.

## Statistical approach

Only some simple statistical methods have been employed in this investi-

gation (see also Drooger, 1952). Mean values and often their standard errors were calculated for each of the parameters and for each assemblage thought to be homogeneous. These values together with the number and range of the observations per sample are given in tables I-IV. The total number of observations per assemblage is often different for different parameters, as all the characteristics could not be counted or measured with sufficient accuracy if the sample contains poorly made thin sections.

The distributions of X, Y,  $\gamma$  and I are represented in histograms for several of the samples. Scatter diagrams were plotted in order to investigate the relations between various parameters investigated.

The possibility of significant difference between the means of some parameter in different samples was tested by application of Student's t-test, whenever the distributions did allow for such a test. Reference is made to Simpson et al. (1960) for the formulae involved.

### Parameters and designation of the species

In the present investigation, the specific units of *Miogypsina* have been recognized by applying the  $\bar{X}$  and  $\bar{V}$  scales, in combination with other features. For details on principles of classification and on the numerical scales the reader is referred to Drooger (1952, 1963). Some of the details on classification and on diagnostic characters of different species will be discussed in a later part of this paper, and some modifications and additions will be proposed.

## Chapter II

### KUTCH

#### DESCRIPTION OF STRATIGRAPHIC SECTIONS

Tertiary sediments are exposed more or less continuously all along the western, southern and south-eastern coast of Kutch over a distance of more than 175 kilometers from Lakhpat in the northwest to beyond Anjar in the east (fig. 3). The succession of Eocene, Oligocene and Miocene sediments is best developed in the south-western part. The composite Tertiary sequence measures not more than 600 meters. The area is especially suitable for biostratigraphic studies because of the simple geological structure and the fairly good exposures along the banks of rivers and streamlets, most of which flow in down dip direction. Some of the sections in Kutch attracted the attention of many a paleontologist in the last 130 years. Reference is made to Tewari (1957) for reviews on previous studies.

However, there has been considerable confusion regarding the stratigraphic nomenclature of the Tertiary sediments of Kutch. In order to avoid lengthy discussions on the problems of local stratigraphic nomenclature, the details of the relevant stratigraphic sections are given in the local stage nomenclature proposed by Biswas (1965, 1970) and in rock-stratigraphic terms proposed by Biswas & Raju (1971, MS).

The succession of the relevant local stages and formations is given below:

<i>Formation</i>	<i>Member</i>	<i>Stage</i>	<i>Age</i>
Sandhan			Pliocene
Vinjhan	} Siltstone Chhasra	Vinjhan	} Miocene
Khari Nadi		Aida	
Maniyara Fort	{ Ber Coral Limestone Lumpy Clay Basal	Waior	} Oligocene
		Ramania	
		Fulra	

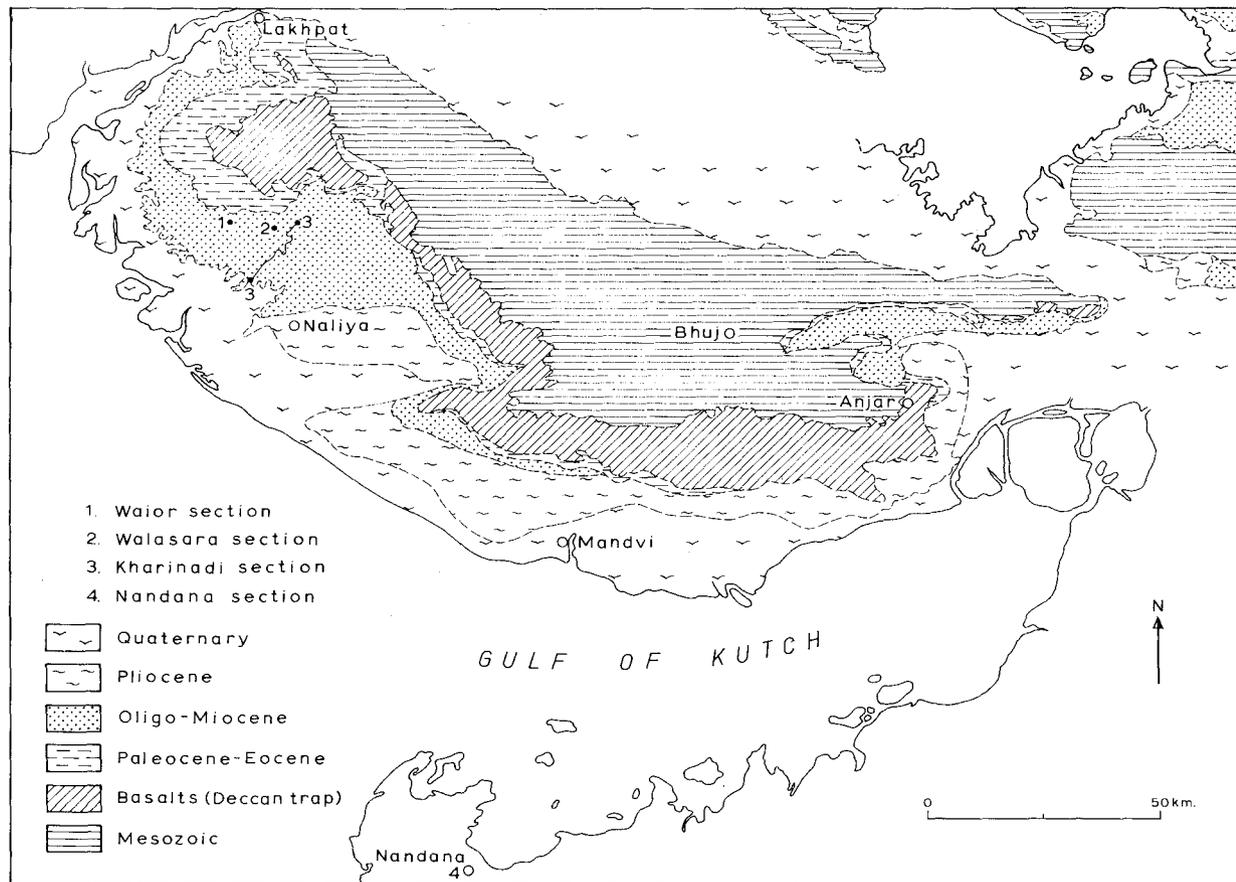


Fig. 3 Schematic geological map of Kutch showing the location of sections (modified after Biswas & Deshpande, 1970).

The details of the sections, investigated because of the *Miogypsinidae*, are given below.

### Waior section

All the samples from this area were collected along the right bank of the Waior-Cheropadi stream, just north of Waior village (fig. 4). The beds dip very gently, about  $1^{\circ}$  to  $3^{\circ}$  to the south. Three minor faults disturb the sequence. The fault planes are nearly vertical, and precaution could be taken that there is no repetition in the sampled succession. The stratigraphic column is given in fig. 7. In terms of the local stages this section covers the upper part of the Ramania Stage, the stratotype of the Waior Stage and the basal part of the Aida Stage. The rock-stratigraphic subdivision is also given in fig. 7.

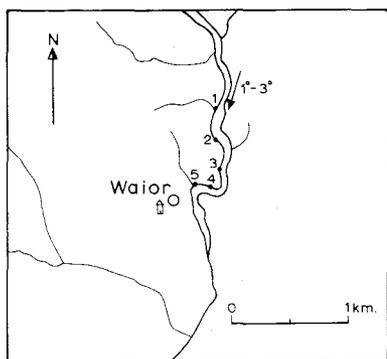


Fig. 4 Schematic map of the Waior area showing the sample localities with the type section of the Waior Stage (2 - 4).

Because of the presence of *Miogypsina*, the stratotype of the Waior Stage is briefly described here. The composite stratotype is exposed at three localities over a distance of 500 meters (fig. 4).

Loc. 2: The uppermost part of the Coral Limestone Member (or simply Limestone Member) and the lower part of the Ber Member are exposed in this locality. The lower 11 feet of the Ber Member conformably overlie the Coral Limestone. Both members belong to the Maniyara Fort Formation. The grey, white limestone at the top of the Limestone Member is studded with reticulate *Nummulites*. The basal sediments of the Ber Member consist of glauconitic friable sandstone, calcareous clay and silty claystone.

Loc. 3: A 22 feet high cliff section is exposed in this locality. The sediments include about 2 feet of calcareous silty clay with a few small size

molluscs and 20 feet of grey, yellowish sandy to clayey limestone with several fossils. The lower part of the limestone is more sandy and thin bedded. The upper part is thick bedded and is relatively rich in fossils including echinoids, *Pecten*, gastropods, a few corals and foraminifera. The described Miogypsinidae were all found in this section in two well separated intervals.

Loc. 4: The section includes the uppermost part of the Ber Member and the basal part of the Khari Nadi Formation. The actual contact is not exposed. About five feet of grey marly limestone with thin beds of calcareous clay, studded with *Spiroclypeus* belong to the Ber Member. The *Spiroclypeus* beds are overlain by bluish, grey clay and silty claystone of the Khari Nadi Formation.

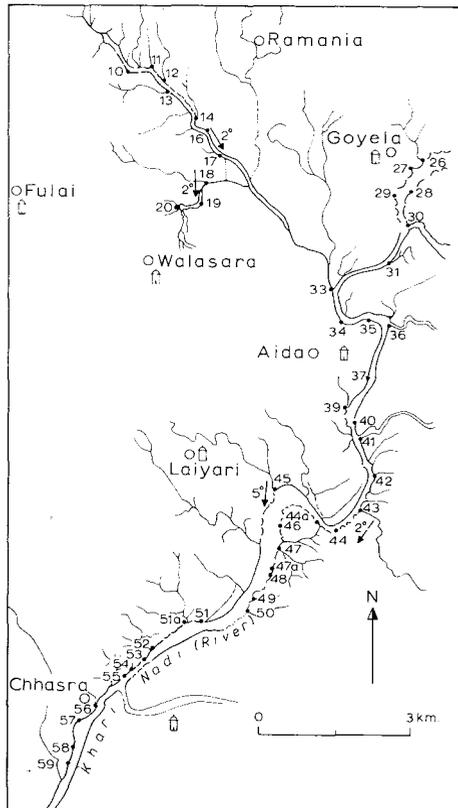


Fig. 5 Schematic map showing sample localities of the Khari Nadi and Walasara sections with the type sections of the Ramania (13 – 19) and Aida (30 – 45) Stages and the paratratotype of the Vinjhan (45 – 59) Stage.

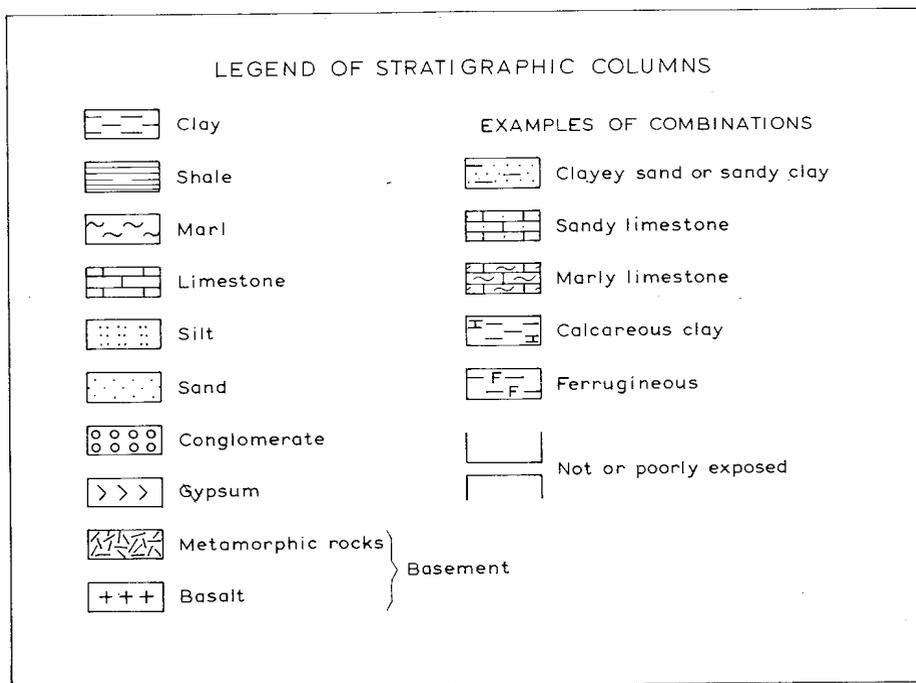


Fig. 6 Legend of stratigraphic columns.

The succession from the top of the grey, white limestone with reticulate *Nummulites* (loc. 2) to the top of the *Spiroclypeus* limestone (loc. 4) constitutes the composite stratotype of the Waior Stage.

A preliminary study of *Miogypsina* from locality 3 indicated that  $\bar{X}$  values increased in upward stratigraphic direction (Raju, 1971). Later, Mr. Biswas and the author revisited the area to check if the strata are overturned, but no evidence could be found that would suggest that the strata of this section are upside down. There is no evidence for turbidite action either.

### Walasara section

The samples from this locality were collected from a continuous section of about 400 meters, exposed over a short distance along a stream, at a distance of 1 km. northeast of the village of Walasara ( $68^{\circ}46'30''$ :  $23^{\circ}25'40''$ ). The locations are shown in fig. 5. The section covers the uppermost part of the stratotype of the Ramania Stage and the overlying Waior Stage. The sediments of the lower part of the section, which is referred to the Coral Limestone Member, includes hard foraminiferal limestone usually full of

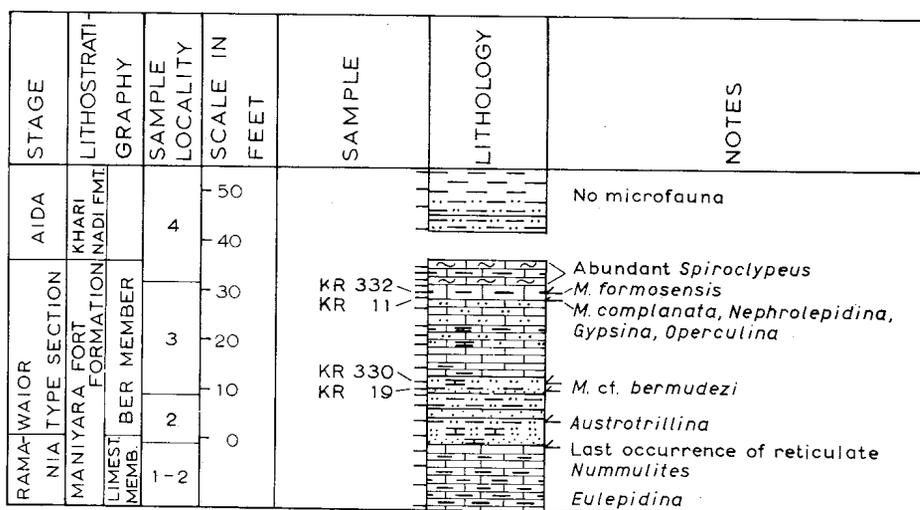


Fig. 7 Stratigraphic column of the Waior section, Kutch.

reticulate *Nummulites* and *Eulepidina*, gypsiferous clay and fossiliferous calcareous sandstone. They are conformably overlain by the succession of the Ber Member. The sediments placed in the Ber Member include, from bottom to top, glauconitic sandstone, calcareous sandstone with a few molluscs and marly limestone. The hard marly limestone beds, in the uppermost 4 feet of the section, contain either numerous molluscs or *Spiroclypeus*. *Miogypsina* samples (fig. 8) were derived only from the upper part of the sediments placed in the Waior Stage.

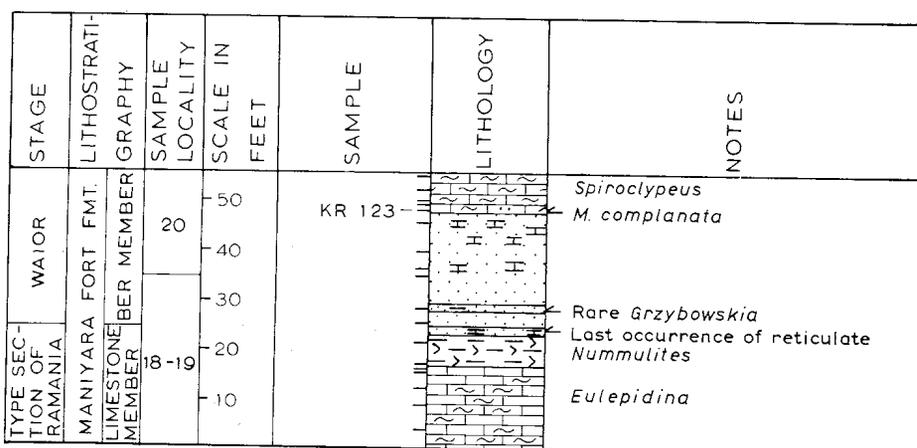


Fig. 8 Stratigraphic column of the Walasara section, Kutch.

## Khari Nadi section

Samples were collected from the discontinuous succession exposed along the Khari Nadi (nadi means river), over a distance of 16 km, starting at the outcrop 0.8 km. southeast of Goyela ( $68^{\circ}49'25''$  :  $23^{\circ}26'40''$ ) to a point one km. south of Chhasra ( $68^{\circ}46'40''$  :  $23^{\circ}21'20''$ ). The stratigraphic column is given in fig. 9. The exposures are small cliffs along the banks of the river. All the locations are shown in fig. 5. The beds dip at low angles of less than  $5^{\circ}$  towards the south. Except for a few small nearly vertical faults, there are no tectonic complications involved. Considering the discontinuous nature of the complete section, it is possible that small parts of the sequence are missing between one cliff section and the next. Such possible gaps in the succession are indicated as unexposed in the stratigraphic column of fig. 9. By careful checking the dip directions in successive cliffs and the nature and order of the superposed strata, sufficient caution could be taken to ensure that there is no repetition in the sample record.

In terms of local stages, this succession covers sediments equivalent to the uppermost part of the Waior Stage, the stratotype of the Aida Stage and a "parastratotype" of the Vinjhan Stage. The limits of these local units and also the terminology of rock-stratigraphy have been entered in fig. 9.

Many of the previous workers paid attention to only part of the Khari Nadi succession, possibly because of the lack of road communications.

The succession of the Khari Nadi section belongs to three lithostratigraphic units: Ber Member of the Maniyara Fort Formation, Khari Nadi Formation and Chhasra Member of the Vinjhan Formation. Various details show that the entire succession was laid down under frequently changing shallow water conditions. Some data on the three units are briefly given below.

*Ber Member:* Only the upper part of this member is exposed along the Khari Nadi. It consists of about 5 feet of moderately hard foraminiferal marly limestone full of *Spiroclypeus*, alternating with calcareous clay. The *Spiroclypeus* beds are conformably overlain by sediments of the Khari Nadi Formation.

*Khari Nadi Formation:* The sediments consist predominantly of mottled, variegated or laminated clay alternating with very thin beds of siltstone. Thin layers of gypsum occur at a few intervals. A 12 to 13 feet section in the basal part consists of bluish grey clay alternating with grey clayey silt. About 25 feet of fine grained, micaceous, cross-bedded sandstone occur at about the middle part of the formation. Another unit of about 20 feet of fine grained, clayey sandstone occurs at the top of the formation. A few thin beds of

STAGE	LITHOSTRATIGRAPHY	SAMPLE LOCALITY	SCALE IN FEET	SAMPLE	LITHOLOGY	NOTES
V I N J H A N	CHHASRA MEMBER OF VINJHAN FORMATION	57-58	500	KR 34		<i>M. excentrica</i>
		56	480	KR 36		<i>M. globulina, M. excentrica</i>
		55	460			
		51a-52	440	G 1401 G 1406		<i>M. globulina, M. droogeri</i> <i>Austrotrillina howchini, Archaia</i>
		51	420	G 1415		<i>M. indica, M. thecideaformis</i>
		50	400	G 1417		<i>M. indica, M. globulina</i>
		49	380			
		48	360	G 1421		<i>M. dehaartii, M. globulina</i>
		47a	340			
		47	320			
		45	300			
		45	280			
		45	260	G 1437		<i>M. globulina-tani, Nephrolepidina, Archaia, Austrotrillina</i>
		44a	240			
		43-44	220			
		42	200			
		40-41	180	G 1448		<i>M. tani, M. dehaartii, Nephrolepidina, Gypsina</i>
		39	160			
38	140					
38	120					
38	100					
34	80	KR 155		<i>M. tani</i> <i>Operculina</i>		
33	60					
31	40					
30	20					
30	0					
WAI-OR	BER MEM-BER	28	0	KR 140		<i>M. complanata, Spiroclypeus</i>
TYPE SECTION OF AIDA						
KHARI NADI FORMATION						
						> Plant remains

Fig. 9 Stratigraphic column of the Khari Nadi section, Kutch.

highly fossiliferous impure limestone with molluscs and foraminifera occur intermittently. Except for a few occurrences, as shown in fig. 9, fossils are very rare or absent in the major portion of the formation.

The formation is conformably overlain by the Chhasra Member of the Vinjhan Formation.

*Chhasra Member:* The sediments consist of highly fossiliferous limestone, with various admixtures of marl, clay or sand, alternating with beds of siltstone, clay, clayey siltstone or marl. Several of the limestone beds are very rich in fauna — some of them could be referred to as shell beds — including echinoids, *Turritella*, large *Ostrea*, *Pecten*, *Conus*, other molluscs, worm tubes, and foraminifera. Some of the calcareous clay beds are also rich in foraminifera. On the other hand beds of siltstone and clayey silt are usually poor in fossils with only a few small molluscs, ostracoda and foraminifera (usually *Ammonia* assemblages).

#### DESCRIPTION OF MIOGYPSINA ASSEMBLAGES

##### Waior section

From locality 3 in the Waior section four assemblages of Miogypsinidae were studied. They are from bottom to top: KR 19 and KR 330 close together, and KR 11 and KR 332 higher up and again close together (fig. 7). All the samples were collected from a single, well exposed cliff section, so that there is not the slightest doubt about the superposition of the two major groups of occurrences. Another two samples, KR 17 and KR 12, from levels between KR 330 and KR 11, yielded only a few specimens. Specimens from all the samples were usually well preserved.

*Sample:* KR 19

*Material:* some 60 specimens

*Description:* Test thin, usually small. Maximum diameter of individuals varies between 0.55 and 1.5 mm. Usually the test is longer than wide or of equal length and width. Apical portion broadly rounded in smaller individuals, slightly protruding in the larger ones. In a few small individuals, some of the features, like the number of nepionic chambers, and the shape of equatorial chambers are clearly visible without sectioning. The surface has small pustules, rather evenly distributed in larger specimens. In small individuals only a few pustules are present on the spiral part near the apex, while the surface is smooth towards the frontal margin. Maximum thickness is in

some specimens near the apex, at the centre of the trochoid nepionic spiral; several individuals are of approximately uniform thickness from apex to frontal margin.

The early nepionic spire is low trochoid. The nepionic chambers, 9 to 16 ( $\bar{X} = 12.52$ ) are arranged in a single spire of about one and a half to two whorls. Y ranges from 4 to 10,  $\bar{Y} = 6.66$ . Equatorial chambers are predominantly of arcuate shape, a few are ogival.

In transverse sections (3 observations) the outer walls, on each side of the median layer, are thin (0.025–0.084 mm) with laminated radial structures and without any distinct lateral chambers.

Microspheric individuals are rare. In two equatorial sections, the value of X is 22 and 24, the corresponding values of Y are 16 and 17 respectively.

*Sample:* KR 330

*Material:* some 40 specimens.

*Description:* Externally the individuals of this assemblage are so similar to those of the previous sample, KR 19, that the description will not be repeated.

As to the nepionic chambers, X ranges from 11–15 ( $\bar{X} = 12.55$ ). Y from 3 to 9 ( $\bar{Y} = 6.35$ ).

In transverse sections (4 observations) the outer walls on each side of the median layer are thin with laminated radial structures, and without distinct lateral chambers. However, in one of the sections, small cavities (size less than 0.04 mm), which look like incipient lateral chambers, have been noted in the lateral walls, mainly at places near the contacts between adjacent "median" chambers.

In contrast to KR 19, microspheric forms are very common in this sample. In five sections, the value of X ranges from 21 to 24. In three more sections, poorly made, the value of X appears to be within this range. Variation of Y is between 14 and 17.

*Sample:* KR 11

*Material:* more than 50 specimens; in some of them the frontal margin is broken.

*Description:* Test usually fan shaped, unequally biconvex, rarely concavo-convex. The greatest thickness of the test is near the apex, generally corresponding with the position of the trochoid nepionic spire. The test flattens towards the frontal margin. The largest diameter of the test varies between 0.85 mm. and 2.1 mm. Maximum thickness is about 0.48 mm. The apical portion is broadly rounded, except in a few individuals in which it

protrudes slightly. In a few large individuals the frontal margin is slightly undulated. The surface of the test is well ornamented with pustules, which are evenly distributed. Pustules on the spiral part are slightly larger (up to 0.1 mm. in diameter).

The nepionic spire is distinctly trochoid; in a few small individuals the trochoid, "Rotalia"-like, stage is visible from the exterior. The nepionic chambers are 15 to 22 in number ( $\bar{X} = 17.8$ ); they are arranged in a single spire of about  $1\frac{1}{2}$  to  $2\frac{1}{4}$  whorls, Y ranges from 8 to 13,  $\bar{Y} = 9.72$ . The equatorial chambers are arcuate, ogival and a few rhombic.

In transverse sections (5 observations) the outer walls on each side of the median layer are moderately thick (about 0.085 – 0.25 mm.), with finely laminated, and radial structures, without lateral chambers. Small cavities (about 0.025 mm.) are present.

Microspheric forms are common. In four sections, the value of X ranges between 30 and 34, that of Y between 22 and 26.

*Sample:* KR 332

*Material:* Some 50 specimens; in several of the individuals part of the frontal margin is broken, which damage was essentially caused during the process of washing.

*Description:* Externally the individuals are very similar to those of KR 11 and so the description is not repeated.

The nepionic spire is trochoid, the value of X ranges between 14 and 21 ( $\bar{X} = 16.12$ ). Y ranges from 6 to 11 ( $\bar{Y} = 8.6$ ). In transverse sections (4 observations) the outer walls are moderately thick with vertical, radial structures, without distinct lateral chambers.

#### *Results of counts and measurements*

The results of X, Y and Z counts and of measurements of I and II are given in table I together with the number of observations by means of range, mean and its standard error. Histograms for the X, Y,  $\gamma$  and I observations are shown in fig. 10.

The frequency distributions of Y,  $\gamma$  and I appear to be fairly normal in all four samples, although a few of them, viz. Y of KR 330 and  $\gamma$  of KR 11, show slightly irregular patterns. The histograms of X in KR 19, KR 11 and KR 332, show more irregular distributions, which might suggest that the assemblages are heterogeneous. However, this irregular shape of the histograms of X might as well be due to too high a number of classes with respect to the numbers of observations. To check this, histograms of X and Y with a

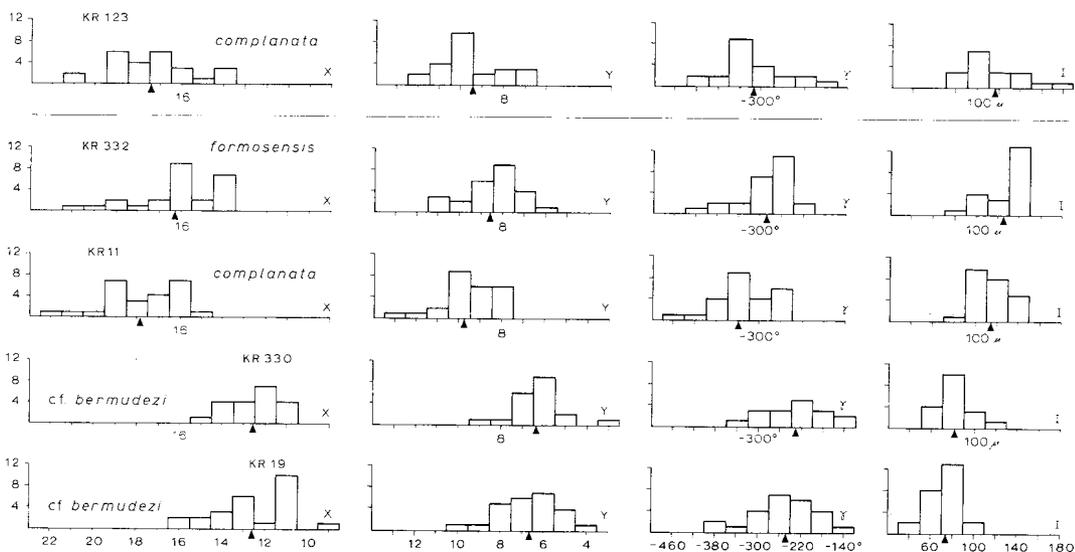


Fig. 10 Histograms of X, Y,  $\gamma$  and I values of successive assemblages of *Miogypsinoides* in samples from the Waior and Walasara sections, Kutch.

reduction of the classes to half the previous number (not given here) were made, which show fairly normal, unimodal patterns. As a consequence we assume that each of our assemblages is tolerably homogeneous.

The mean values of X, Y, Z and  $\gamma$  enable a clear separation into two groups of samples, with a strong difference from the older two to the younger two samples (table I).

For none of the parameters a difference can be shown between KR 19 and KR 330 (table V). Both assemblages might have belonged to a single homogeneous population.

$\bar{X}$  increases abruptly from KR 330 to KR 11, from 12.55 to 17.8. The increase in  $\bar{X}$ ,  $\bar{Y}$ ,  $\bar{Z}$ ,  $\bar{I}$  and  $\bar{II}$  and the decrease in  $\bar{\gamma}$  from KR 330 (or KR 19) to KR 11 are highly significant.

In the upper pair of samples,  $\bar{X}$  decreases again from KR 11 to KR 332, from 17.8 to 16.2.  $\bar{Y}$  and  $\bar{Z}$  also show a decrease while  $\bar{\gamma}$  increases. For  $\bar{X}$  and  $\bar{Y}$ , the probability of a significant difference between KR 11 and KR 332 is 99.9%, while the means of Z,  $\gamma$ , I and II are not that significantly different.

Contrary to the fluctuations in the other parameters, the mean values of protoconch ( $\bar{I}$ ) and deutoconch  $\bar{II}$  show a sustained increase from bottom to top of the section, i.e. from KR 19 to KR 332, with the greatest jump between KR 330 and KR 11.

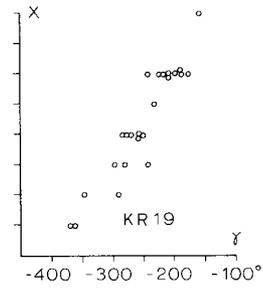
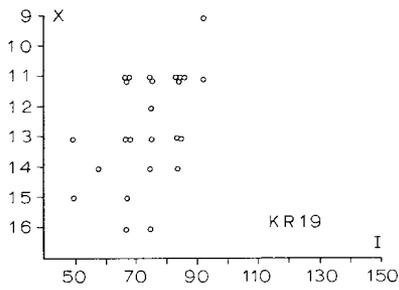
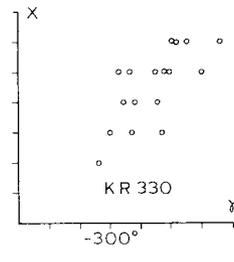
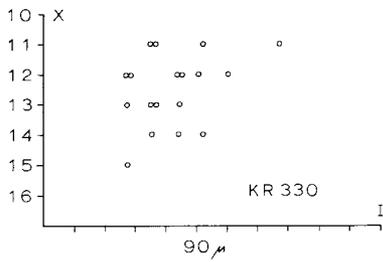
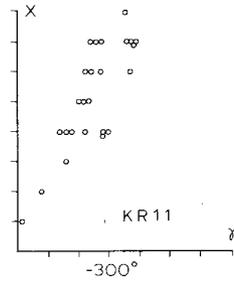
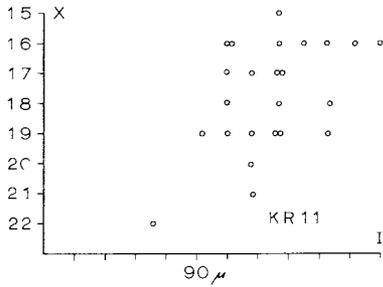
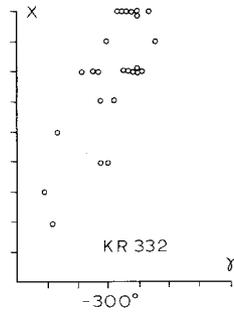
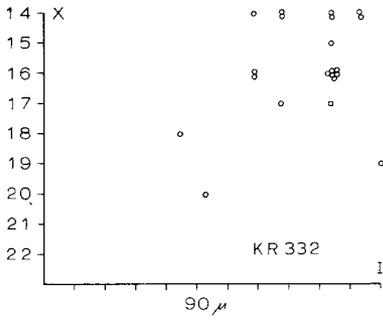


Fig. 11 Relation between X and I for specimens of *Miogypsinoides* in samples from the Waioi section, Kutch.

Fig. 12 Relation between X and  $\gamma$  for specimens of *Miogypsinoides* in samples from the Waioi section, Kutch.

### Conclusions

1) Because of the features of the lateral walls, all four assemblages from the Waior section belong to the subgenus *Miogypsinoidea*, although some cavities or doubtful incipient lateral chambers have been observed in KR 330.

2) In this single cliff section, the mean values of X, Y and Z show a strong increase and  $\bar{y}$  a similar decrease from the lower set of samples KR 19 and KR 330, to KR 11. These observations point to a trend opposed to the principle of nepionic acceleration. The values of  $\bar{I}$  and  $\bar{II}$ , however, increase steadily from bottom to top of the section. Further details are discussed in the chapter on phylogeny.

3) The assemblages from KR 19 and KR 330 are referred to as *M. cf. bermudezi* (see taxonomy regarding the problem of designation of a name for these assemblages). The assemblage of KR 11 belongs to *M. complanata*, that of KR 332 is determined as *M. formosensis*, but both assemblages are close to the limit between *M. complanata* and *M. formosensis*.

### Walasara section

From Walasara section only one sample, KR 123, was studied. Another sample KR 122, from a level just one foot above KR 123, contains only a few *Miogypsina*, which were not investigated (fig. 8).

This section is situated about 10 kilometers east of the Waior section. From field relations, particularly the comparable order of lithostratigraphic subunits, it may be inferred that the level of KR 123 is approximately the same as that of KR 11–KR 332 of Waior section.

*Sample:* KR 123

*Material:* some 40 specimens, most of them are well preserved.

*Description:* In external features the individuals of this assemblage are similar to those of KR 11.

The nepionic spire is trochoid. The 14 to 21 nepionic chambers ( $\bar{X} = 17.42$ ) are arranged in a single spiral. Y ranges from 6 to 12 ( $\bar{Y} = 9.5$ ). One equatorial section of a microspheric form shows 31 nepionic chambers.

#### *Results of counts and measurements*

A preliminary study of this sample (Raju, 1971) gave an  $\bar{X}$  value of 17.16 for 19 specimens. Six additional sections were made and the counts repeated. The new value of  $\bar{X}$  is  $17.42 \pm 0.35$  for 25 thin sections. The difference in  $\bar{X}$  values is smaller than the standard error of the mean.

Corresponding means of all other parameters in KR 123 and KR 11 are not significantly different. However, at the limit of clear significance there is

a difference for the means of X and Y between KR 123 and KR 332 (table V). Although seemingly in between, the assemblage of KR 123 is closest to that of KR 11. This conclusion supports the assumption based on lithostratigraphic correlation that the level of KR 123 is approximately equivalent to those of KR 11 – KR 332 of Waior.

*Conclusion:* The assemblage from KR 123 is referred to *M. (Miogypsina) complanata*, though its  $\bar{X}$  is very close to the limit of this species with *M. formosensis*.

## Khari Nadi Section

From the Khari Nadi section, eleven samples were studied in detail. They are from bottom to top, KR 140, KR 155, G 1448, G 1437, G 1421, G 1417, G 1415, G 1406, G 1401, KR 36 and KR 34 (fig. 9). All these samples, except KR 34, are rich in *Miogypsina*.

In addition to these eleven samples, *Miogypsina* have been found in another seven samples from this section. These seven samples are not considered either because of the small number or too poorly preserved specimens, or because the sample is stratigraphically very close to one of the investigated samples.

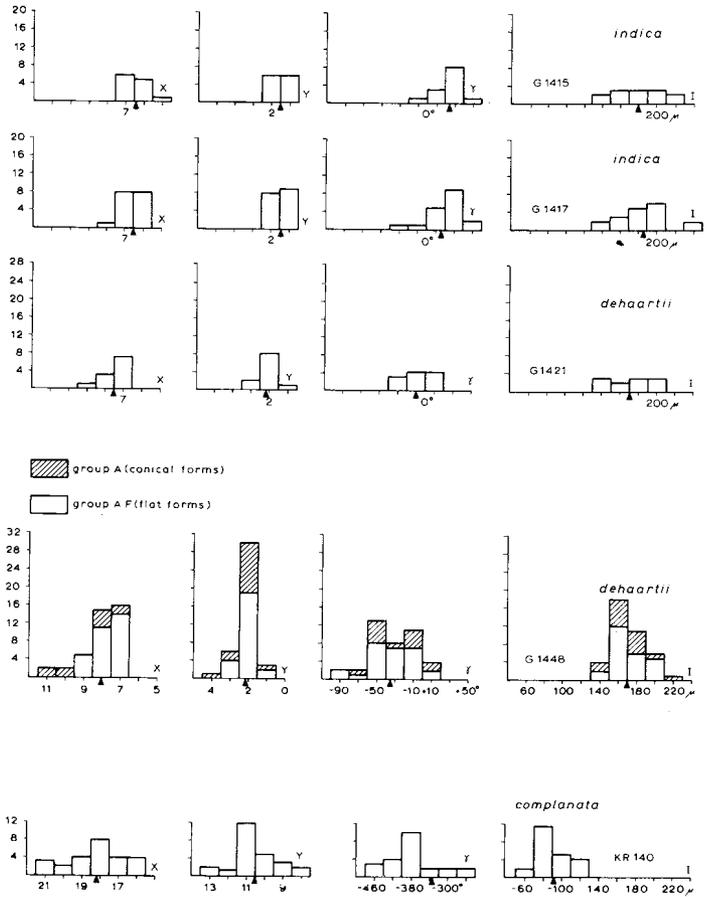
During the preliminary study, it became evident already that some of the samples contain representatives of more than one subgenus of *Miogypsina*. In these cases the *Miogypsina* contents have been separated on outer characteristics into two or more groups, whenever some morphological gap was suspected. Observations on broken specimens and/or while making the thin sections under the microscope have been used as further criteria for the separation into groups. The validity of such rough separation was checked with the aid of the measurable characteristics. Because such problems were met with in most of the Khari Nadi samples, some relevant remarks regarding the separation of the groups, and their specific determinations are given for each of the samples immediately following the description of the morphological features. On the other hand, the discussion on trends in individual parameters based on the means, and on relations between various parameters, are discussed in the concluding paragraphs on this section.

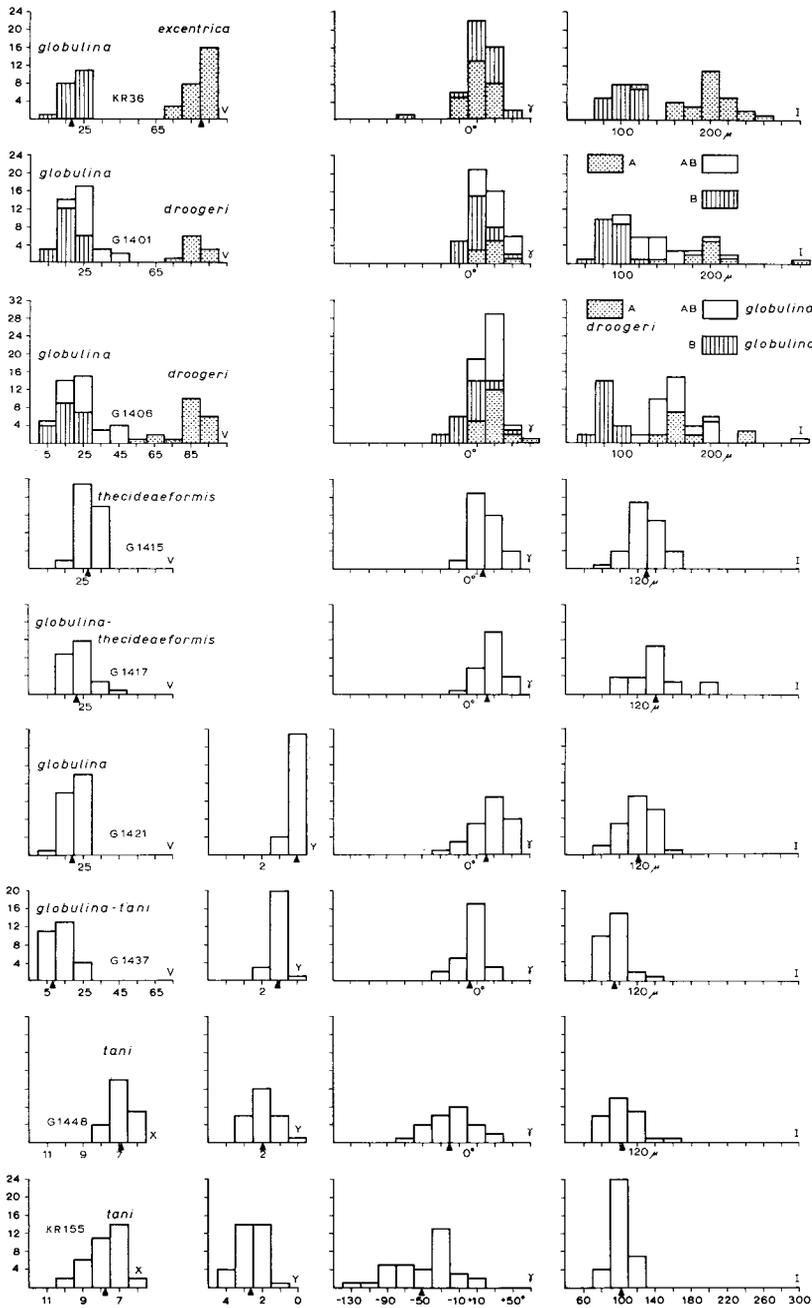
*Sample:* KR 140

*Material:* some 50 specimens. Most of them are fairly well preserved.

*Description:* Test small, thin, unequally biconvex. Apical portion in most of the individuals broadly rounded. Greatest thickness of the test near the apex,

Fig. 13 Histograms of X, Y,  $\gamma$ , V and I classes of successive assemblages of Miogypsinidae in samples from the Khari Nadi section, Kutch.





coinciding with the position of the trochoid embryonic-nepionic stage. The frontal margin is slightly undulated in a few individuals. Maximum diameter between 0.7 mm and 2 mm.

The surface is ornamented with pustules and short ridge-like elevations.

The embryonic-nepionic stage is distinctly trochospiral. In several of the individuals, especially in small ones, the "Rotalia"-like, nepionic stage is clearly visible from the outside, and the spiral and umbilical sides can be distinguished. The ornamentation in such individuals is similar to that of the associated *Pararotalia* specimens. On the umbilical side the sutures are either beaded with one or two rows of pustules, or each chamber is marked by, ridge-like, elevations. On the spiral side ornamentation is less prominent and about 2–2½ whorls are visible. However, in some forms, the entire surface is evenly covered with pustules and the "Rotalia" stage is not clearly visible.

The nepionic chambers, 16–21 ( $\bar{X} = 18.2$ ), belong to a long single spiral. Y ranges from 8 to 13 ( $\bar{Y} = 10.5$ ).

In five transverse sections, the outer walls are thin (0.042–0.117 mm) with finely laminated and radial structures, without any distinct lateral chamber.

*Remarks:* A preliminary study (RAJU, 1971) of this sample gave an  $\bar{X}$  value of 17.95 for 24 individuals. For the present study three of the earlier sections were discarded because of their poor quality, four new sections are added, and counts were repeated. The present value of  $\bar{X}$  is  $18.2 \pm 0.31$ . The change in  $\bar{X}$  is smaller than the standard error of the mean.

The histograms of X, Y,  $\gamma$  and I (fig. 13) show a fairly normal distribution. Scatter diagrams (fig. 14) give a similar impression.

*Determination:* *Miogypsina (Miogypsinoides) complanata* (table II)

*Sample:* KR 155

*Material:* more than 100 specimens.

*Description:* Test usually small, thin, unequally biconvex; length greater than width to equal to width, Greatest thickness between apex and midpoint along the apical-frontal line. Maximum diameter in the majority of specimens between 0.85 mm. and 1.55 mm., very few individuals range up to 2.5 mm. The apical portion is protruding and clearly discernible.

The surface is well ornamented with pustules. However, several of the specimens that are poorly preserved have a smooth appearance because calcareous matter is sticking to the surface.

Nepionic chambers, 7 to 10 ( $\bar{X} = 7.77$ ), are arranged in a single spiral. The last formed 1–3 chambers are usually very small. Y ranges from 1 to 4 ( $\bar{Y} = 2.62$ ). In one specimen, out of 35, there is a very small second principal

auxiliary chamber. In yet another 4 sections its presence is possible. Equatorial chambers are usually ogival, but the shape varies from arcuate via ogival to rhombic.

In eleven transverse sections there are lateral chambers of variable character. In moderately thick individuals they are of unequal size, convex towards the outside and arranged in irregular rows, and up to four on top of one another. In thin individuals, there are but few irregularly placed lateral chambers. However, in a twelfth transverse section, lateral chambers are not clearly visible.

*Remarks:* This assemblage is referred to *Miogypsina* s.s. However, occasional specimens may show the features of *Miogypsinoidea*. The histograms of X, Y,  $\gamma$  and I (fig. 13) suggest a fairly normal distribution. The single cluster in the X – I scatter diagram with poor correlation between both parameters (fig. 14) also suggests that the assemblage could have been drawn from a homogeneous population.

*Determination:* *Miogypsina (Miogypsina) tani* (table II)

*Sample:* G 1448

*Material:* more than 200 specimens.

Based on a preliminary study, this assemblage was considered to contain representatives of two or three species. On external features the assemblage was divided into three groups:

**A:** individuals with nearly smooth surface and the test low and oblique-conical in shape.

**AF:** individuals with nearly smooth surface and the test relatively flat, planoconvex to biconvex in shape.

**B:** individuals with prominent pustules and usually biconvex test.

Nearly 75% of the specimens of this sample belong to group B. There is complete gradation in the shape of the test from group AF to group A. Morphological features in each of the groups are described separately.

*Description:*

(A): Test usually a low and oblique cone, concavo-convex, subcircular to fan-shaped in outline. Maximum thickness slightly away from the apex of the test, approximately coinciding with the apex of the low-oblique cone. The cones have a steep slope at the apical side while the slope towards the frontal margin is very gentle. Maximum diameter of the test between 0.9 mm. and 2.2 mm. Maximum thickness is about 0.75 mm.

Surface of the test either without any ornamentation or with a few large

pustules. Such pustules have a diameter up to 0.15 mm. Most of the specimens appear to be smooth.

The embryonic-nepionic chambers are situated away from the periphery in an eccentric position. The embryonic-nepionic stage is distinctly trochoid. The nepionic chambers, 7 to 11 ( $\bar{X} = 8.87$ ) are arranged in a single spiral of one to one and a half whorl.  $\bar{Y} = 2.17$ ,  $\bar{\gamma}$  is negative,  $-38.3^\circ$ . The equatorial chambers are arcuate to ogival.

In two transverse sections, the outer walls on either side of the median layer are thick, amorphous to laminated with vertical structures. The median layer is curved, with the apical side strongly bent downward.

(AF): Test usually subtriangular in outline, unequally biconvex to plano-convex, a few specimens are concavo-convex; the test is varying in shape from longer than wide to about equal in length and width. The apex is protruding. The maximum thickness is near the apex, approximately coinciding with the position of nepionic spire.

The surface usually appears smooth; some individuals are ornamented with pustules or low elevations, closely spaced and generally of equal height.

The nepionic chambers, 7 or 8 ( $\bar{X} = 7.44$ ) are arranged in a single spiral of about one whorl.  $\bar{Y} = 2.08$ ,  $\bar{\gamma} = -32.2^\circ$ . The equatorial chambers are usually ogival, occasionally arcuate to ogival and rhombic.

In four transverse sections, the outer wall is thick, with horizontal and vertical structures.

(B): Test usually small, slender, longer than wide; some individuals are subcircular in outline. The apical portion is protruding, in a few specimens neck-like, this neck being up to one-fourth the length of the test. The test is equally to unequally biconvex; greatest thickness situated about midway between apex and frontal margin. Maximum diameter of test between 0.75 mm. and 1.5 mm.

The surface is well ornamented with numerous pustules, usually of unequal size per individual. Their diameter varies between 0.04 and 0.09 mm.

The embryonic chambers are distinctly smaller than those in groups A and AF (table II). The nepionic chambers, 6-8 ( $\bar{X} = 6.88$ ), are arranged in a single, plane spiral. The last formed 1-3 chambers are very small.  $\bar{Y} = 1.98$ .  $\bar{\gamma} = -20.2^\circ$ . In two specimens a very small second principal auxiliary chamber is overlain by the last few chambers of the main spiral. In yet another four sections the presence of a second principal auxiliary chamber is possible. Equatorial chambers are arcuate and ogival, and in a few specimens rhombic towards the frontal margin.

In 13 transverse thin sections and a number of broken specimens, there are several lateral chambers on either side of the median layer. The lateral chambers are of unequal size, convex towards the outer surface and there are three to five on top of each other. In very thin individuals, only a few small lateral chambers are present in one or two irregular layers.

*Remarks:* From the features of the lateral walls, observed in transverse sections and also from partly broken specimens, it may be concluded that the assemblages of groups A and AF belong to *Miogypsinoides* and the assemblage of group B belongs to *Miogypsina* s.s.

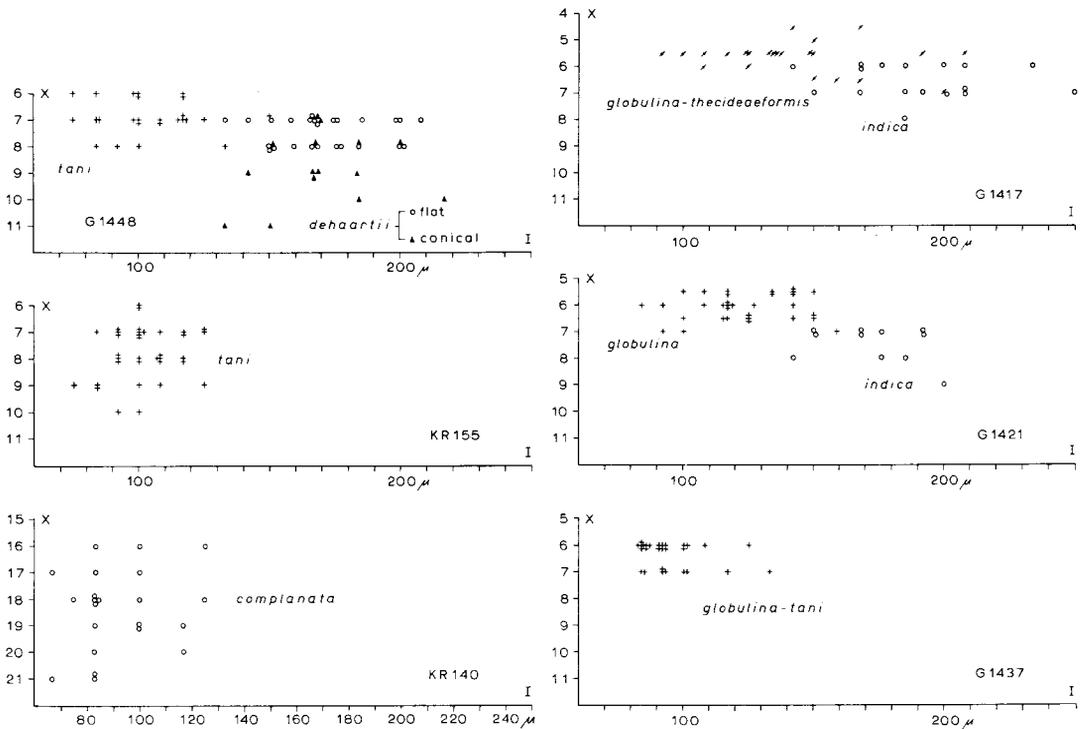


Fig. 14 Relation between X and I for specimens of Miogypsinidae in six samples from the Khari Nadi section, Kutch.

The scatter diagram of X and I (fig. 14) of this sample shows that the specimens of *Miogypsina* s.s. and *Miogypsinoides* have separate distribution fields, the diameter of the protoconch in specimens of the latter being distinctly larger. The scatter diagram of I and II (fig. 15) again shows that the specimens of *Miogypsina* and *Miogypsinoides* clearly fall apart in separate clusters. These observations suggest that the assemblages of *Miogypsina* s.s. and *Miogypsinoides* from this single sample could be separated also on

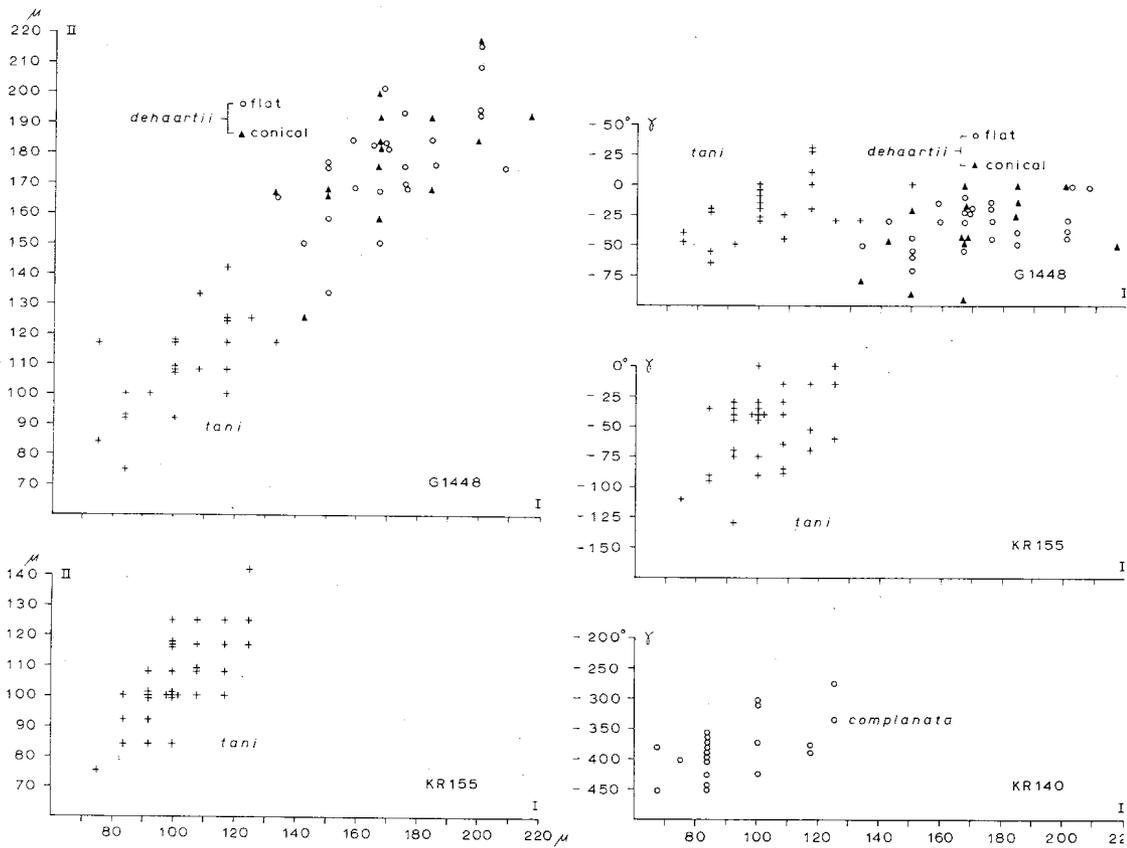


Fig. 15 Relation between I and II for specimens of *Miogypsinidae* in samples KR 155 and G 1448 from the Khari Nadi section, Kutch.

Fig. 16 Relation between  $\gamma$  and I for specimens of *Miogypsinidae* in samples KR 140, KR 155 and G 1448 from the Khari Nadi section, Kutch.

the basis of the features of the embryonic-nepionic stage. The suggestion of at least two different populations (and species) being present is furthermore supported by the scatter-field of the *Miogypsina* s.s. assemblage of KR 155, which corresponds closely to that of *Miogypsina* s.s. in G 1448.

The means of X in group A (subconical) and group AF (relatively flat) are significantly different: while the means of Y or I in these two groups are not significantly different. Apparently the higher value of  $\bar{X}$  in group A is associated with the position of the embryonic apparatus away from the periphery. The assemblage of group AF can be easily referred to *M. dehaartii*. The assemblage of group A is tentatively referred to *M. dehaartii* var. *cupulaeformis*. Details on the interrelation of both forms are briefly discussed in the chapter on taxonomy.

*Determinations:* (B) *Miogypsina (Miogypsina) tani*  
(AF) *Miogypsina (Miogypsinoidea) dehaartii*  
(A) *M. (M.) dehaartii* var. *cupulaeformis*

*Sample:* G 1437

*Material:* More than 150 specimens, most of them well preserved.

*Description:* Test usually small, thin or moderately thick, biconvex to plano-convex, longer than wide, ranging to wider than long in a few specimens. In some individuals the frontal margin is slightly undulated. The apical portion is protruding. The greatest thickness occurs between apex and midpoint of the test. Maximum diameter between 0.6 and 2.8 mm. Maximum thickness up to 0.75 mm. Surface well ornamented with pustules, variable in diameter and height.

Fourteen, out of 28 sectioned specimens, have a small, second principal auxiliary chamber which is usually overlain by the final chambers of the main spiral. In another seven sections the second principal auxiliary chamber may be present. In seven specimens the nepionic chambers, 6 or 7, belong to a single spiral ( $\bar{X} = 6.32$ ).  $\bar{\gamma}$  ( $= + 2.3^\circ$ ) is close to zero,  $\bar{V} = 9.55$ . The equatorial chambers are ogival to rhombic, in a few specimens they are elongate rhombic towards the frontal margin.

In transverse sections, the individuals have several lateral chambers that are convex outwards, and arranged in 3–5 irregular layers in moderately thick individuals, and in only one or two in thin ones.

In a few small, thin, juvenile forms (0.6 – 0.8 mm.) the pattern of the embryonic-nepionic and equatorial chambers could be observed from the exterior; the side walls over the equatorial chambers are very thin and they lack lateral chambers.

*Remarks:* The assemblage belongs to *Miogypsina* s.s. Both small and large individuals of the assemblage were included in the 28 sectioned specimens. The histograms of V, Y,  $\gamma$  and I indicate a fairly normal distribution pattern (fig. 13). Furthermore the X-I scatter diagram shows a single cluster (fig. 14). It may be concluded that this assemblage is representative of a single homogeneous population.

The lack of distinct lateral chambers in small juvenile forms could be attributed to the effect of environmental influences on early growth stages.  
*Determination:* *Miogypsina (Miogypsina) ex. interc. globulina-tani* (table II)

*Sample:* G 1421

*Material:* Some 80 specimens.

External features of the individuals again suggested that this sample

contains representatives of both *Miogypsinoidea* and *Miogypsina* s.s. The groups are dealt with separately.

*Description:*

(A): Specimens of this group are relatively scarce, only some 20 were found. Test subcircular to elongate in outline, concavo-convex; some are of the low-oblique cone shape. The greatest thickness is slightly away from the apical periphery, in subconical forms it is between the apex and the mid-point of the test. The test thins rapidly towards the frontal margin. The surface has a few large pustules, prominent at the thickest part; in other portions the pustules are closely spaced, which ornamentation gives the impression of a smooth surface. Maximum diameter between 1.2 and 2.5 mm.

The embryonic chambers are situated at a slight distance from the periphery in subconical forms, and close to the periphery in relatively flat forms.

The nepionic chambers, 7 to 9 ( $\bar{X} = 7.45$ ), belong to a single spiral.  $\bar{\gamma} = -9.54^\circ$ . The equatorial chambers are ogival to rhombic. In one transverse section, the walls on either side of the median layer were seen to be thick with prominent horizontal lamination, and a few vertical structures. In the other specimens the absence of lateral chambers has been ascertained during the preparation of the equatorial sections.

*Determination: Miogypsina (Miogypsinoidea) dehaartii* (table II)

(B): In moderately large and thin specimens, which are more common, the test is unequally biconvex, of equal width and length or of slightly greater length. The smaller specimens are relatively thick and equally biconvex. The maximum thickness is about half way between apex and midpoint; in several specimens the thickness varies but slightly between the apex and the frontal margin. The apical portion is slightly protruding, in a few specimens it is elongate. Maximum diameter between 1.2 and 3 mm.

Surface with small pustules of about 0.06 mm., but in some specimens there are large pustules of up to 0.25 mm. in the thickest portion of test.

The embryonic apparatus is situated peripherally.

In 33 equatorial sections examined, 30 specimens have a small second principal auxiliary chamber. In 8 of them, this small chamber is covered by the final chambers of the main spiral.  $V = 19.12$ ,  $\bar{\gamma} = +21.9^\circ$ . The equatorial chambers are usually ogival to elongate rhombic. However, in some five specimens they grade towards indistinctly hexagonal near the frontal margin.

In transverse sections (observations on broken specimens) there are several lateral chambers arranged in tiers, up to four per column in thick specimens and only one or two in thin ones.

*Remarks:* Because of the nepionic features (see also the X-I scatter in fig. 14) the assemblages of *Miogypsinoides* and *Miogypsina* s.s. are considered to be well apart.

From histograms of V, Y,  $\gamma$  and I (fig. 13) it may be considered that the *Miogypsina* group of specimens represents a single homogeneous population. On the basis of the configuration of the nepionic stage and the features of the equatorial chambers in the majority of the specimens, this assemblage can be referred to *M. globulina*. However, from the shape of the equatorial chambers in five of the specimens, it may be assumed that the population is tending towards *Lepidosemicyclina*.

*Determination.* *Miogypsina (Miogypsina) globulina* (table II)

*Sample:* G 1417

*Material:* Some 200 specimens. Most of the specimens of *Miogypsina*, as well as those of associated foraminifera, viz. *Operculina*, *Ammonia*, are poorly preserved and slightly worn. In several elongate specimens of *Miogypsina*, it is in particular the frontal margin and the apical portion including part of embryonic apparatus, that are worn away. Only a small proportion of the assemblage could be used in our study.

The sample is considered to contain representatives of two distinct species. They are again described separately.

(A): Specimens of this group are relatively rare. Some 40 specimens were separated. The embryonic-nepionic stage of these specimens is better preserved than it is in the second group.

Test strongly concavo-convex, usually low-oblique, coneshaped, subcircular in outline. Some specimens are relatively flat. The maximum thickness is situated about midway between the apex and the midpoint of the test; it approximately coincides with the position of the embryonic apparatus. The test thins rapidly in all directions away from the thickest part. The apical side of the cone bends strongly downwards. As the edges of the test are broken in most of the individuals, the maximum diameter of the test cannot be obtained. Diameter of the specimens between 1 and 2.5 mm. Maximum thickness about 0.7 mm.

The surface has relatively large, but very low pustules or elevations of equal diameter, that are very closely spaced. This pattern gives the surface a nearly smooth appearance.

The embryonic apparatus is situated at a slight distance from the apex. The protoconch is large ( $\bar{I} = 187 \mu$ ).

The nepionic chambers, 6–8 ( $\bar{X} = 6.58$ ), belong to a single spiral of one

whorl or less. The first principal auxiliary chamber is large, usually subcircular, in some specimens it is larger than either of the embryonic chambers. A small second principal auxiliary chamber has been noticed in three specimens and its presence is assumed in another five, out of 18 individuals examined. This small chamber is covered by the final chambers of the main spiral.

$\gamma$  is negative in only two specimens,  $\bar{\gamma}$  is positive with the high value of +16.66°.

The equatorial chambers are ogival to rhombic.

In three transverse thin sections and in several partly broken specimens the lateral walls are seen to be thick with fine, laminated horizontal structures and very fine radial beams. When the transverse sections are thick, the horizontal laminae are not clearly visible, the lateral walls appear amorphous. *Remarks:* This assemblage is close to *Miogypsinoidea dehaartii*. The present assemblage differs from the near-topotype assemblage of *M. dehaartii* described by Drooger (1953), in having a lower  $\bar{X}$  value, a positive value of  $\bar{\gamma}$ , and a small second principal auxiliary chamber in several specimens. Both assemblages, from G 1448 and G 1421 described from samples lower down in Khari Nadi section, have a negative value of  $\bar{\gamma}$ , and they were referred to *M. dehaartii*.

*Determination:* *Miogypsina (Miogypsinoidea) indica* (table II)

(B): Test flat, elongate, usually length greater than width, subtriangular in outline, equally biconvex to plano-convex. The maximum thickness is in the apical portion; the test gradually thins towards the frontal margin. Some specimens are evenly flat. The apical portion is broadly rounded to slightly pointed. The largest diameter of most of the specimens is between 0.75 and 2.8 mm., a few measure up to 4.5 mm. The surface has pustules, but in many specimens they are worn down.

The embryonic apparatus is situated peripherally. The nepionic chambers belong to two spirals, the shorter one usually represented by the principal auxiliary chamber only. In four specimens, out of 25, the second principal auxiliary chamber is covered by the final chambers of the longer spiral. The  $\bar{V}$  value is 22.6,  $\bar{\gamma} = +24.2^\circ$ .

The equatorial chambers are ogival to elongate rhombic; and in about one-third of the sectioned specimens distinct hexagonal chambers are present towards the frontal margin. The largest dimensions of hexagonal chamber are about  $170 \times 250 \mu$ .

In four transverse sections examined, the lateral chambers are rather low, of unequal size and arranged in 2–5 layers on either side of the median layer.

Five equatorial sections of microspheric forms could be made. Microspheric forms are larger (3.0 to 4.2 mm.) than the megalospheric ones. Some indistinct hexagonal chambers are present near their frontal margin. In one section, the nepionic chambers, 16 or 17, belong to a single spiral; in the others the nepionic chambers of the initial spiral could not be counted.

*Remarks:* Although there is little doubt about the presence of two distinct populations in sample G 1417, it should be noted that their assemblages show clear overlap in X,  $\gamma$  and I (see also fig. 14). The features of the equatorial chambers in group B suggest that this assemblage is intermediate between *Miogypsina* s.s. and *Lepidosemicyclina*.

*Determination:* *Miogypsina* ex. interc. *globulina-thecidaeiformis* (table II)

*Sample:* G 1415

*Material:* More than 150 specimens.

This sample is considered to contain again two species. They are described separately.

(A): Specimens of this group are rather rare. Some 25 specimens have been recorded. In most of them the edges of the test and in some the apical portion are damaged by wear.

Test concavo-convex. Most of the specimens have a low oblique cone shape. A few are relatively flat. In most of the external characteristics this assemblage is similar to that of G 1417 (A). In well preserved specimens, a few large pustules (up to 0.170 mm.) are concentrated around the thickest portion of the test.

The nepionic chambers, 5–7 ( $\bar{X} = 6.42$ ), belong to a single spiral of one whorl or less. A small second principal auxiliary chamber has been noticed in two specimens. It is covered by the final chambers of the main spiral.  $\bar{\gamma} = +24.23^\circ$ . In three transverse sections the lateral walls are thick with fine horizontal laminae and very fine radial, vertical structures. Occasionally the walls between equatorial chambers are clearly double with cavities in between.

*Determination:* *Miogypsina* (*Miogypsinoides*) *indica* (table II)

(B): Specimens of this group vary greatly in their external features. The assemblage was somewhat arbitrarily divided into the following three categories on the basis of external features.

1. Test fairly large and thick, equally biconvex, usually fan-shaped. The thickest portion (up to 1.4 mm.) is half way between apex and midpoint, in some specimens close to the midpoint. Around the bulging, thickest portion, the test is relatively thin towards all margins. In some specimens the frontal

margin is undulated, in a few it is incised giving a bifid appearance to the test. Maximum diameter is up to 4 mm. Pustules are usually small, but large ones are common around the thickest portion.

2. Test relatively small and thick, equally biconvex. Maximum diameter up to 2.5 mm. and greatest thickness about 1.3 mm.

3. Test flat, subtriangular in outline. Maximum diameter up to 2.5 mm., thickness usually between 0.25 and 0.65 mm.

In all specimens the embryonic apparatus is situated peripherally. In two specimens the kidney shaped deuteroconch is strongly embracing the protoconch.

The nepionic chambers belong to two spirals ( $\bar{V} = 28.8$ ).  $\bar{\gamma} = + 18.5^\circ$ . The short spiral consists of one or two chambers. In three specimens the second principal auxiliary chamber is covered by the final chambers of the main spiral.

In most of the specimens of categories 1 and 3, the equatorial chambers start to be elongate-hexagonal after 3 to 8 rows away from the nepionic chambers. The maximum dimensions of the hexagonal chambers are about  $100 \times 220 \mu$ . In five out of 10 specimens of category 2, the equatorial chambers are either short-hexagonal or elongate-hexagonal after some 6 to 8 rows away from the nepionic stage. In the other five the equatorial chambers are usually elongate-rhombic.

The presence of lateral chambers has been ascertained during the grinding. *Remarks:* The histograms of  $V$ ,  $\gamma$  and  $I$  (fig. 13) for the combined assemblage 1–3 are unimodal. The scatter diagram of  $V$  and  $I$  (fig. 17) shows that all the specimens of the three categories form a single cluster. It may therefore be considered that the total assemblage is representative of a single homogeneous population, although a few specimens have no distinct hexagonal chambers. Although occasional variants show the external features of the Indonesian species *M. polymorpha* and *M. bifida*, they lack the extremely elongate-hexagonal equatorial chambers of the latter two species.

*Determination:* *Miogypsina (Lepidosemicyclina) thecidaeiformis* (table II).

*Sample:* G 1406

*Material:* some 150 specimens.

This sample is considered to contain more than one species. The assemblage is divided into three groups and each group is described separately.

*Description:*

(A): Specimens of this group are relatively rare, only some 30 have been found. Some of them are brownish in colour. The frontal margin is broken in almost all specimens.

Test large, flat, elongate, equally biconvex, slightly thicker near the apex but otherwise uniformly flattened towards the frontal margin. The apical portion is broadly rounded. As the frontal margin is broken, the true maximum diameter in this assemblage could not be ascertained; available broken specimens have a diameter up to 3.5 mm. Maximum thickness is about 0.6 mm.

The surface is ornamented with low pustules, rather uniform in size and closely spaced.

The embryonic stage is situated near the apical periphery. The protoconch ( $\bar{I} = 191 \mu$ ) is circular. The size and shape of the deuterconch is variable; in some specimens it is distinctly larger than the protoconch and it even strongly embraces the latter, in others it is smaller. The two protoconchal nepionic spirals are usually of unequal length, but in a few specimens the configuration is nearly symmetrical ( $\bar{V} = 83.7$ ). In the majority of the individuals the spirals along the outer side of the deuterconch are incomplete, in a few they cover the entire circumference. In two, out of 20 sections, one small accessory auxiliary chamber is present on the deuterconch and in another three such a chamber may be present.

The equatorial chambers are usually of short to elongate hexagonal shape. In some specimens elongate hexagonal chambers are common from about the third row away from the nepionic chambers. In others, the equatorial chambers of the first 7 to 10 rows are isodiametric-hexagonal and the later ones more elongate. Large equatorial chambers have dimensions of  $150 \times 260 \mu$  or  $125 \times 250 \mu$ .

The lateral chambers are arranged in two to four low layers on either side of the median layer.

*Remarks:* On the basis of the predominantly elongate-hexagonal equatorial chambers, this assemblage is referred to the subgenus *Lepidosemicyclina*. Regarding the embryonic-nepionic development, it is very close to that of *M. (L.) droogeri* Mohan & Tewari, which was originally described from Vinjhan-Miani area, Kutch.

*Determination:* *Miogypsina (Lepidosemicyclina) droogeri* (table II)

(B) Test small, relatively thick, equally or unequally biconvex, usually of equal width and length. The apical portion is protruding, in some specimens broadly rounded. Maximum thickness (up to 0.8 mm.) about half way between apex and midpoint. Maximum diameter between 0.8 and 2.5 mm. Surface ornamented with pustules.

Embryonic apparatus situated near the apex. Protoconch ( $\bar{I} = 82 \mu$ ) and deuterconch are very small.

In twenty equatorial sections examined, seventeen show a second principal auxiliary chamber; in six of them it is covered by the final chambers of the main spiral.  $\bar{V} = 15.6$ ,  $\bar{\gamma} = +1.0^\circ$ . Equatorial chambers are ogival to rhombic, elongate-rhombic near the frontal margin. The presence of lateral chambers has been ascertained from partly broken specimens and during grinding.

*Determination: Miogypsina (Miogypsina) globulina* (table II)

(AB): In external features specimens of this group appear to be intermediate between those of groups (A) and (B). There is nearly complete gradation between groups B and AB.

Test flat, usually subtriangular in outline, unequally biconvex, with equal length and width or length greater than width. Apical portion protruding. Maximum diameter between 1.5 and 4 mm. Maximum thickness around 0.4 mm., in some specimens up to 0.6 mm. Surface with pustules of unequal height.

Embryonic chambers situated peripherally. Protoconch circular ( $\bar{I} = 157 \mu$ ). Deuteroconch slightly larger than protoconch. Twenty out of 21 sectioned specimens, have a distinct second principal auxiliary chamber.  $\bar{V} = 25.52$ ;  $\bar{\gamma} = +23.8^\circ$ .

The equatorial chambers are usually ogival to rhombic; some indistinct short hexagonal chambers (dimensions  $170 \times 170 \mu$ ) are present near the frontal margin; in two specimens such chambers start after five to six rows from the nepionic chambers.

Distinct lateral chambers, arranged in three to four layers on either side of the median layer, have been noted in partly broken specimens.

*Remarks:* There has been no problem in placing the assemblages of group A and group B in *M. (L.) droogeri* and *M. (M.) globulina* respectively, notwithstanding the low  $\bar{\gamma}$  value of the latter.

As to specific determination of group AB, we again arrive at *M. (Miogypsina) globulina*. The only hesitation might be the presence of some hexagonal equatorial chambers in two of the specimens. Since a somewhat hexagonal shape of equatorial chambers is quite common in the younger Indo-Pacific species of *Miogypsina* s.s. there is no reason to classify group (AB) as intermediate between *Miogypsina* s.s. and *Lepidosemicyclina*. Figure 17 clearly shows that both our groups of *M. globulina* fall apart because of differences in the diameter of the protoconch. There is also considerable difference in  $\gamma$ . Although it should be reminded that the number of observations per assemblage is small, the gap between the clusters is conspicuous. If the gap would be filled the total variation of the combined *M. globulina*

groups would not be excessive for a single homogeneous population. No clear solution can be given for our discontinuous record, but the possibility of sedimentary washing together of two groups of ecophenotypes of the same species may be considered.

*Sample:* G 1401

*Material:* some 100 specimens. This sample is again considered to contain more than one species. The total assemblage is divided into three groups in the same way as that of G 1406 and the groups are described separately.

(A): The specimens of this group are rare and badly preserved. Only some 15 specimens are recorded. They are brownish in colour and large parts along the frontal margin are broken off. Pustules are partly worn. Except for the state of preservation the individuals are similar to those of group (A) from G 1406. The apical portion is broadly rounded. Ten equatorial sections could be made. All the chambers are filled with ferruginous calcareous matter.

The embryonic apparatus is situated near the periphery. The protoconch is circular and moderately large ( $\bar{I} = 204 \mu$ ). The two protoconchal spirals are nearly of equal length ( $\bar{V} = 86.5$ ). Spirals along the circumference of the deuteroconch are either incomplete or they cover this chamber entirely. In three specimens one accessory auxiliary chamber appears to be present. Equatorial chambers are predominantly hexagonal, isodiametric in the early 3 to 7 rows, more elongate in later rows.

*Determination:* *Miogypsina (Lepidosemicyclina) droogeri* (table II)

(B): The specimens of this group are well preserved. Externally the specimens of this group are similar to those of group (B) from G 1406, described earlier. Maximum diameter between 0.9 mm and 2.2 mm.

The embryonic apparatus is situated peripherally. Protoconch ( $\bar{I} = 89 \mu$ ) and deuteroconch are small.  $\bar{V} = 15.42$ ,  $\bar{\gamma} = + 3.8^\circ$ . Equatorial chambers are ogival to elongate rhombic (up to  $125 \times 208 \mu$ ).

*Determination:* *Miogypsina (Miogypsina) globulina* (table II)

(AB): Specimens of this group are also well preserved. Externally this group is more or less similar to that of group (AB) from G 1406. There is again gradation to group (B) of this sample.

Maximum diameter between 1.5 and 4.5 mm. Maximum thickness 0.7 mm., but usually the specimens are flatter (about 0.4 mm.).

Embryonic apparatus is situated peripherally. The protoconch is circular ( $\bar{I} = 147 \mu$ ). The deuteroconch is slightly larger; in one specimen distinctly

obliquely kidney shaped. All the sectioned specimens (18) have a distinct second principal auxiliary chamber, in two it is covered by the final chambers of the main spiral. In four specimens, the second chamber of the main nepionic spiral is elongate and equal to or distinctly larger than either of the embryonic chambers.  $\bar{V} = 26.46$ ;  $\bar{\gamma} = +25.55^\circ$ .

The equatorial chambers are ogival to elongate rhombic. In six specimens, out of 18, there are short hexagonal chambers ( $150 \times 200 \mu$ , rarely  $125 \times 200 \mu$ ) towards the frontal margin, after some 7 to 9 rows away from the nepionic chambers. The presence of lateral chambers has been noticed.

*Remarks:* Figure 17 shows that groups B and AB again form different clusters because of differences in protoconch diameter, but this time the total distribution is not discontinuous, as in G 1406. Since variation is considered to be not excessive, we might explain this variation to be due to correlated gliding changes of size parameters under environmental control.

*Determination:* *Miogypsina (Miogypsina) globulina* (table II)

*Sample:* KR 36

*Material:* some 150 specimens.

This sample is considered to contain two different species. Their assemblages are described separately below.

(A): Test usually large, flat and elongate; about one and a half times as long as wide. The width of the test increases very gradually from the apex to the frontal margin. A few large individuals are nearly fan-shaped. The apical portion is broadly rounded. Thickness is greatest near the apex and it decreases rather gradually towards the frontal margin. The maximum diameter of the test varies from 1.3 to 8 mm.; the majority of the individuals measure between 3 and 5 mm. The maximum thickness is about 0.75 mm.

The surface is ornamented with pustules, that are closely spaced and low, and evenly distributed over the entire surface. In some specimens, pustules are more prominent and larger (up to 0.2 mm.) near the apex. Some specimens seem to be smooth due to the close spacing of low and even sized pustules.

In several of the specimens the embryonic stage is situated at a distance from the apical periphery, in an eccentric position. The protoconch is large ( $\bar{I} = 199 \mu$ ) and usually circular. The deuterococonch, distinctly larger than the protoconch, embraces a considerable part of the protoconch.

The two principal auxiliary chambers are usually of unequal size. The configuration of both protoconchal nepionic spirals is nearly symmetrical.  $\bar{V} = 90.7$ ;  $\bar{\gamma} = +5^\circ$ . Accessory auxiliary chambers (one to three) around the

deuteroconch are distinct in 17 out of 27 sectioned specimens, and their presence is possible in another 6 specimens.

The equatorial chambers are of distinctly elongate-hexagonal shape. However, in a few poorly made thin sections, this shape is not very clear. In some individuals, the elongate-hexagonal shape is attained by equatorial chambers immediately following the nepionic chambers, in others this shape becomes prominent at a distance of two to four rows from the nepionic chambers. Most of the large equatorial chambers, particularly those near the frontal margin, have dimensions of about  $125 \times 250 \mu$  or  $150 \times 260 \mu$ . In two transverse sections there are three to five layers of lateral chambers, elongate in apical-frontal direction, on either side of the median layer.

*Remarks:* On the basis of the presence of distinctly elongate-hexagonal equatorial chambers, this assemblage is referred to the subgenus *Lepidosemicyclina*. In more than 60% of the specimens, the embryonic stage is situated at some distance from the periphery and in most specimens distinct accessory auxiliary chambers have developed around the deuteroconch.

*Determination:* *Miogypsina (Lepidosemicyclina) excentrica* (table II)

(B): Specimens of this group are relatively rare; only some 30 specimens were found.

Test usually small, biconvex, elongate to subcircular in outline. Some relatively large individuals are thin, wider than long. Maximum thickness is usually in the area around the midpoint of the test. The apical portion is protruding in slender forms and more evenly rounded in broader forms. The maximum diameter of the test is between 0.8 and 2.5 mm., rarely up to 3.4 mm. The surface is covered with pustules; large ones (up to 0.115 mm.) are most prominent around the thickest portion of the test.

The embryonic chambers are situated near the apical periphery and they are small in size.  $\bar{I} = 103 \mu$ .

In most specimens the nepionic chambers belong to two spirals, the shorter one usually represented by no more than the small second principal auxiliary chamber. In one specimen out of 20, there is only a single protoconchal spiral. In seven, the second principal auxiliary chamber is covered by the final chambers of the main spiral.  $\bar{V} = 18.7$ ,  $\bar{\gamma} = + 18.3^\circ$ .

Equatorial chambers are usually ogival to rhombic. In a single section a few short hexagonal chambers are present near the frontal margin. The presence of lateral chambers has been ascertained from partly broken specimens or during grinding for the equatorial sections.

*Remarks:* This assemblage belongs to *Miogypsina* s.s. In none of the characteristics there is intergradation between the assemblages (A) and (B) of this

sample. The groups are rather widely apart in the degree of nepionic development (fig. 13, 17).

*Determination: Miogypsina (Miogypsina) globulina* (table 11)

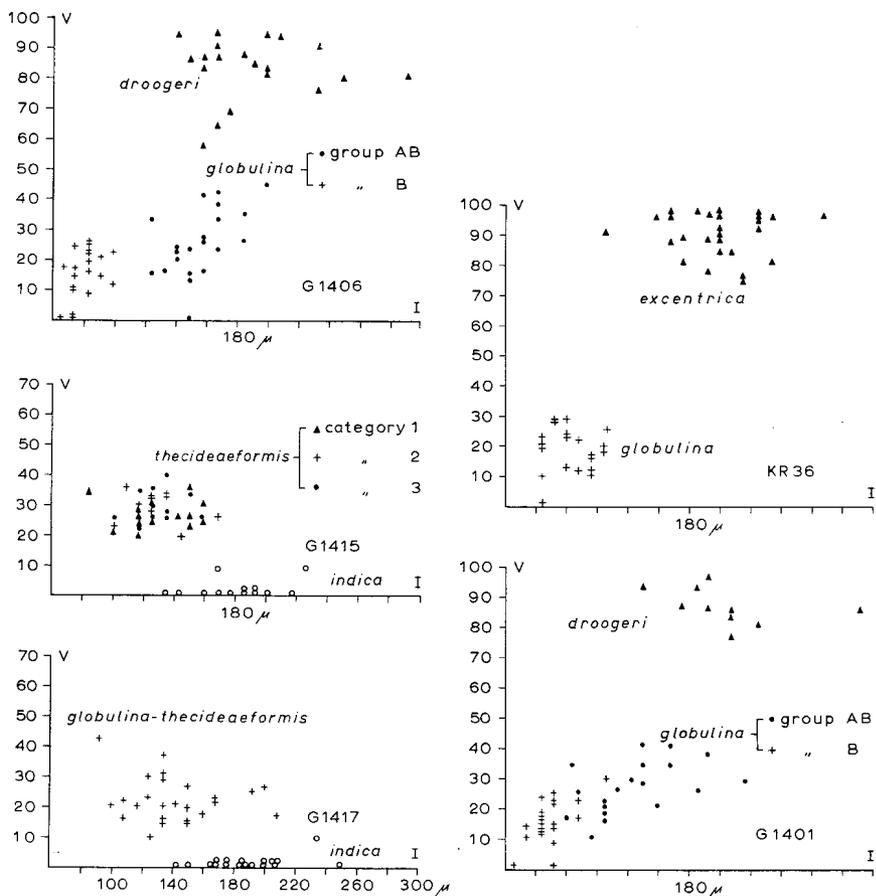


Fig. 17 Relation between V and I for specimens of Miogypsinae in five samples from the Khari Nadi section, Kutch.

*Sample:* KR 34

*Material:* A solitary specimen could be isolated from this hard limestone.

*Description:* Test thin. The apical periphery is broadly rounded.

The embryonic apparatus is situated at some distance from the periphery. The protoconch is circular and large ( $234 \mu$ ). The deuteroconch, distinctly larger ( $317 \mu$ ), embraces part of the protoconch. Both principal auxiliary

chambers are of unequal size. The arrangement of the protoconchal nepionic spirals is nearly symmetrical. Two distinct auxiliary chambers are present on the deuteroconch. The equatorial chambers are distinctly elongate-hexagonal in shape.

*Determination: Miogypsina (Lepidosemicyclina) excentrica*

#### *Results of counts and measurements*

The results of counts and measurements are given in table II. Histograms for the X, Y,  $\gamma$  and I observations in successive samples are given in figure 13.

The distribution of X or V, Y,  $\gamma$  and I are fairly unimodal in all the assemblages from samples KR 140 to G 1415 (fig. 13). The irregular pattern of the I distribution in G 1421 and G 1417 might be due to the small number of observations relative to the high number of classes.

As mentioned in the description of the individual samples, the assemblages of *Miogypsinoidea* and *Miogypsina* s.s. or *Lepidosemicyclina* can be easily separated. Apart from the usual criterion of absence or presence of lateral chambers, plotting of I – II and of X – I or V – I gives a fairly good separation, because the assemblages of *Miogypsinoidea* have a distinctly larger embryonic apparatus than those of the associated groups with lateral chambers. Histograms of these assemblages are given separately.

*Miogypsina* s.s.-like and *Lepidosemicyclina*-like individuals occur together in five samples. They can be easily separated in the three stratigraphically higher samples, G 1406, G 1401 and KR 36.

Apart from the criterion of absence or presence of predominant hexagonal equatorial chambers, histograms of V and scatter diagrams of V–I show the separate groups. In two samples, G 1417 and G 1415, which are stratigraphically older, it is difficult to separate assemblages of different types; intergradation in all features causes the individuals in each sample to be taken together for specific determination.

*Miogypsinoidea*:  $\bar{X}$ ,  $\bar{Y}$  and  $\bar{Z}$  values (table II) decrease from bottom to top.  $\bar{X}$  decreases from KR 140 to G 1415, from 18.2 to 6.42. It should be noted that *Miogypsinoidea* assemblages with  $\bar{X}$  value between 18.2 and 7.98 have not been found in this section.  $\bar{Y}$  decreases from KR 140 to G 1417 from 10.5 to 0.5. In histograms of X and Y, there is a modal shift in successive samples corresponding with the decrease of  $\bar{X}$  and  $\bar{Y}$  respectively (fig. 13). The number of classes of X and Y becomes gradually reduced from bottom to top. The Y histogram for G 1417 shows a high peak of zero values.

$\gamma$  increases from KR 140 to G 1415 from  $-374^\circ$  to  $+24.43^\circ$ . Histograms of  $\gamma$  show a modal shift corresponding to the increase of  $\gamma$ .  $\bar{I}$  increases from KR 140 to G 1417 from  $92 \mu$  to  $189 \mu$ , but it shows a slight, insignificant, decrease to  $180 \mu$  in the highest sample G 1415.

*Miogypsina s.s. and Lepidosemicyclina*: In the early part of *Miogypsina s.s.*  $\bar{X}$ ,  $\bar{Y}$  and  $\bar{Z}$  values (table II) decrease from bottom to top.  $\bar{X}$  decreases from KR 155 to G 1437 from 7.77 to 6.32.  $\bar{Y}$  decreases from KR 155 to G 1417 from 2.62 to 0.05. The histograms of X and Y show a gradual modal shift corresponding to the decrease in  $\bar{X}$  and  $\bar{Y}$  respectively (fig. 13).  $\bar{\gamma}$  increases from KR 155 to G 1417 from  $-51.6^\circ$  to  $+24.2^\circ$ .

The assemblages from samples G 1417 and G 1415 are considered to be transitional between *Miogypsina s.s.* and *Lepidosemicyclina*.  $\bar{V}$  increases from G 1437 to G 1415 from 9.55 to 28.8. In the higher assemblages of *Miogypsina s.s.*,  $\bar{V}$  values show no further trend. They are below the value of 28.8 found in sample G 1415, with even the lowest value in the topmost sample KR 36.

In the succession of *Lepidosemicyclina*, there is a wide gap between samples G 1415 and G 1406. Assemblages with  $\bar{V}$  values between 28.8 and 83.7 have not been found.  $\bar{V}$  increases more slowly from G 1406 to KR 36, from 83.7 to 90.7.  $\gamma$  decreases from G 1406 to KR 36 from  $+26.3^\circ$  to  $+5^\circ$ .  $\bar{I}$  seems to increase from 191 to  $199 \mu$ .

### Conclusions

1. In Khari Nadi section, *Miogypsinoidea* is represented by *M. complanata*, *M. dehaartii* with its var. *cupulaeformis* and *M. indica*. The gap in the succession of *Miogypsinoidea* may be attributable to unfavourable environmental conditions, as the sediments from the intermediate interval were deposited under non-marine to brackish-lagoonal conditions. *M. dehaartii* with its var. *cupulaeformis* apparently invaded the area during a transgressive phase.

At the stages of *M. dehaartii* and *M. indica* there is a clear morphological break between the associated assemblages of *Miogypsina s.s.* and *Miogypsinoidea*. The trends in the development of *Miogypsinoidea* are in accordance with the principle of nepionic acceleration.

2. *Miogypsina s.s.* is represented by *M. tani* and *M. globulina*. The trend of development up to an early stage of *M. globulina* (up to sample G 1421) is again in accordance with the principle of nepionic acceleration. However, trends in the development of later *M. globulina* (samples G 1406 – KR 36)

seem to be completely absent. The pattern may be further complicated by the presence of different “ecophenotypes”. Details will be discussed in the chapter on phylogeny.

3. *Lepidosemicyclina* is represented, from bottom top, by *M. thecideaeformis*, *M. droogeri* and *M. excentrica*. The trends in the development of these three species are in accordance with the principle of nepionic acceleration, but assemblages with  $\bar{V}$  values between 28.8 and 83.7 have not been found.

## Chapter III

### SAURASTRA

Miocene marine sediments are exposed in isolated patches in the western, southern, and eastern coastal parts of Saurashtra (also referred to as Kathiawar in previous literature). They unconformably overlie basalt sheets of the so-called Deccan traps, of Late Cretaceous – (probably) Early Tertiary age. Foraminifera from the Miocene sediments of Saurashtra were studied by several authors particularly in the last three decades. For a review on previous studies, the reader is referred to Bhatia & Mohan (1959).

Chatterji et al. (1953) reported the presence of *Miogypsina*, *Miogypsinoidea*, and a few other foraminifera from Saurashtra. Mohan (1958) described *M. (M.) irregularis*, *M. (M.) bhogotensis* n.sp., *M. (L.) polymorpha* and *M. (L.) thecidaeiformis* from three localities of this region. However, the presence of *Miogypsinoidea* was not documented so far.

For the present study only two samples will be dealt with because they contain *Miogypsinoidea* together with *Miogypsina*.

#### Nandana section

The stratigraphic column is given in figure 18. The section is located about 400 meters SSW of Nandana village (22° 07' 30" N: 69° 16' 30"). It is about 4.5 km. north of Bhatia, which is one of the *Miogypsina* localities mentioned by Mohan (1958).

From this section one sample was studied in detail.

*Sample:* SG 4

*Material:* more than 300 specimens. This sample from calcareous clay is very rich in *Miogypsina*. Almost all the specimens are very well preserved.

Externally the individuals are highly variable. A few transverse sections and observations on partly broken specimens show that this sample contains two distinct groups, one without lateral chambers and another with lateral chambers. They are described separately.

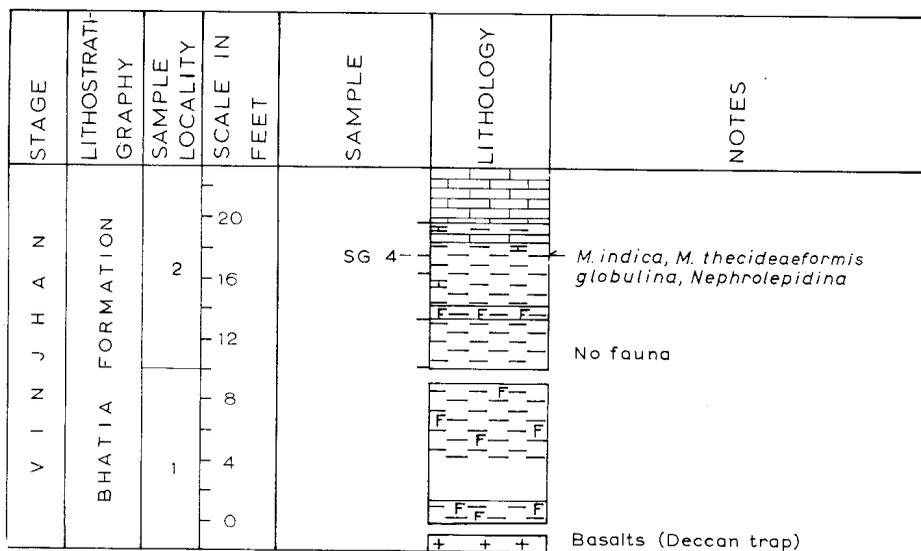


Fig. 18 Stratigraphic column of the Nandana section, Saurashtra.

(I): Some 45 specimens have been analysed. In most of them the edges are broken. In some of the specimens the thickest portion is slightly worn.

In relatively large specimens the test is strongly concavo-convex, subcircular in outline, and of low oblique cone shape. Relatively smaller specimens are unequally biconvex. The greatest thickness is near the midpoint, or half way between apex and midpoint. The diameter of the test varies from 1 mm. to slightly greater than 2.7 mm. Maximum thickness is up to 1 mm. In most of the specimens the surface has a smooth appearance, being covered by low, very closely spaced elevations. Some individuals have a few large pustules (up to 0.15 mm.) in the area of the thickest portion.

The embryonic apparatus is situated at a distance from the apical border in subconical forms, and close to the apex in a few thin forms. The protoconch is subcircular and large ( $\bar{I} = 193 \mu$ ). The nepionic chambers, 5–8 ( $\bar{X} = 6.5$ ) belong to a single spiral of one or slightly less than one whorl.  $\bar{\gamma} = + 16.81^\circ$ . A small second principal auxiliary chamber has been observed in two specimens out of 22, and its presence is possible in another 6 specimens. The equatorial chambers are ovigal to rhombic.

In transverse sections, the side walls are thick, with laminated horizontal structures and without any trace of lateral chambers.

*Determination: Miogypsina (Miogypsinoidea) indica* (table III)

(II): All the specimens of this rich assemblage are well preserved. Exter-

nally the individuals are highly variable; at one extreme end they are large with strongly undulated frontal margin and at the other end of the variation they are small and thick. However, there is complete gradation from one end to the other. The assemblage has been arbitrarily split into 4 groups, based on external morphology, because it was thought worthwhile to check whether these extremes are also different with respect to the internal features. The groups are described separately below.

(A): Test long and thin, with the frontal margin strongly undulated. Some specimens are of equal length and width. The apical portion protrudes slightly. Maximum diameter between 2 and 6 mm.; maximum thickness up to 0.7 mm., but usually less than 0.4 mm. Surface covered with numerous pustules, usually low and evenly distributed.

The embryonic apparatus is situated peripherally. The deuteroconch ( $\bar{I}\bar{I} = 182 \mu$ ) is distinctly larger than the protoconch ( $I = 138 \mu$ ). In four specimens, out of 20 examined, the deuteroconch is oblique kidney shaped. In all the sectioned specimens, there is a second principal auxiliary chamber, in some it is followed by a small second protoconchal chamber.  $\bar{V} = 34.9; \gamma = +40.5^\circ$ .

Because of the strongly undulated test, most of the equatorial chambers could not be observed in the thin sections. The equatorial chambers are usually hexagonal, after 4 to 8 rows following the nepionic chambers. Several of them are isodiametric. In some specimens distinct elongate-hexagonal chambers (dimensions around  $100 \times 200 \mu$ , rarely  $125 \times 250 \mu$ ) are present after 4 to 8 rows. Equatorial chambers which immediately adjoin the nepionic chambers are usually ogival to rhombic. In transverse section, the lateral chambers are very low.

(B): Test usually thin, of equal length and width. Some individuals are relatively thick at about halfway between apex and midpoint. The maximum diameter is between 1.2 and 5.5 mm.

In internal features the individuals of this group are similar to those of group A. The deuteroconch is oblique kidney shaped in three specimens and very irregular in one. Hexagonal chambers are less prominent than in group A.  $\bar{V} = 26.6; \bar{\gamma} = +31.6^\circ$ .

(C): Test relatively thick and biconvex. The apical portion is slightly protruding to broadly rounded. Maximum diameter between 1 mm. and 2.8 mm.; maximum thickness up to 1 mm.

With respect to the nepionic features, the specimens of this group have lower mean values of  $V$  ( $\bar{V} = 23.5$ ) and of  $\gamma$  ( $\bar{\gamma} = +8.5^\circ$ ). In about half of the sectioned specimens, the equatorial chambers are ogival to elongate-rhombic. In other individuals, which are the relatively larger ones of this group, there

are short-hexagonal chambers near the frontal margin.

(D): In some eight individuals, the frontal margin is incised, giving rise to finger like projections from the main body of the test. However, these projections are less extreme than those of the "bifida" type of Indonesia; they better resemble Tan's "musperi" type.  $\bar{V} = 16.2$ ,  $\bar{\gamma} = +25.7^\circ$ ;  $\bar{X} = 7$ .

Remarks: 1) In strongly undulated (A) and in thin specimens (B), the equatorial chambers usually become hexagonal after 4 to 8 rows following the nepionic chambers. On the other hand, in the small and thick specimens (C), the equatorial chambers are predominantly ogival to elongate-rhombic, except for a few hexagonal chambers near the frontal margin. If the shape of the equatorial chambers is taken as the main criterion, this assemblage would include representatives of both *Lepidosemicyclina* and *Miogypsina* s.s.

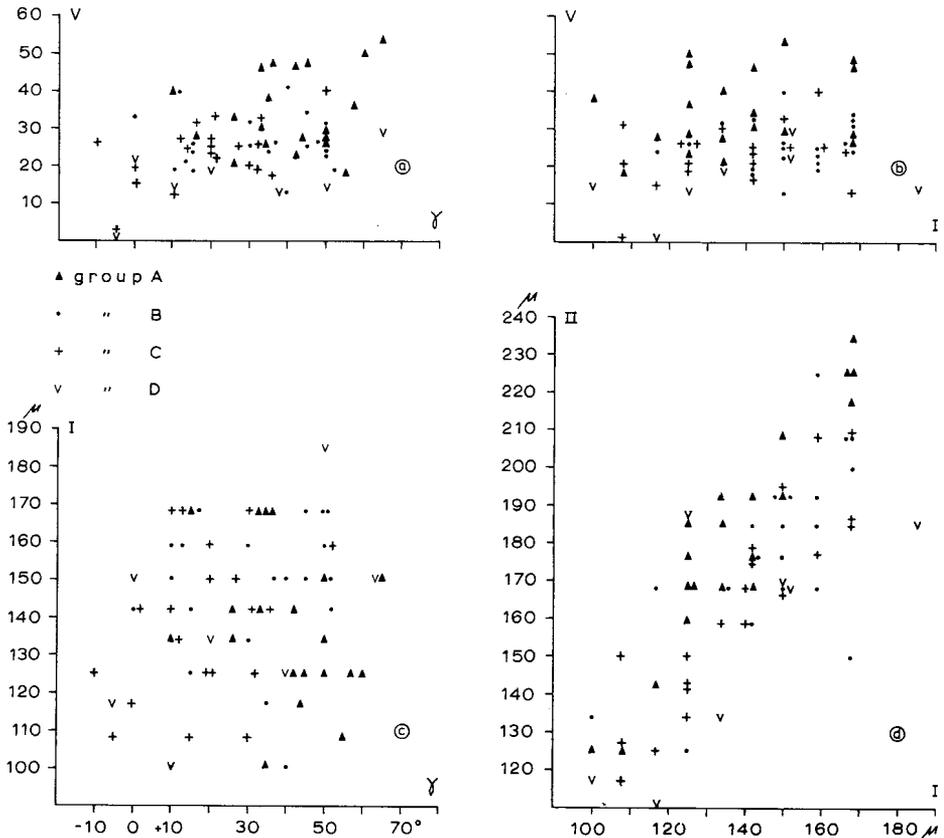


Fig. 19 Relation between V and  $\gamma$  (a), V and I (b), I and  $\gamma$  (c), and I and II (d), for specimens of *M. thecideaformis* in sample SG 4 from the Nandana section, Saurashtra.

2) The scatter diagrams of V and  $\gamma$  (fig. 19a), V and I (fig. 19b), I and  $\gamma$  (fig. 19c), and I and II (fig. 19d) show that the specimens of the four groups together form a single cluster. Fig. 19a shows that the upper right side of the scatter field is mainly occupied by part of the undulated specimens (A), while the lower left corner of the field is occupied by some of the small, thick specimens (C). However, such a differentiation is less evident in the other scatter diagrams. Most of the specimens of all four groups fall within the main field around the centre. As a whole the scatter diagrams suggest that the total assemblage represents a homogeneous population. Within the wide range of variation some of the external features (size) seem to have some degree of correlation with internal morphology (shape of equatorial chambers, V and  $\gamma$ ).

*Determination: Miogypsina (Lepidosemicyclina) thecideaeformis* or *M. ex. interc. thecideaeformis - globulina* (table III)

### Jagatia shallow well

This well is situated near the town of Verval in the southern part of Saurashtra. The coordinates of the location of the well are: 70°46' E: 20°53'40'' N.

One cutting sample from the Jagatia shallow well was studied. The sample contains the highest occurrence of *Miogypsina* in this well.

*Sample:* 24–27 m., drill cuttings.

*Material:* some 30 specimens. In most of them the edges are broken. This sample contains two different assemblages. They are described separately below.

(A): Relatively large individuals of this assemblage are strongly concavo-convex, low oblique cone shaped and subcircular in outline. Smaller forms are unequally biconvex and slightly elongate. Maximum diameter between 0.7 mm. and 2.5 mm.; maximum thickness up to 1.0 mm. In smaller individuals only a few pustules are present around the thickest portion of the test, whereas the rest of the surface appears to be smooth. Relatively large specimens have several pustules of unequal size.

The embryonic apparatus is situated peripherally in the smaller specimens, and halfway between midpoint and periphery in the larger, conical forms. The nepionic chambers, 6 to 8 ( $\bar{X} = 7.1$ ) belong to a single spiral of about one whorl.  $\bar{\gamma} = -8.6^\circ$ . The equatorial chambers are ogival to rhombic.

In three transverse sections the lateral walls are thick with very fine

horizontal lamination and some vertical structures. The horizontal laminae are slightly undulated. A few, small cavities, which measure up to  $40 \mu$  are present.

*Determination:* *Miogypsina (Miogypsinoidea) dehaartii* including its variety *cupulaeformis* (table III)

(B): Specimens of this group are very rare. Test relatively small, biconvex and subcircular in outline, or slightly elongate. The apical portion protrudes slightly. Maximum diameter between 1 and 1.5 mm. The surface is uniformly covered with pustules. In all four equatorial sections examined, the embryonic apparatus is situated peripherally. A small second principal auxiliary chamber is distinct in two specimens and its presence in the other two is possible. V ranges from 0 to 10. The value of  $\bar{v}$  is low and positive ( $+10^\circ$ ). Equatorial chambers are ogival to rhombic. Presence of lateral chambers has been ascertained during the grinding.

*Determination:* Probably *Miogypsina (Miogypsina) globulina* (table III).

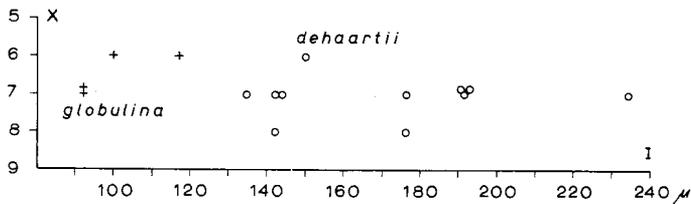


Fig. 20 Relation between X and I for specimens of *Miogypsinae* from the Jagatia shallow well, 24–27 m., Saurashtra.

Chapter IV  
CAUVERY BASIN

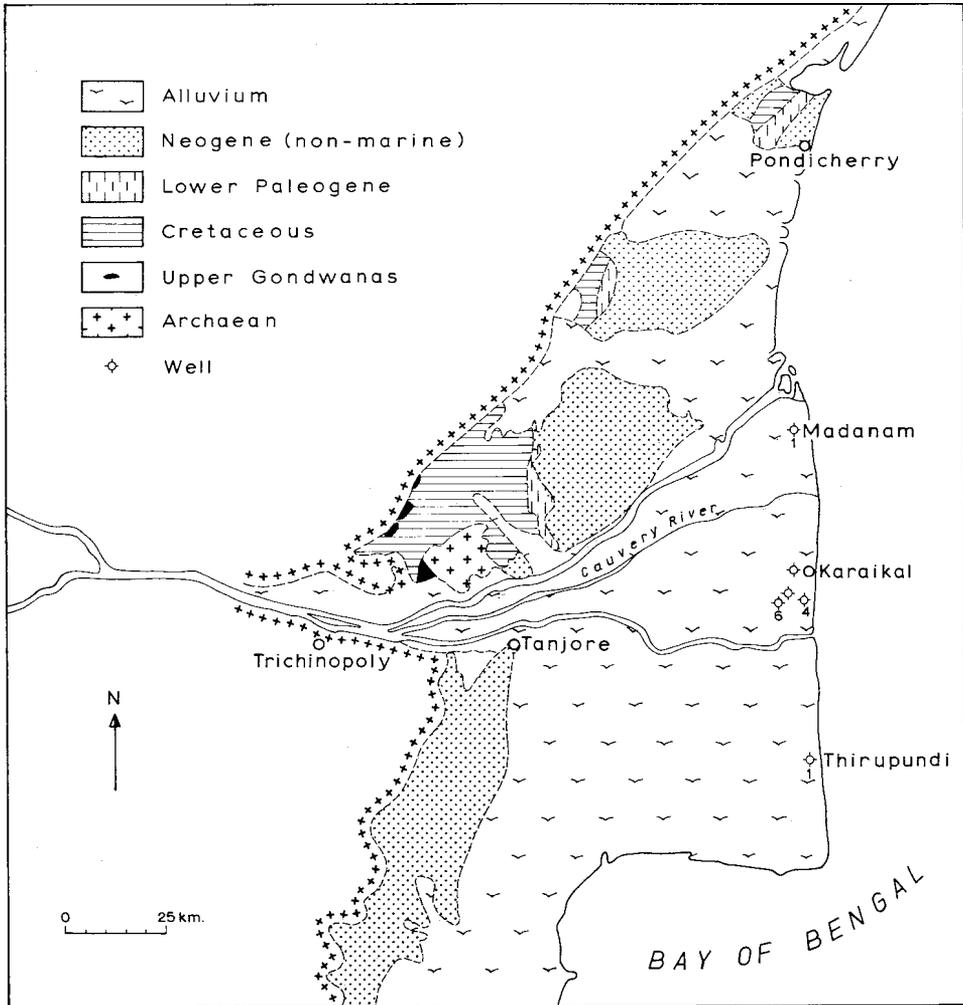


Fig. 21 Schematic geological map of Cauvery Basin showing well locations.

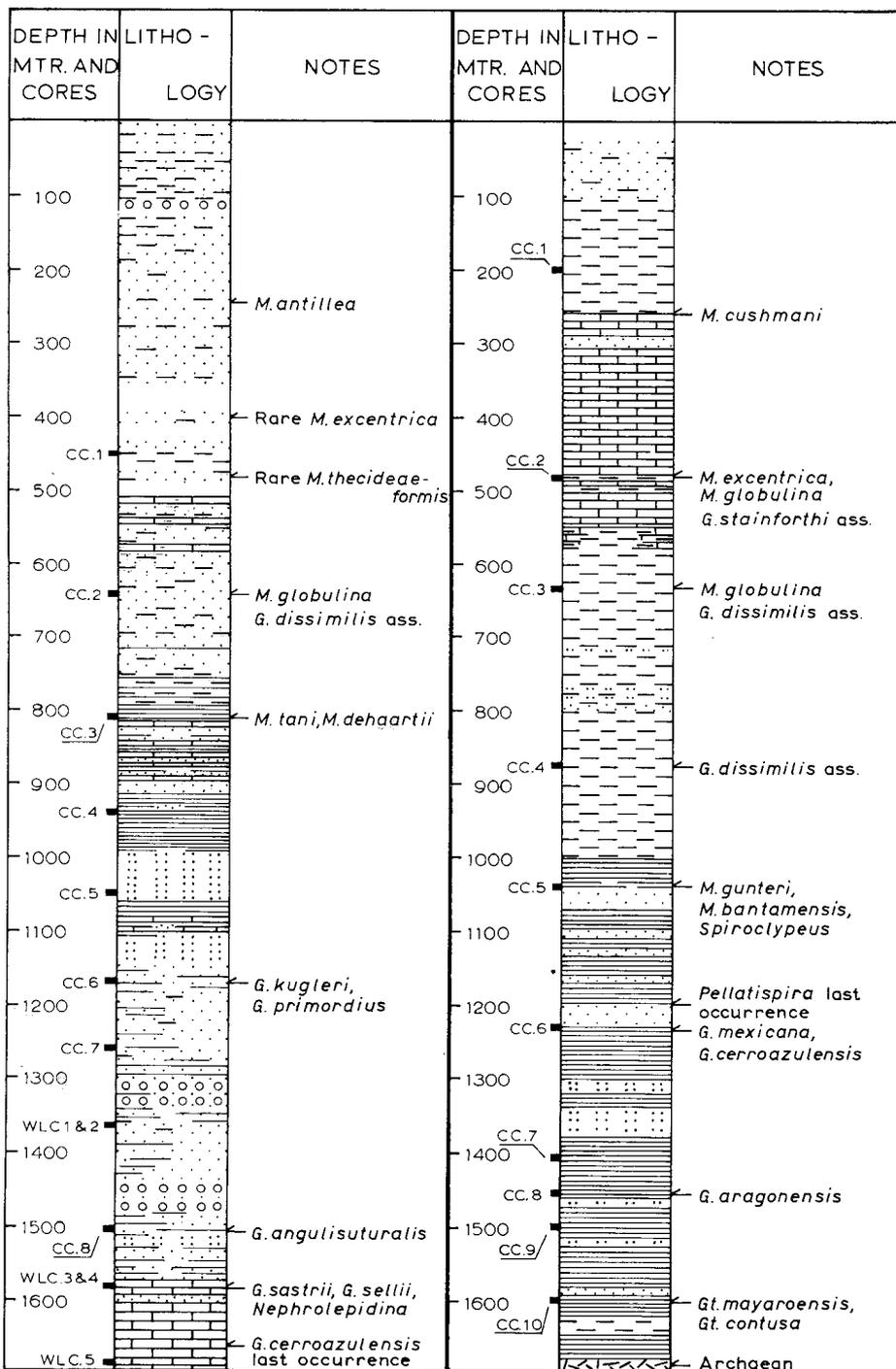


Fig. 22 Stratigraphic columns of Karaikal well 4 (left) and Madanam well 1 (right), Cauvery Basin.

In Cauvery basin, the exposed sediments include the so-called "Upper Gondwanas" followed by a marine succession of Cretaceous (Albian–Maastrichtian) to Paleocene or Lower Eocene, and continental deposits of Neogene age known as "Cuddalores" (fig. 21).

Oligocene and Miocene marine sediments are only known from deep exploration wells drilled by the Oil & Natural Gas Commission since 1964. From the first well, Karaikal – 1, the presence of *Miogypsina* and of a few other foraminifera and ostracoda was reported by Guha et al. (1965). Since then, *Miogypsina* were met with in all the wells drilled in the coastal part of Cauvery basin (fig. 21).

A nearly continuous succession of Cenozoic marine sediments has become known from these deep wells. In most of the wells, the Eocene-Oligocene, and in a few the Lower Miocene as well, appeared to be rich in planktonic foraminifera which formed the main basis for biostratigraphic subdivision and chronostratigraphic correlation of this interval (Raju 1970, 1971). The presence of some of the species of *Miogypsina* has been mentioned by Raju (1970).

However, a thick succession of Lower – Middle Miocene sediments, in some wells as much as 800 to 1300 meters, remained poorly correlated, because of their shallow water character. The presence of *Miogypsina* in this interval looks promising for correlations.

Core samples and a few drill cutting samples have been studied from two wells, Madanam-1 and Karaikal-4. Karaikal-4 is located some 50 km. south of Madanam-1 (fig. 21). Two isolated samples, one from TPD-1 and another from Karaikal-6, have also been investigated. The lithological columns, together with the position of the samples, are given in fig. 22.

### Thirupundi deep well – 1

This well is situated about 45 km. south of Karaikal-4 (fig. 21). One sample from this well was studied.

*Sample:* 879–888 m., drill cuttings.

*Material:* some 20 specimens.

*Description:* Test usually fan-shaped, unequally biconvex. Apical portion broadly rounded. Maximum diameter between 1.2 and 2.8 mm. Maximum thickness up to 0.9 mm.

The embryonic-nepionic stage is distinctly trochoid. In relatively small individuals, the "*Rotalia*" like embryonic-nepionic stage shows only the last

whorl on the umbilical side, and some two whorls on the spiral side. These whorls are clearly visible from the outside. In some specimens only a few equatorial chambers are present. The individuals show a few large pustules (up to 0.2 mm.) in the thickest portion of the test, and ridge-like elevations on each of the later nepionic and equatorial chambers. In relatively large specimens the entire surface is covered with pustules. The nepionic chambers, 17 to 29 ( $\bar{X} = 22.6$ ), are arranged in a single spiral of  $1\frac{1}{2}$  to  $2\frac{1}{2}$  whorls.  $\bar{Y} = 14.05$ ,  $\bar{\gamma} = -430.5^\circ$ ,  $\bar{I} = 110 \mu$ . Equatorial chambers are arcuate to ogival.

In transverse sections (3 observations) the side walls are relatively thin with predominantly vertical structures and without any lateral chamber.

Two good equatorial sections of microspheric forms could be made. The values of X are 46 and 47. The value of Y is around 31 in both. The  $\gamma$  values would be about  $-1120^\circ$ .

*Remarks:* In none of the Indian *Miogypsinoidea* assemblages we found so high  $\bar{X}$  values. Whether this indicates older deposits in the sample of Thirupundi well is considered open to doubt.

*Determination:* *Miogypsina (Miogypsinoidea) complanata* (table IV)

### Madanam well-1

From this well, five samples were studied in detail. They are, from bottom to top: core no. 5 (258–263 cm. below the top of the core between 1040.27 and 1043.27 m.), core no. 3 (217–221 cm. below the top of the core between 631 and 637.5 m.), two samples from core no. 2 (103–109 cm. and 10–16 cm. below the top of the core between 484 and 487 m.) and one composite drill cutting sample from depths between 260 and 266 m. The cutting sample from 260 m. represents the highest occurrence of *Miogypsina* in this well, and as such this assemblage is considered to be free from contamination due to caving.

*Sample:* Core no. 5; 1040.27 – 1043.27 m.

*Material:* some 100 specimens.

This core is a hard foraminiferal limestone. The edges of several of the specimens were partly broken during the process of crushing and washing of the sample.

During a preliminary study in 1969, some 25 thin sections were made without separating the assemblage into groups. Examination of a few transverse sections and of partly broken specimens shows that this sample contains representatives of both *Miogypsina* s.s. and *Miogypsinoidea*.

Later the assemblage was divided into two groups based on external features and on examination of partly broken specimens. Ten equatorial and three transverse sections have been made for each group. Both assemblages are described separately. Data on the original 25 sections have been entered separately in table IV.

(A): Specimens of this group are more common than those of group (B). Test small, equally biconvex, usually with length greater than width or of equal length and width. Maximum thickness near the midpoint of the test. The apical portion is protruding, in some specimens like a short neck. Maximum diameter of the test between 0.75 and 1.7 mm., maximum thickness about 0.7 mm.

The surface is well ornamented with pustules, usually of unequal size (diameter 35–100  $\mu$ ), rather evenly distributed on the entire surface.

The embryonic apparatus is situated peripherally. The nepionic chambers 10–14 ( $\bar{X} = 11.1$ ), are arranged in a single spiral of  $1\frac{1}{4}$  to  $1\frac{1}{2}$  whorls.  $\bar{Y} = 5.6$ ,  $\bar{\gamma} = -161.5^\circ$ . The nepionic spiral is slightly trochoid. Equatorial chambers are predominantly rhombic; they are ogival near the nepionic chambers.

In three transverse thin sections and in a number of partly broken specimens, several lateral chambers could be observed, each one convex towards the outside. The chambers are arranged in 3 to 5 irregular layers. The walls of the lateral chambers have radially arranged structures.

*Determination: Miogypsina (Miogypsina) gunteri* (table IV)

(B): Test usually plano-convex or concavo-convex, equal width and length or width slightly greater than length. Maximum thickness about halfway between apex and midpoint. Apical portion broadly rounded, in some specimens slightly protruding. Maximum diameter of the test between 1 mm. and 2.5 mm; maximum thickness about 0.7 mm. Surface with a few prominent pustules around the thickest portion of the test, and with rare and small ones towards the frontal margin, which part of the test has a smooth appearance.

The embryonic stage is situated peripherally. The nepionic chambers, 9 to 15 ( $\bar{X} = 11.5$ ) belong to a single spiral of  $1\frac{1}{4}$  to  $1\frac{1}{2}$  whorls.  $\bar{Y} = 4.8$ ,  $\bar{\gamma} = -154.5^\circ$ . In a few specimens the nepionic spiral is slightly trochoid. Equatorial chambers are ogival to rhombic, in some specimens elongate-rhombic towards the frontal margin.

In transverse sections the outer walls, on either side of the median layer, are thick with finely laminated horizontal structures and without lateral chambers.

*Determination: Miogypsina (Miogypsinoides) bantamensis* (table IV)

*Remarks:* Both assemblages from core no. 5 cannot be proved to be different in X, Y, or  $\gamma$ , but they fall apart on diameter of the embryonic chambers (fig. 23). Nevertheless variation in these size parameters cannot be proved to be discontinuous.

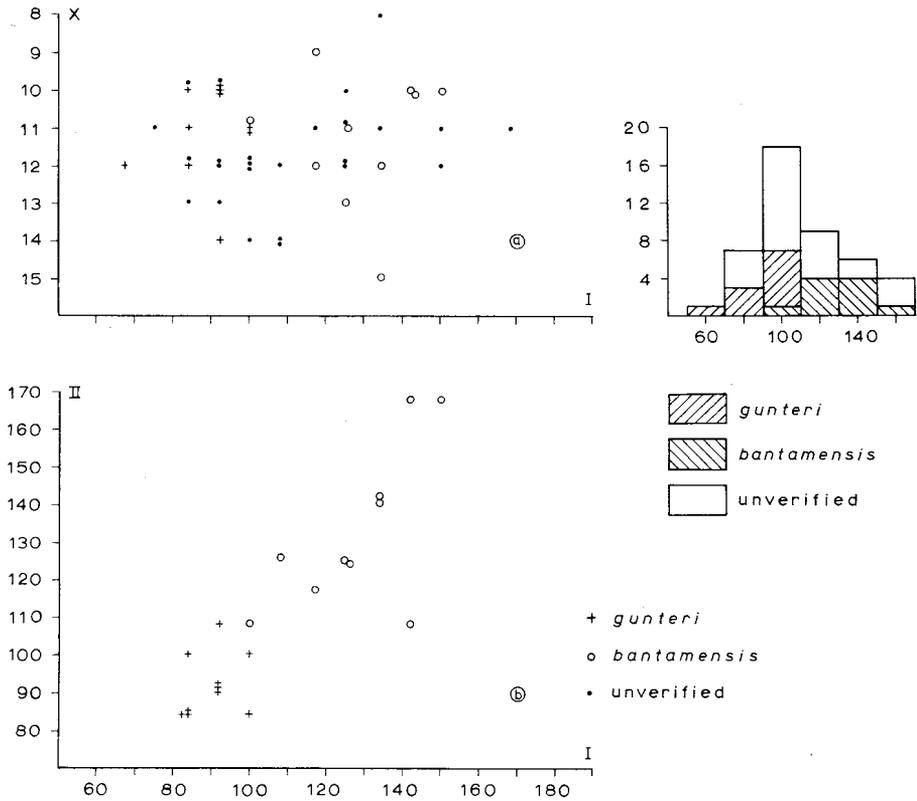


Fig. 23 Relation between X and I (a) and I and II (b) for specimens of Miogypsinae from core no. 5, Madanam well 1, Cauvery Basin. The histogram shows the size distribution of I.

*Sample:* Core no. 3: 631 –637.5 m.

*Material:* Only 6 small specimens were found. One of them is partly broken.

*Description:* All six specimens are thin and small. The maximum diameter is between 0.3 and 0.7 mm. Four of the specimens have very thin walls and lack distinct lateral chambers. The features of the embryonic-nepionic stage and the equatorial chambers could be observed from the exterior. In two specimens, which are the larger ones, at least one layer of lateral chambers covers the equatorial layer.

The embryonic chambers are situated peripherally. A small second principal auxiliary chamber is observed in three of the specimens, its presence is possible in two others. The main spiral has 6 to 7 chambers ( $\bar{X} = 6.4$ ).  $\bar{\gamma} = + 9^\circ$ .

*Determination:* *Miogypsina (Miogypsina) globulina* close to the limit with *M. tani* (table IV)

*Sample:* Core 2; 484–487 m., 103–109 cm.

*Material:* Some 30 specimens. The frontal margin is broken in most of the specimens. The sample is considered to contain two distinct species. They are described separately.

(A): Test relatively flat, elongate, unequally biconvex. In two specimens the apical portion of the test is twisted. Maximum thickness at some distance from the apical periphery, usually coinciding with the position of the embryonic apparatus. The apical periphery is broadly rounded. In a few elongate specimens the frontal margin is slightly undulated. The diameter of the available specimens, in which the frontal margin is always broken, varies between 1.4 and 3.5 mm. The surface is covered with pustules, which are more prominent around the thickest portion of the test.

In all the specimens the embryonic-nepionic chambers are situated at some distance from the periphery. The distance between the centre of protoconch and the apex ( $\epsilon$ ) ranges from  $390\mu$  to  $840\mu$  ( $\bar{\epsilon} = 600\mu$ ).

The protoconch is of widely variable large size ( $\bar{I} = 226\mu$ ), usually circular to subcircular, in some individuals subtriangular (fig. 24). The average size of the deuteroconch ( $\bar{II} = 353\mu$ ) is distinctly larger than that of the protoconch; the size and shape are strongly variable. In some cases the deuteroconch is very large, strongly embracing the protoconch. In other specimens it is subquadrate or irregular in shape. In some individuals the wall of the embryonic apparatus is very thin (about  $8\mu$ ). Characteristics of the embryonic stage in the equatorial plane are illustrated in plate 2.

Both principal auxiliary chambers are nearly equal in size. A single accessory auxiliary chamber on the protoconch has been noticed; its presence is possible in another three specimens. In other specimens the protoconchal nepionic spirals are symmetrical or nearly so ( $\bar{V} = 90.79$ ). In all 17 equatorial sections examined, there are distinct accessory auxiliary chambers on the deuteroconch. Their number varies from three to six. Some of the accessory auxiliary chambers on the deuteroconch are larger than the principal auxiliary chambers.

The equatorial chambers are distinctly of elongate-hexagonal shape. In most of the specimens the elongate-hexagonal shape has been attained by

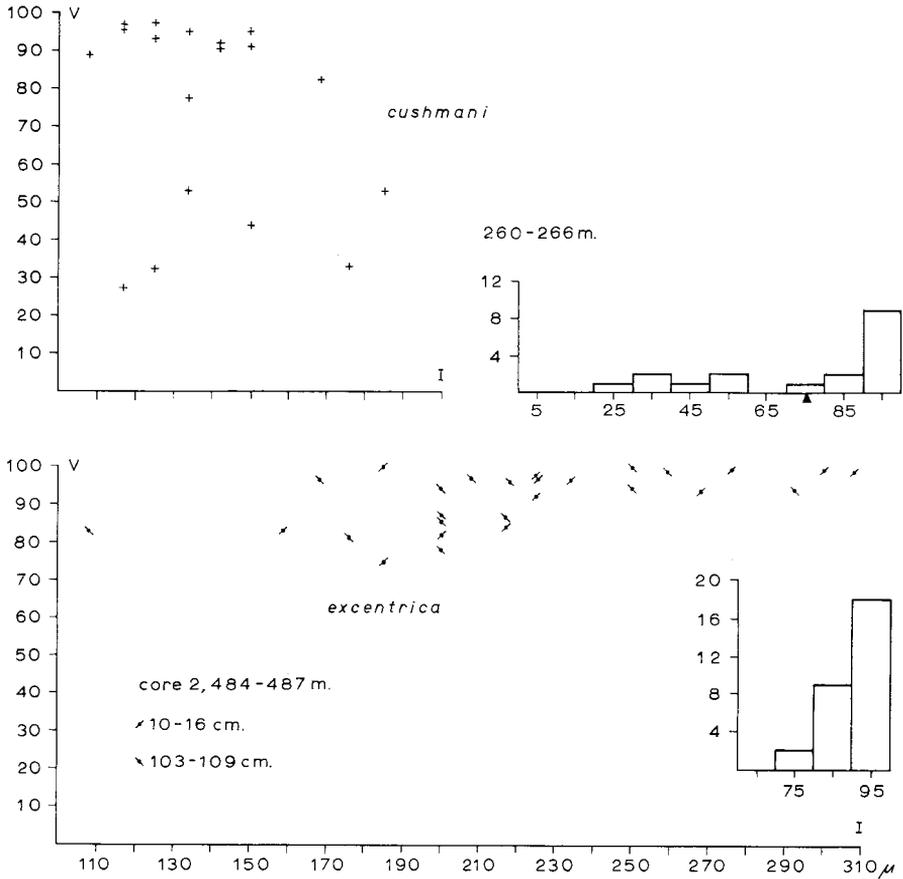


Fig. 24 Relation between V and I for specimens of Miogypsinidae in two samples, core no. 2 and 260-266 m., from Madanam well 1, Cauvery Basin. The histograms show the distribution of V classes.

chambers that directly adjoin the nepionic chambers. Some of the elongate chambers have dimensions of  $90 \times 250\mu$ .

In transverse sections (two observations) the lateral chambers are arranged in up to 5 layers in the thickest portion of the test. The median layer is relatively thin ( $67 - 84\mu$ ). The lateral chambers are distinctly elongate in apical-frontal direction.

*Determination: Miogypsinina (Lepidosemicyclina) excentrica* (table IV)

(B): Only four specimens of this group were found. They are poorly preserved and only three equatorial sections could be made.

Test small, relatively thick and biconvex; subcircular in outline. The apical portion protrudes slightly. Maximum diameter about 1.15 mm. Surface with pustules.

The embryonic apparatus is situated peripherally. A very small second principal auxiliary chamber has been observed. The main spiral has six chambers, the last one of which partly covers the small second principal auxiliary chamber. The mean value of  $\gamma$  is positive ( $\bar{\gamma} = +9^\circ$ ).

*Determination:* *Miogypsina (Miogypsina) globulina*, possibly close to the limit with *M. tani*

*Sample:* core 2, 484–487 m., 10–16 cm.

*Material:* Some 20 specimens. The frontal margin is broken in most of the specimens.

*Description:* In external features the specimens of this assemblage are similar to those of group A from 103–109 cm. of the same core, described above.

Thirteen equatorial sections have been examined. With respect to the internal features, this assemblage is also similar to that of group A from 103–109 cm. Some of the additional features of the embryonic-nepionic chambers are illustrated in plate 2, figs. 12–22.

*Determination:* *Miogypsina (Lepidosemicyclina) excentrica* (table IV)

*Cutting sample:* 260–266 m.

*Material:* Some 30 specimens. The edges are slightly worn in some of them. The frontal margin is broken in relatively large specimens.

*Description:* The assemblage shows considerable variation in external features. Relatively large specimens are thin, unequally biconvex, elongate or of equal length and width. The smaller individuals are equally biconvex; the apical portion protrudes. Maximum diameter from 1.2 mm. to greater than 4 mm. The surface has numerous pustules; prominent large ones occur in the thickest portion of the test.

The embryonic apparatus is situated peripherally. In two specimens the deuteroconch is oblique kidney shaped. The two protoconchal spirals are of unequal length or nearly symmetrical. The value of  $V$  ranges from 27.9 to 99.7,  $\bar{V} = 74.4$ ;  $\bar{\gamma} = +18^\circ$ .

Equatorial chambers are rhombic to hexagonal. In most of the specimens elongate-hexagonal chambers are present only near the frontal margin.

*Remarks:* The histogram of  $V$  (fig. 24) shows an irregular distribution, which might be due to the small number of observations. The scatter field of  $V$  and  $I$  does not show a clear separation of clusters. It is quite possible that a larger number of observations might fill this gap. Tentatively we consider the

sample to represent a single population. However, a mixture of two populations in this 6 m. cutting sample cannot be ruled out, in which case we would be dealing with *M. antillea* and advanced *M. globulina*. The individuals with hexagonal chambers near the frontal margin are quite different from the *Lepidosemicyclina* assemblages lower down in this well. They are considered to be within the range of variation of younger Indo-Pacific *Miogypsina* s.s.

*Determination: Miogypsina (Miogypsina) cushmani* (table IV)

#### Karaikal well-4

From Karaikal well-4, five samples with *Miogypsina* were studied. They are, from bottom to top: core no. 3 (115–120 cm. below the top of the core between 810.14 and 813.14 m.), core no. 2 (134–142 cm. below the top of the core between 639.18 and 644.43 m.), drill cuttings from 480–483 m., 402–405 m., and 246–252 m. *Miogypsina* are rare in the drill cuttings from the intervals of 480–483 m. and 402–405 m. In the other three samples, *Miogypsina* are abundant. The assemblage from 246–247 m. represents the highest occurrence of *Miogypsina* in this well, and contamination, due to caving, needs not to be expected.

*Sample:* Core no. 3, 810.14 – 813.14 m.

*Material:* Some 150 specimens. They are in general well preserved. During a preliminary study, 22 equatorial sections were made without dividing the assemblage into groups. Examination of a few transverse sections and some partly broken specimens shows that the sample contains representatives of both *Miogypsina* s.s. and *Miogypsinoidea*. Later the sample has been divided into two groups. For each 12 more equatorial sections and three transverse sections were made. They are described separately below. Figure 23 shows that nearly all individuals of the preliminary study belonged to one of the groups (*Miogypsina* s.s.).

(A): The individuals of this group are more abundant than those of the other group. Test usually small, length greater than width, equally biconvex. Maximum thickness near the midpoint of the test. The apical portion is protruding and clearly discernible. Maximum diameter of the test between 0.9 and 1.5 mm; maximum thickness up to 0.8 mm. The surface is covered with numerous pustules.

The embryonic apparatus is situated peripherally. The nepionic chambers, 6–11 ( $\bar{X} = 8.33$ ) belong to a single spiral of one to one and a half whorls.

The equatorial chambers are ogival to rhombic; in some elongate-rhombic towards the frontal margin. In three transverse thin sections and in broken specimens there are several lateral chambers arranged in 2–4 irregular layers. *Determination: Miogypsina (Miogypsina) tani* (table IV)

(B): Test usually fan shaped to subcircular in outline, planoconvex to concavo-convex, width greater than length or width equal to length.

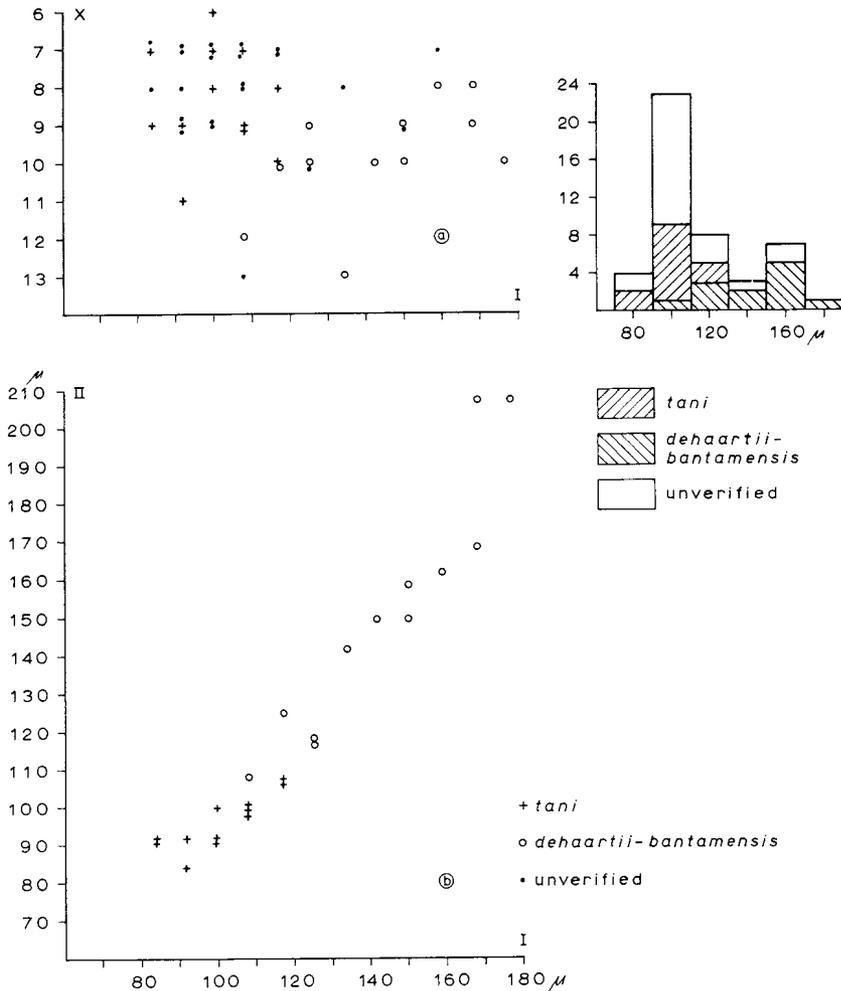


Fig. 25 Relation between X and I (a) and I and II (b) for specimens of Miogypsina in the sample from core no. 3, from Karaikal well 4, Cauvery Basin. The histogram shows the size distribution of I.

Maximum thickness near the apical portion. Apex broadly rounded to slightly protruding. The maximum diameter of the test is between 1.2 and 2.6 mm. The surface has a few low pustules or elevations. The major part of the surface appears smooth due to the close spacing of low elevations.

The embryonic apparatus is situated peripherally. The nepionic chambers, 8–13 ( $\bar{X} = 9.83$ ) belong to a single spiral of one to 1½ whorls. The equatorial chambers are ogival to rhombic.

In transverse sections the lateral walls on either side of the median layer are thick, with laminated horizontal structures, without lateral chambers.

*Remarks:* The relation of both groups is very similar to that of the groups in Madanam well, core 5. The difference in  $\bar{X}$  is significant. If both groups were to belong to a single homogeneous population, the  $X - I$  scatter (fig. 25) would have a remarkable shape, suggesting negative correlation of “evolutionary” features. If we are really dealing with two good species, the difference in internal features is not yet accompanied by a clear morphological break. One might wonder whether we are dealing with speciation (difference between *Miogypsina* and *Miogypsinoidea*) caused by differences in adjoining habitats.

*Determination:* *Miogypsina (Miogypsinoidea) ex.interc.dehaartii - bantamensis* (table IV)

*Sample:* core 2, 639.18–644.43 m., 134–142 cm.

*Material:* Some 40 specimens. All of them are well preserved.

*Description:* Test usually very thin, unequally biconvex, length greater than width; a few specimens are of equal length and width. The apical portion is slightly protruding. Maximum thickness up to 0.45 mm., near the apex. Maximum diameter between 0.4 and 1.7 mm. The larger individuals are ornamented with pustules.

In small individuals, with maximum size between 0.4 and 0.7 mm., the pattern of the embryonic-nepionic as well as the equatorial chambers can be observed from the exterior, more clearly so if the specimens are wetted with water. In these individuals the side walls are thin and usually smooth except for a few pustules; they lack lateral chambers. Relatively large and thick specimens have distinct lateral chambers, arranged in irregular layers.

In 22 specimens, out of 23 examined, there is a distinct small second principal auxiliary chamber. In 11 of them this small chamber is covered by the final chambers of the main spiral.  $\bar{V} = 17.6$ . The equatorial chambers are ogival to rhombic; in some individuals elongate-rhombic towards the frontal margin.

*Determination:* *Miogypsina (Miogypsina) globulina* (table IV)

*Sample:* 480–483 m., drill cuttings.

*Material:* Some 12 specimens; the frontal margin is broken in most of them.

*Description:* Test relatively thin, unequally biconvex. Apical portion broadly rounded. In two specimens the frontal margin is slightly undulated. Surface covered with numerous pustules.

The embryonic apparatus is situated close to the periphery. In all six thin sections examined, the second principal auxiliary chamber is present ( $\bar{V} = 30.4$ ). The equatorial chambers are rhombic and isodiametric to elongate-hexagonal in succession.

*Determination:* *Miogypsina (Lepidosemicyclina) thecidaeformis* (table IV)

*Sample:* 402–405 m., drill cuttings.

*Material:* Three specimens and a few fragments.

*Description:* Test elongate and relatively thin. Apical portion broadly rounded. Surface with a few pustules.

Two equatorial sections were examined. The embryonic apparatus is at some distance from the periphery. The distance  $\epsilon$  between the centre of the protoconch and the apex is  $460 \mu$  and  $840 \mu$ . The protoconch is circular and large ( $208 \mu$  and  $359 \mu$ ). The deuteroconch ( $350 \mu$  and  $525 \mu$ ) embraces an important part of the protoconch. There are 3 or 4 accessory auxiliary chambers on the deuteroconch. In one specimen, there may be an accessory auxiliary chamber on the protoconch. In the other the protoconchal spirals are nearly symmetrical. The equatorial chambers are of distinctly elongate-hexagonal shape.

*Determination:* *Miogypsina (Lepidosemicyclina) excentrica*

*Sample:* 246–252 m.

*Material:* Some 40 specimens. All of them are well preserved.

*Description:* Test usually thick, equally to unequally biconvex, subcircular in outline, in some specimens the length is greater than the width. Maximum thickness between apex and midpoint of the test; in a few individuals close to the midpoint. Apical portion broadly rounded or slightly protruding. Maximum diameter between 0.9 and 2.5 mm. Greatest thickness up to 0.9 mm.

The surface is ornamented with numerous pustules, a few large ones, up to 0.2 mm. in diameter, are concentrated on the thickest portion.

The embryonic apparatus is situated near the apical periphery. The distance  $\epsilon$  between the centre of the protoconch and the apex varies between 200 and  $400 \mu$ . The two protoconchal spirals are nearly symmetrical ( $\bar{V} = 92.9$ ). In 22 specimens, out of 27, the value of  $V$  is greater than 90.

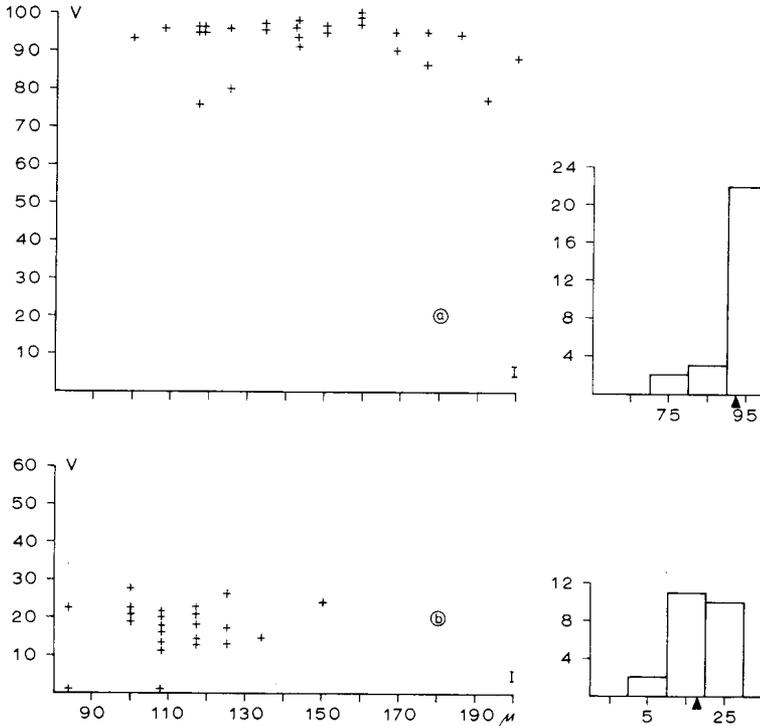


Fig. 26 Relation between V and I for specimens of *Miogypsina* s.s. in two samples: 246–252 m. (a) and core no. 2 (b), from Karaikal well 4, Cauvery Basin. The histograms show the distribution of V classes.

Spirals around the deuteroconch are usually incomplete, but in 7 specimens spiral chambers completely surround the deuteroconch. A small accessory auxiliary chamber has been noted in two specimens and its presence is presumed in another two.

The equatorial chambers are usually elongate-rhombic. In some of the specimens there are short-hexagonal chambers near the frontal margin, 8–10 rows away from the nepionic chambers. The dimensions of the hexagonal chambers, when present, are about  $110 \times 150 \mu$ ; however, one specimen has a few chambers with dimensions of  $100 \times 200 \mu$ .

In transverse sections there are numerous lateral chambers arranged in up to 6 layers in the thickest portion of the test.

*Remarks:* The combination of near-symmetrical nepionts and slight development of hexagonal equatorial chambers, excludes this assemblage from the *Lepidosemicyclina* lineage.

*Determination:* *Miogypsina (Miogypsina) antillea* (table IV)

## Karaikal well-6

This well is located about 6 km. west of Karaikal well-4. One cutting sample from this well was studied.

*Sample:* 201–204 m., drill cuttings.

*Material:* some 25 specimens. In some of the specimens the apical portion is slightly worn.

*Description:* Test usually small and biconvex. Some of the specimens are slightly elongate, others are of about equal length and width. The apical portion is slightly pointed. In one specimen, the frontal margin is strongly indented, giving it a bifid appearance. Maximum diameter usually between 1.2 and 2 mm. The surface has several pustules. A solitary specimen of 4 mm. turned out to be microspheric.

The embryonic apparatus is situated near the apical periphery. The relative size of the principal auxiliary chambers varies strongly, from approximately equal to grossly unequal. The protoconchal spirals are nearly symmetrical to very unequal in length. In one specimen the second principal auxiliary chamber is covered by the final chambers of the main spiral. The spirals around the deuteroconch are usually incomplete.

One small, thin specimen (about 0.8 mm.) shows some of the characters from the exterior. It has a smooth surface, thin side walls, some 20 equatorial chambers and no distinct lateral chambers. A slight polishing from one side revealed that both protoconchal spirals are nearly symmetrical.

The equatorial chambers are predominantly rhombic, occasionally they are

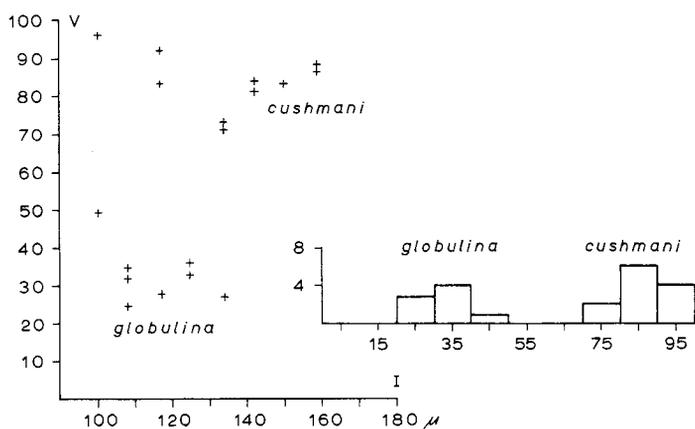


Fig. 27 Relation between V and I for specimens of *Miogypsina* s.s. in cutting sample, 201–204 m. from Karaikal well 6, Cauvery Basin. The histogram shows the distribution of V classes.

elongate. In some relatively large specimens a few hexagonal chambers are present near the frontal margin, about 9 to 10 rows away from the nepionic chambers.

*Remarks:* The histogram of V (fig. 27) shows a distinctly bimodal distribution. We may consider this sample to contain a mixed assemblage of two populations of the same lineage, i.e. *M. globulina* and *M. cushmani*. However, it appeared impossible to gather evidence from the drill cuttings to decide whether both groups are from exactly the same level or from different levels in the three meters interval, or whether one of them somehow had been reworked from older sediments.

*Determination:* (A) *Miogypsina (Miogypsina) cushmani* (table IV), (B) *Miogypsina (Miogypsina) globulina*

## Chapter V

### TAXONOMY

In this chapter a short review of pertinent data will be given on the species recognized.

#### FAMILY MIOGYPSINIDAE

#### Genus *Miogypsina* Sacco, 1893

#### Subgenus *Miogypsinoides* Yabe and Hanzawa

#### *Miogypsina (Miogypsinoides) cf. bermudezi* Drooger

Pl. 1, figs. 1–5; pl. 3, figs. 1, 2; pl. 5, figs. 1–3

cf. *Miogypsina (Miogypsinella) bermudezi* Drooger, 1951, p. 357–359, figs. 1–6.

*Miogypsina (Miogypsinoides) cf. M. bermudezi* Drooger, Akers and Drooger, 1957, p. 670, 674.  
Barker, 1965, p. 316, Pl. 1, figs. 9, 10.

*Locality and samples:* Waior section, Kutch, Samples KR 19 and KR 330.

*Diagnosis:* Populations of *Miogypsinoides* characterized by extremely thin side walls.  $\bar{X}$  values are relatively low, no range being defined so far.  $\bar{I}$  values are lower than in all other species of *Miogypsinoides*.

*Remarks:* *M. bermudezi* was originally described from the Oligocene sequence in Baños well, Cuba. The small type assemblage was characterized by thin smooth walls without ornamentation and 13–17 chambers in a trochoid nepionic spiral.

Later, an assemblage comparable to this species, *M. cf. bermudezi* was described from the Gulf Coast (Akers & Drooger, 1957). The specimens from the Gulf Coast have pustules on the surface and the value of X ranges from 10 – 15 ( $\bar{X} = 12.3$ ) in 13 individuals. Our present assemblages from Kutch are comparable with the Gulf Coast populations with respect to the range of X values,  $\bar{X}$  and surface ornamentation. The assemblages from

Kutch, however, appear to differ slightly in having cavities or doubtful lateral chambers in extreme forms.

*Miogypsinella borodinensis* Hanzawa, 1940, was originally described from deep well cores from North Borodina Island. From the features of the two equatorial sections figured (Hanzawa, 1940, pl. 39, figs. 5, 7) this species might also be within the range of the Kutch assemblages. However, little is known of the assemblage of *M. borodinensis* and its stratigraphic position with reference to *M. complanata*. As a consequence the specific name *borodinensis* has not been applied for the Kutch samples.

*Distribution:* Gulf Coast, Cuba, Puerto Rico and Kutch, India.

*Miogypsina (Miogypsinoides) complanata* Schlumberger  
Pl. 1, figs. 6–9; pl. 3, figs. 3–7.

*Miogypsina complanata* Schlumberger, 1900, p. 330, Pl. 2, figs. 13–16; Pl. 3, figs. 18–21.

*Miogypsina (Miogypsinoides) complanata* Schlumberger, Drooger, 1954, p. 230–232, table 1, locality-1 (not locality-2). Drooger 1963, figs. 2, 4, 6, 9, 13, 16, 24. Drooger & Freudenthal, 1964, p. 513–514. Raju, 1971, p. 85–87, figs. 3–6.

*Miogypsinoides ubaghshi* Tan Sin Hok, 1936, p. 47, 48, Pl. 1, figs. 1–7.

*Miogypsinoides grandipustulosa* Cole, 1954, p. 602–603, Pl. 221, figs. 2–9, 19–22; Pl. 222, figs. 12, 14.

*Miogypsinoides saipanensis* Hanzawa, 1957, p. 93, Pl. 15, figs. 2, 8.

*Locality and samples:* Sample KR 11, Waior section; sample KR 123, Walasara section; sample KR 140, Khari Nadi section; Kutch. Cuttings 879–888 m., Thirupundi well, Cauvery basin.

*Diagnosis:* Populations of *Miogypsinoides* with values of  $\bar{X}$  greater than 17.

*Remarks:* This species was originally described from St. Etienne-d'Orthe in southwestern France. In early works Drooger (1951–1957) used the specific name *M. complanata* in a very wide sense for nearly all *Miogypsinoides*, but later in 1963 and 1964 he restricted this name for assemblages with values of  $\bar{X}$  greater than 17.

The illustrated specimens of *M. grandipustulosa* Cole and of *M. ubaghshi* Tan Sin Hok from the Eniwetok and the Bikini drill holes (Cole, 1957, 1964) have relatively high values of X and Y. Assemblages with high values of  $\bar{X}$  (greater than 22) are known from Europe (Drooger & Freudenthal, 1964) and also from the Thirupundi well, Cauvery basin in India.

*Distribution:* Widely distributed in all three provinces.

*Miogypsina (Miogypsinoidea) formosensis* Yabe and Hanzawa  
Pl. 4, fig. 1

*Miogypsina (Miogypsinoidea) dehaartii* Van der Vlerk var. *formosensis* Yabe and Hanzawa, 1928, p. 534, figs. 1a-b. Yabe and Hanzawa, 1930, p. 1-36, Pl. 3, figs. 4-5, Pl. 7, fig. 12, Pl. 11, figs. 3, 6, 12.

*Miogypsina (Miogypsinoidea) formosensis* Yabe and Hanzawa, Drooger, 1963, fig. 2.

*Locality and samples:* Sample KR 332 from the Waior section, Kutch.

*Diagnosis:* Populations of *Miogypsinoidea* with values of  $\bar{X}$  between 17 and 13.

*Remarks:* This species was originally described from Taiwan. A single pictured equatorial section of a specimen from the type assemblage shows some 16 nepionic chambers. Cole (1957, Pl. 111, figs. 10, 11) illustrated two equatorial sections of topotype specimens of *M. formosensis*. They show  $\bar{X}$  values of 13 (or 14) and 9 (or 10). Possibly Yabe and Hanzawa illustrated an extreme variant, and Drooger's choice of a specific name for *Miogypsinoidea* with  $\bar{X}$  between 17 and 13, seems to be rather unfortunate.

A second problem concerning this specific name is that so far assemblages of *Miogypsinoidea* with  $\bar{X}$  values between 16 and 14 have not been reported. As such the status of *M. formosensis* in the  $\bar{X}$ -scale finds little support in actual populations.

*Distribution:* Indo-Pacific and Mediterranean.

*Miogypsina (Miogypsinoidea) bantamensis* (Tan Sin Hok)  
Pl. 1, figs. 10-13; pl. 5, fig. 4.

*Miogypsinoidea complanata* forma *bantamensis* Tan Sin Hok, 1936, p. 48-50, Pl. 1, fig. 13.

*Miogypsina (Miogypsinoidea) bantamensis* (Tan Sin Hok), Drooger, 1963, fig. 2.

*Miogypsinoidea complanata* (Schlumberger) var. *mauretana* Bronnimann p. 77-80, Pl. 7, figs. 7-14, Pl. 8, fig. 18, Pl. 9, figs. 1, 2; Pl. 11, figs. 9-17. Souaya, 1961, p. 672-676, Pl. 1, figs. 1-10, Pl. 2, figs. 1-13.

*Locality and samples:* Core no. 5, Madanam well-1, Cauvery basin.

*Diagnosis:* Populations of *Miogypsinoidea* with values of  $\bar{X}$  between 13 and 10.

*Remarks:* This species was originally described from S. Klindjau in East Borneo. In the single equatorial section pictured (Tan Sin Hok, 1936, Pl. 1, fig. 13) the  $\bar{X}$  value is 12,  $\bar{Y}$ =5 or 6. Otherwise little is known about the type assemblage. Tan Sin Hok (1936, p. 57, Pl. 1, figs. 14-16) described *Miogypsina primitiva* n.sp. from the same sample as *M. bantamensis*. The status

of *M. primitiva* is uncertain, the type specimen could well be an advanced individual of the same population as *M. bantamensis*.

In Cauvery basin *M. bantamensis* is accompanied by *M. gunteri*.

*Distribution:* Indo-Pacific and Mediterranean.

*Miogypsina (Miogypsinoidea) dehaartii* Van der Vlerk

Pl. 1, figs. 19–25; pl. 3, fig. 8, pl. 4, figs. 2–4

*Miogypsina dehaartii* Van der Vlerk, 1924, p. 429–432, text figs. 1–3. Drooger, 1953, p. 110–114,

Pl. 1, figs. 15–19, 20–26. Van der Vlerk, 1966, p. 422–423, Pl. 1, figs. 7–10, Pl. 2, fig. 1.

*Miogypsinoidea dehaartii* (Van der Vlerk) var. *pustulosa* Hanzawa, 1940, p. 780–782, Pl. 40, figs. 9–29; Pl. 42, fig. 13.

*Locality and samples:* Samples G 1448, G 1421 from Khari Nadi section, Kutch; Sample 24–30 m. from Jagatia well, Saurashtra; core-3, Karaikal well-4, Cauvery basin.

*Diagnosis:* Populations of *Miogypsinoidea* with values of  $\bar{X}$  below 10 and negative values of  $\bar{y}$ . An additional feature is that the values of  $\bar{Y}$  are greater than 0.75. Conical variants may be present.

*Remarks:* This species was originally described from the Island of Larat of the Tanimbar Islands, southeastern Indonesia. Drooger (1953) described in detail an assemblage of *M. dehaartii* from the Island of Larat, from about the same stratigraphic level as the type sample. This assemblage gave an  $\bar{X}$  value of  $6.9 \pm 1.5$  and  $\bar{y} = -17^\circ$ . However, Drooger remarked that this  $\bar{X}$  value of 6.9 might be too low as it was possible that not all spiral chambers were counted in the conical individuals. This species has a very wide distribution in the Indo-Pacific province, where it is considered as a marker species.

Van der Vlerk (1966) investigated an assemblage of *M. dehaartii* from the type locality in the Island of Larat and gave an  $\bar{X}$  value of 6.5 and a  $\bar{y}$  value of  $-16.3^\circ$ .

*Miogypsina cupulaeformis* Zuffardi-Comerci, 1928 (Boll. Soc. Geol. Ital., Roma, vol. 47, fasc. 2, p. 142. Pl. 9, figs. 12, 13, 20) was originally described from southeastern Borneo. Drooger (1953) investigated the original material of Zuffardi-Comerci and suggested that the name *cupulaeformis* may be used for a variant of *M. dehaartii*. However, some recent authors (Cole, 1954; Adams, 1970) apparently recognize *M. cupulaeformis* as a species. Our present study shows that the conical forms are invariably accompanied by relatively flat individuals. Although the conical forms gave relatively higher values of  $X$  than the accompanying flatter ones, there is a complete morphological gradation between the extreme forms. As such *M. cupulaeformis*

cannot be recognized as a separate specific unit.

As the level of the development of the subconical forms appears to be useful in correlation of sections in the Indo-Pacific province, the name *cupulaeformis* is retained as a variant of *M. dehaartii*.

*Distribution:* Indo-Pacific and Mediterranean.

*Miogypsina (Miogypsinoidea) indica* Raju  
Pl. 1, figs. 31–38; pl. 3, figs. 9–11; pl. 4, figs. 5–7

*Miogypsina (Miogypsinoidea) indica* Raju, 1973, p. 140–142, Pl. 1, figs. 1–14.

*Locality and samples:* Sample SG 4, Nandana Section, Saurashtra, and Samples G 1417 and G 1415 from Khari Nadi Section, Kutch.

*Type level:* Fossiliferous calcareous clay (sample SG 4) immediately underlying the oldest limestone beds; Lower Miocene.

*Type locality:* A small stream section, about 400 m. SSW of Nandana village, northwestern part of Saurashtra, India.

*Diagnosis:* Populations of *Miogypsinoidea* with  $\bar{X}$  values below 8 and positive  $\bar{\gamma}$  values. An additional feature is the high mean value of the diameter of the protoconch.

*Remarks:* This species differs from near-topotype assemblages of *M. dehaartii* Van der Vlerk, described by Drooger (1953) and Van der Vlerk (1966) in having distinctly positive values of  $\bar{\gamma}$ , relatively low  $\bar{X}$ , and a large protoconch. The succession from the Khari Nadi section suggests that *M. indica* has derived from *M. dehaartii*.

*Distribution:* Kutch and Saurashtra, India.

Subgenus *Miogypsina* Sacco

*Miogypsina (Miogypsina) gunteri* Cole  
Pl. 1, figs. 14–18.

*Miogypsina gunteri* Cole, 1938, p. 42, Pl. 6, figs. 10–12, 14; Pl. 8, figs. 1–9. Drooger, 1952, p. 21, 51, Pl. 2, figs. 11–15. Drooger, 1955, p. 22–23, 51, Pl. 2, figs. 16–20.

*Locality and samples:* Core no. 5, Madanam well-1, Cauvery basin.

*Diagnosis:* Populations of *Miogypsina* s.s. with values of  $\bar{X}$  between 12.5 and 9.

*Remarks:* This species was originally described from Florida, U.S.A. Drooger (1952) investigated a topotype assemblage and defined the limits of *M. gunteri* in terms of  $\bar{X}$ . Later this species was described from Peru, Northern Italy and southwestern France. With respect to all the internal features studied, the assemblage from the Cauvery basin closely resembles the Floridan assemblage. This is also the first definite record of the presence of *M. gunteri* in the Indo-Pacific region. In Cauvery basin the assemblage is still very close to the accompanying *M. bantamensis*.

*Distribution:* America, Mediterranean, and India.

*Miogypsina (Miogypsina) tani* Drooger  
Pl. 1, figs. 26–30; pl. 5, fig. 5.

*Miogypsina (Miogypsina) tani* Drooger, 1952, p. 26–27, 51–52, Pl. 2, figs. 20–24, Pl. 3, figs. 2a, b. Drooger, 1954, p. 234–235. Drooger, 1955, p. 23–24, Pl. 1, figs. 11–15.

*Locality and samples:* Samples KR 155, G 1448 from the Khari Nadi section, Kutch; and core no. 3, Karaikal well-4, Cauvery basin.

*Diagnosis:* Populations of *Miogypsina* s.s. with values of  $\bar{X}$  below 9 and negative values of  $\bar{\gamma}$ . Less than 50% of the specimens per sample may have a second principal auxiliary chamber.

*Remarks:* *M. tani* was originally described from Costa Rica. It was further described from Northern Italy and southwestern France. This species is stratigraphically very important as it is known from the stratotype of the Aquitanian Stage and has a wide geographical distribution.

As remarked by Drooger (1952, p. 52) the pictured specimens of *Miogypsina borneensis* Tan Sin Hok (1936, p. 53, Pl. 1, figs. 18, 19, Pl. 2, fig. 1) come within the range of variation of *M. tani*. It is possible that a thorough restudy of the type assemblage of *M. borneensis* might show that it is a senior synonym to *M. tani*. Recent authors on Indo-Pacific Miogypsinidae use the specific name *borneensis* in a typological sense for widely different assemblages (including those with positive  $\bar{\gamma}$ ), and it might therefore only lead to further confusion to use this name for assemblages defined numerically.

*Distribution:* American, Mediterranean and Indo-Pacific regions.

*Miogypsina (Miogypsina) globulina* (Michelotti)  
Pl. 2, figs. 1–4; pl. 5, figs. 6, 7; pl. 6, fig. 1.

*Nummulina globulina* Michelotti, 1841, p. 297, pl. 3, fig. 6.

*Nummulites irregularis* Michelotti, 1841, p. 297, pl. 3, fig. 5.

*Miogypsina irregularis* (Michelotti), Drooger, 1952, p. 54, Pl. 2, figs. 25–29. Drooger, 1954, p. 238, Pl. 2, figs. 1–5. Mohan, 1958, p. 378–381, Pl. 1, figs. 1–10, text-figs. 1a-b, 3a-c.

*Miogypsina (Miogypsina) globulina* (Michelotti), Drooger and Socin, 1959, p. 420, Pl. 1, figs. 5–6 (additional references).

*Miogypsina kotoi* Hanzawa, 1931, p. 154, Pl. 25, figs. 14–18. Tan Sin Hok, 1937, p. 31–32, figs. 1–6.

*Locality and samples:* Core no. 2, Karaikal well-4; core no. 3, Madanam well-1; Cauvery basin. Samples G 1437, G 1421, G 1406, G 1401 and KR 36 from the Khari Nadi section, Kutch.

*Diagnosis:* Populations of *Miogypsina* s.s. with values of  $\bar{V}$  between zero and 45, and values of  $\bar{\gamma}$  positive. An additional feature is that more than 50% of specimens per sample have a second principal auxiliary chamber.

*Remarks:* This species was originally described from a locality near Turin, Italy. Drooger and Socin (1959) showed that the name *Nummulites irregularis* Michelotti is a homonym of *Nummulites irregularis* Deshayes, 1838. They suggested that the name *N. globulina* is valid and should be used for all assemblages earlier described under *M. irregularis*.

Based on the detailed description and the few equatorial sections pictured by Hanzawa, 1935, and by Tan Sin Hok, 1937, *Miogypsina kotoi* Hanzawa, 1931, is considered to be a synonym of *M. globulina*.

*Distribution:* Widely distributed in the American, the Mediterranean and the Indo-Pacific provinces.

### *Miogypsina (Miogypsina) cushmani* Vaughan

*Miogypsina cushmani* Vaughan, 1924, p. 802, 813, Pl. 36, figs. 4–6. Tan Sin Hok, 1937, p. 92–95, Pl. 1, figs. 6–11, Pl. III, figs. 3–9, 14; Pl. IV, fig. 14. Drooger, 1952, p. 37, 38, 56, table II, Pl. 2, figs. 40–44.

*Locality and samples:* cuttings 260–266 m., Madanam well-1; cuttings 201–204 m., Karaikal well-6, Cauvery basin.

*Diagnosis:* Populations of *Miogypsina* s.s. with values of  $\bar{V}$  between 70 and 100, usually less than 90. In more than 50% of the specimens per sample the value of  $V$  should be less than 90.

*Remarks:* This species was originally described from the Panama Canal zone. Drooger (1952) investigated a topotype assemblage and defined the limits of *M. cushmani* in terms of  $\bar{V}$ .

Tan Sin Hok (1937) considered *M. indonesiensis* Tan Sin Hok, 1936 to be a variety of *M. cushmani*. From the few equatorial sections pictured by Tan

Sin Hok, it will be difficult to decide whether *M. cushmani* var. *indonesiensis* Tan Sin Hok, *M. cushmani* var. *subtilis* Tan Sin Hok, 1937 (p. 97, Pl. I, fig. 16, Pl. III, figs. 15–18) and *M. musperi* Tan Sin Hok, 1936 are synonyms of *M. cushmani* or of *M. antillea*.

*Distribution*: Widely distributed in regions of America, the Mediterranean and the Indo-Pacific.

*Miogypsina (Miogypsina) antillea* (Cushman)  
Pl. 2, figs. 23–29; pl. 5, fig. 9; pl. 6, figs. 7, 8

*Heterosteginoides antillea* Cushman, 1919, p. 50, Pl. 5, figs. 5, 6.

*Miogypsina antillea* (Cushman), Drooger, 1952, p. 42, 56, Pl. 2, figs. 45–49.

*Miogypsina tuberosa* Tobler, 1926, p. 323–327, figs. 1, 2, 4.

*Locality and samples*: 246–252 m., Karaikal well-4, Cauvery basin.

*Diagnosis*: Populations of *Miogypsina* s.s. with values of  $\bar{V}$  between 70 and 100, usually greater than 90. In more than 50% of the specimens per sample, the value of  $V$  should be greater than 90.

*Remarks*: This species was originally described from the island of Anguilla, West Indies. Drooger (1953) investigated the type assemblage of *M. tuberosa* Tobler, 1926, and found that this name is a junior synonym of *M. antillea*.

Assemblages from the Indo-Pacific region frequently have distinct hexagonal chambers near the frontal margin and rarely they possess a small accessory auxiliary chamber on the deuterocoel. They are commonly reported as *M. indonesiensis* Tan Sin Hok.

Cole (1957, 1967) used the specific name *M. antillea* in a wider typological sense, to cover all species which have a biserial protoconchal nepionic configuration. As remarked already, his classification is considered not acceptable.

*Distribution*: American and Indo-Pacific regions.

Subgenus *Lepidosemicyclina* Rutten

*Miogypsina (Lepidosemicyclina) thecideaformis* (Rutten)  
Pl. 6, figs. 2–4.

*Lepidosemicyclina thecideaformis* Rutten, 1911, p. 15 (1157).

*Miogypsina thecideaformis* (Rutten), Rutten, 1912, p. 204, Pl. 12, figs. 1–5. Drooger, 1953, p. 109–110, Pl. 1, figs. 10–14, 32.

*Miogypsina (Lepidosemicyclina) thecideaeformis* (Rutten), Mohan, 1958, p. 382–384, Pl. 2, figs. 8–13, text-figs. 1e, 4d-f.

*Miogypsina (Lepidosemicyclina) polymorpha* (Rutten), Mohan, 1958, p. 386, Pl. 3, figs. 1–8, text-figs. 1f, 5a-c.

*Miogypsina (Miogypsina) boghotaensis* Mohan, 1958, p. 381–382, Pl. 2, figs. 1–7, text-figs. 1d, 4a-c, 7a-h.

*Locality and samples:* Sample SG 4, Saurashtra; 480–483 m., Karaikal well-4, Cauvery basin; Samples G 1415 and G 1417, Khari Nadi section, Kutch.

*Diagnosis:* Populations of *Lepidosemicyclina* with  $\bar{V}$  values between zero and 45.

*Remarks:* This species was originally described from East Borneo. Drooger (1953) investigated the internal characteristics of *M. thecideaeformis* as well as those of *M. polymorpha* (Rutten) and *M. bifida* (Rutten) from the type area. From his studies it is clear that both *M. polymorpha* and *M. bifida* (Rutten) differ from *M. thecideaeformis* in having very elongate hexagonal equatorial chambers, already adjacent to the nepionic chambers, very high mean values of the diameter of the protoconch and an irregular pattern of embryonic-nepionic chambers. Our present study on a rich assemblage from sample SG 4 (Saurashtra) suggests that the external shape – strongly undulated frontal margin or bifid shape – cannot be used as characteristics in specific determination.

Mohan (1958) described *M. polymorpha* (Rutten) and *M. boghotaensis* n.sp. from a single sample from Saurashtra, India, but he did not establish any distinct morphological break between them with respect to the measurable internal features. Possibly the specimens of his two species represent extreme variants of a homogeneous population as in our sample SG 4. As a consequence *M. boghotaensis* would not be a valid species. On the basis of the described internal features, *M. polymorpha* of Mohan (1958) is considered here as a synonym of *M. thecideaeformis*. *M. polymorpha* described by Coleman (1963) from the Solomon Islands also appears to be *M. thecideaeformis*.

*Distribution:* Widely distributed in the Indo-Pacific province.

*Miogypsina (Lepidosemicyclina) droogeri* Mohan and Tewari  
Pl. 2, figs. 5–11; pl. 5, figs. 8, 10, 11.

*Miogypsina (Lepidosemicyclina) droogeri* Mohan and Tewari, 1958, in Mohan, 1958, p. 386–387; Pl. 3, figs. 9–12, text-figs. 1f, 5d-f, 7i-n.

*Locality and samples:* Khari Nadi section, samples G 1406 and G 1401, Kutch.

*Diagnosis:* Populations of *Lepidosemicyclina* with values of  $\bar{V}$  between 70 and 90. An additional feature is that accessory auxiliary chambers around the deuterocoenoch, if present, should occur in less than 50% of the specimens per sample.

*Remarks:* This species was originally described by Mohan and Tewari, in Mohan (1958) from bed no. 4, Vinjhan-Miani area, Kutch. According to the original description, *M. (L.) droogeri* is characterized by  $\bar{V} = 83$ , the presence of elongate hexagonal chambers and the lack of accessory auxiliary chambers around the deuterocoenoch.

The presently described assemblages were derived from the Khari Nadi section, which is some 40 km. west of the type area (the exact type locality of the species was not given). Assemblages from both G 1406 and G 1401 show close resemblance to the original *M. (L.) droogeri* assemblage with respect to figures, numerical data and description.

*Distribution:* Kutch, India. So far not described from other regions.

*Miogyopsina (Lepidosemicyclina) excentrica* (Tan Sin Hok)  
Pl. 2, figs. 12–22; pl. 4, figs. 8, 9; pl. 7, figs. 1–10.

*Miopleidocyclina excentrica* Tan Sin Hok, 1937, p. 40–42, Pl. I, fig. 12; Pl. II, figs. 1–7, 8, 9; Pl. III, figs. 1–9.

*Locality and samples:* Khari Nadi section, samples KR 36 and KR 34, Kutch; Madanam well, core no. 2 (484–487 m.) and Karaikal well-4, cuttings 402–405 m., Cauvery basin.

*Diagnosis:* Populations of *Lepidosemicyclina* with distinct accessory auxiliary chambers around the deuterocoenoch, at least in more than 50% of the specimens per sample. Values of  $\bar{V}$  are usually greater than 90. Additional features appear to be the low values of  $\bar{\gamma}$ , although a few individuals may have a value of up to  $\pm 180^\circ$ .

*Remarks:* This species was originally described from the oldest outcrop sediments on the northern flank of Rantjak Tandjung Anticline, northern Sampang in central Madura, Indonesia. Although *M. excentrica* has been mentioned in discussions concerned with phylogeny (Drooger, 1963) and biostratigraphy (Adams, 1970; Clarke & Blow, 1969), assemblages of this species have not been described since the original work of Tan Sin Hok.

The results of C value counts in six of our *Lepidosemicyclina* samples are given below:

Sample	N	Range	Mean $\pm \sigma_M$	Determination
Core 2, 10–16cm., Madanam-1	12	2–7	4.25 $\pm$ 0.325	<i>excentrica</i>
Core 2, 103-109cm., Madanam-1	14	3–7	4.11 $\pm$ 0.391	<i>excentrica</i>
KR 36, group A	22	0–3	1.30 $\pm$ 0.169	<i>excentrica</i>
G 1401, group A	9	0–1	0.44 $\pm$ 0.129	<i>droogeri</i>
G 1406, group A	20	0–1	0.3 $\pm$ 0.091	<i>droogeri</i>
G 1415, group B	35	0		<i>thecidaeformis</i>

The scatter diagram with the relation between  $\bar{C}$  and  $\bar{\epsilon}$  shows a good positive correlation. These  $\bar{C}$  values may appear to be useful as an additional quantitative criterion to distinguish *M. droogeri* from *M. excentrica*. It is as yet difficult to compare the rate of this evolution in *Lepidosemicyclina* with that in *Nephrolepidina*, for which the mean values of C have been considered to be useful (Drooger and Freudenthal, 1964).

*Distribution:* Indonesia and India.

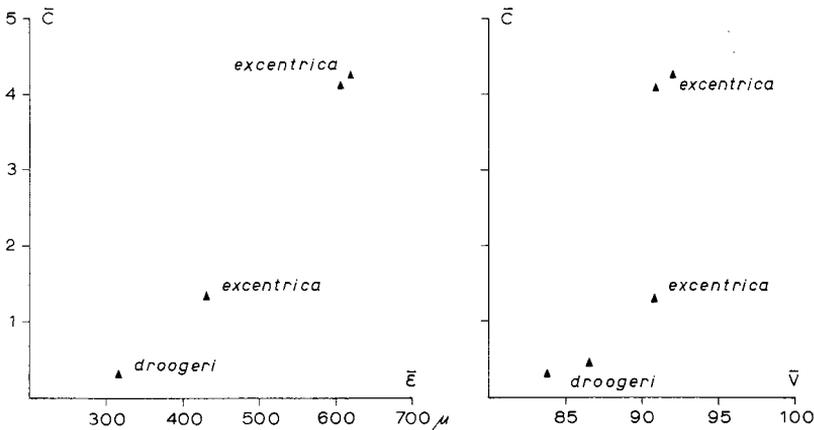


Fig. 27a Relation between  $\bar{C}$  and  $\bar{\epsilon}$  and between  $\bar{C}$  and  $\bar{V}$  for the *Lepidosemicyclina* assemblages of *M. droogeri* and *M. excentrica*.

## Chapter VI

### PHYLOGENY

#### THE GENERAL OUTLINE

Much of the history of Indian Miogypsinidae can be understood on the basis of our knowledge of the family in other regions of the globe (Mediterranean, America, Indonesia). This means that in all cases in which the succession of assemblages cannot be based on actual superposition of strata, we will rely on the principle of nepionic acceleration.

This principle of nepionic acceleration, as originally introduced by Tan Sin Hok in his studies on larger foraminifera and as later elucidated by Drooger, suggests that during development of the family in the course of geological time the nepionic stage was accomplished with increasing rapidity. In several publications, Drooger (1952–1964) critically examined the validity of this principle. In 1963, he discussed in detail the changes in various morphological characters of the Miogypsinidae and concluded that the evolutionary trends in some of the features are well correlated with time. For the general outline of the evolution, nepionic acceleration certainly is correct, but for details this principle frequently lacks adequate stratigraphic control. Such stratigraphic confirmation will be needed over and again, and we may expect that local development, peculiar to the Indian subcontinent, cannot be readily explained with the general evolutionary theory alone.

If we may take the various parts of India to fit in with the pattern of a single sub-province of the Miogypsinidae — which cannot be proved to be unrealistic —, the history of the family may be fairly complete. Both very primitive species, *M. cf. bermudezi* and *M. complanata*, and highly advanced ones, such as *M. excentrica* and *M. antillea*, appear to be present.

However, the record in between is far from complete, and we will see that several problems have to be left open. It can not be proved that we are dealing with a single evolving stock. The possibility of repeated immigrations from other areas might in some cases give an easier explanation to the problems.

RELATION BETWEEN PARAMETERS

First of all we will try to get an insight in the possible homogeneity of all the assemblages, for which the relations between different parameters might give some clues. The relations between the means of different parameters are briefly discussed below:

1) **Relation between X and Y;  $\bar{X}$  and  $\bar{Y}$ :** Fig. 28 shows the relation between X and Y in 10 samples from Kutch and Cauvery basin. The scatter suggests a more or less good positive correlation in the separate samples. For the entire group the data give the impression of a very good rectilinear arrangement. There is a much better alignment than for the comparable assembled data from all over the world (Drooger, 1963, fig. 4).

The means of X and Y show a distinct positive correlation (fig. 29). All the values are very close to a straight line. The assemblages of the youngest *Miogypsinoides*, *M. dehaartii* and *M. indica*, might be slightly away from this

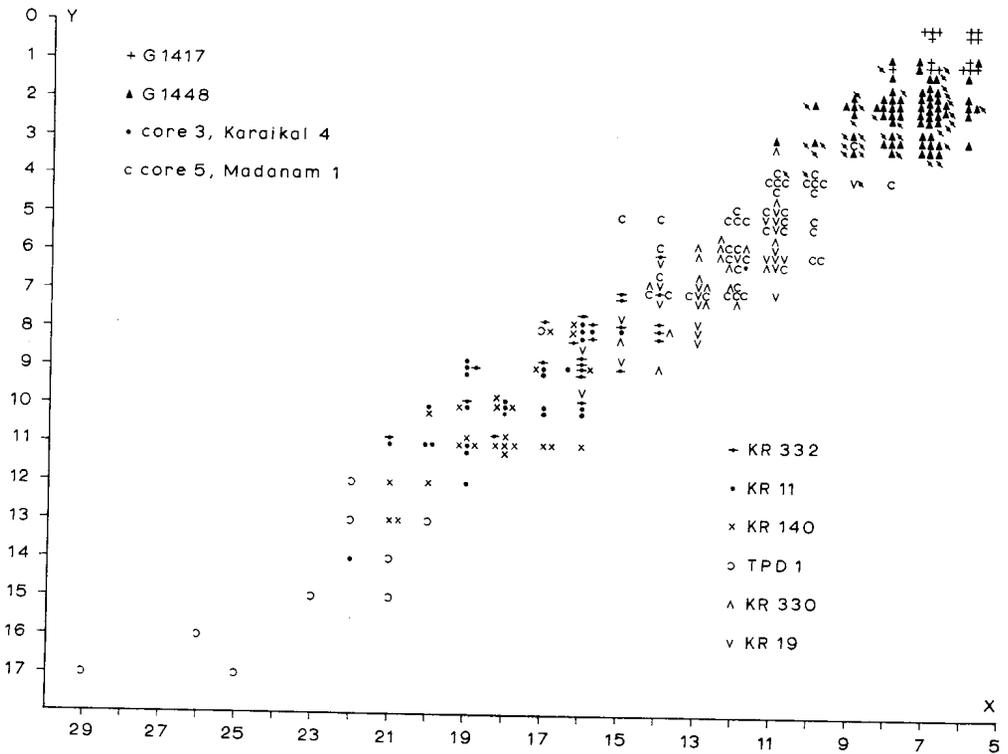


Fig. 28 Relation between X and Y in 10 Miogypsinidae samples from India.

straight path. This would mean that in these end members the reduction in  $\bar{X}$  is relatively less than that of  $\bar{Y}$ . This deviation coincides with the presence of subconical forms in these *Miogypsinoides* species, which forms have relatively high X values when compared to Y. The centripetal trend of the early ontogenetic stages may be held responsible for the relatively slow shortening of the nepionic spiral.

The straight character of the  $\bar{X} - \bar{Y}$  line might suggest that all the Indian populations of the single-spiralled *Miogypsinidae* are closely related. The comparable data from other parts of the world (Drooger, 1963, fig. 5) show a much wider scatter. The trend in the Indian forms resembles that of the American forms better than the data from the Mediterranean.

Most of the Indian  $\bar{X}-\bar{Y}$  data are not opposed against the principle of nepionic acceleration. An exception is formed by the assemblages from the Waior section, in which the succession from *M. cf. bermudezi* to *M. complanata* or *M. formosensis* suggests a probable nepionic retardation.

2) The relation between X and Z, and between  $\bar{X}$  and  $\bar{Z}$ : Fig. 30 gives the same picture as those between the previous parameters.

3) The relation between  $\bar{X}$  and  $\bar{\gamma}$ : The means of X and  $\gamma$  show a very good correlation (fig. 31). All the assemblages fall along an almost straight path.

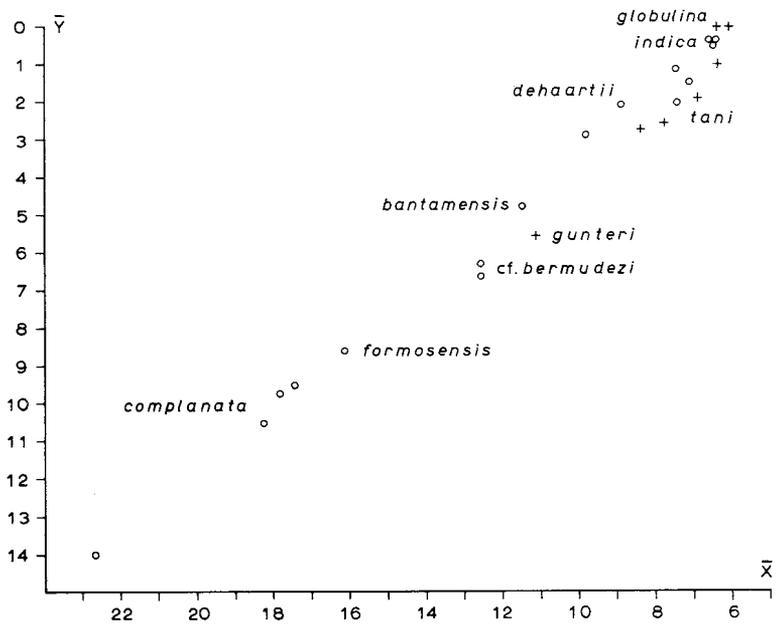


Fig. 29 Relation between  $\bar{X}$  and  $\bar{Y}$  for the assemblages of *Miogypsinidae* from India.

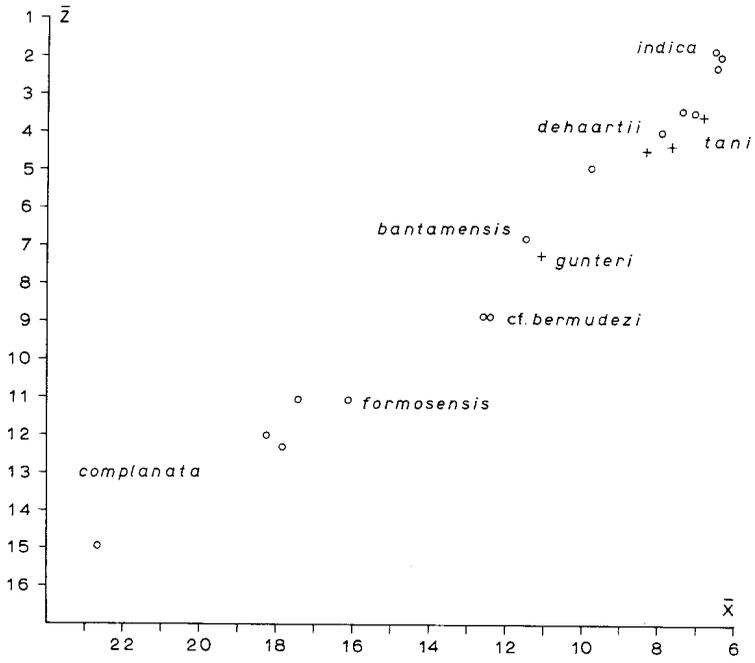


Fig. 30 Relation between  $\bar{X}$  and  $\bar{Z}$  for the assemblages of Miogypsinidae from India.

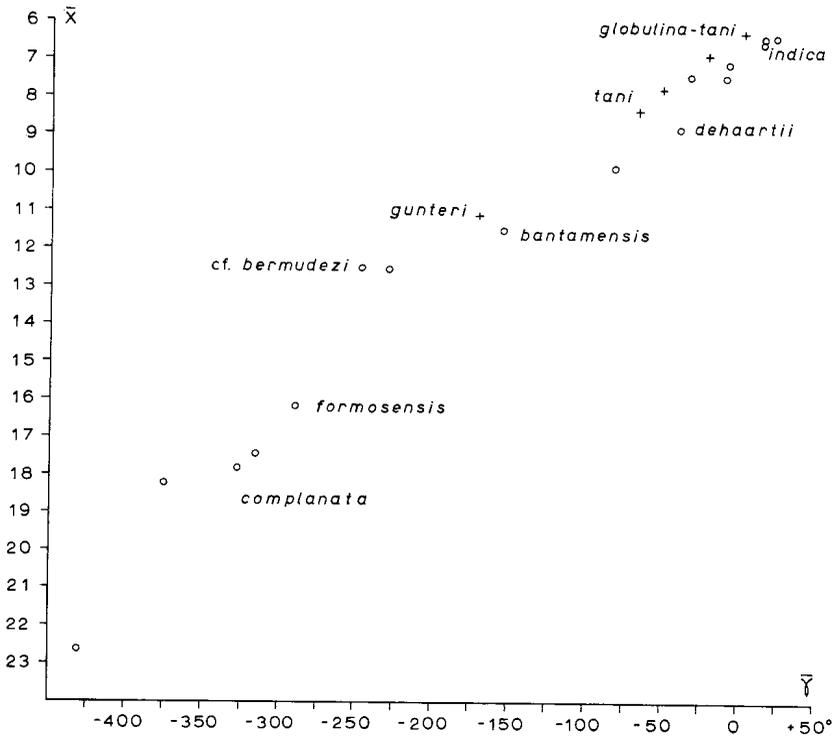


Fig. 31 Relation between  $\bar{X}$  and  $\bar{Y}$  for the assemblages of Miogypsinidae from India.

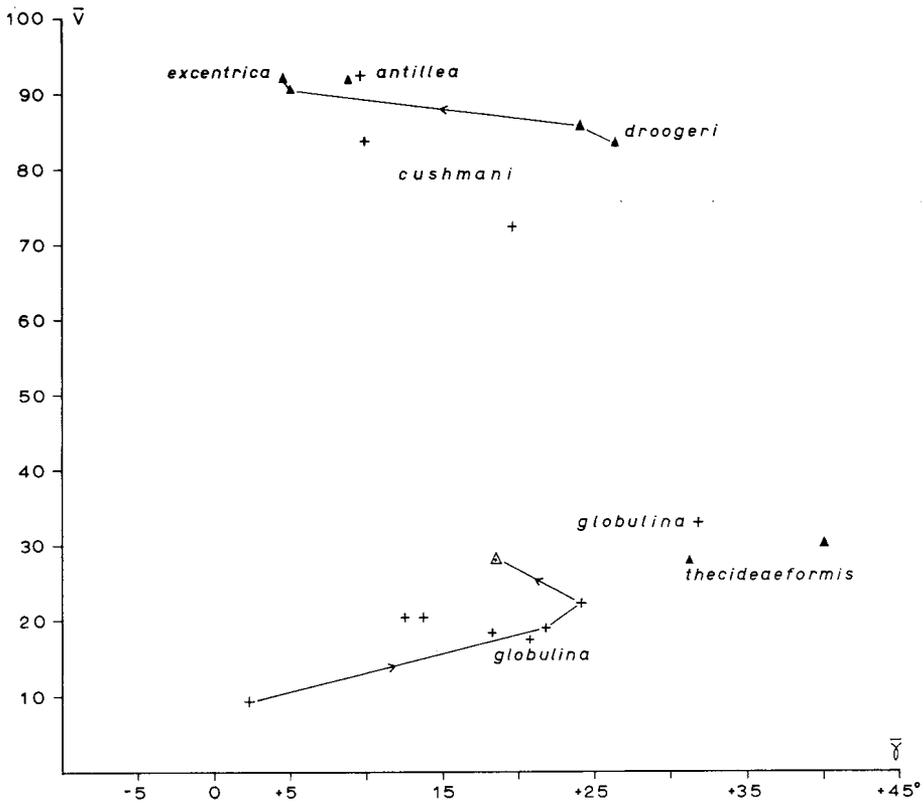


Fig. 32 Relation between  $\bar{V}$  and  $\bar{\gamma}$  for the assemblages of Miogypsinidae from India.

4) The relation between  $\bar{V}$  and  $\bar{\gamma}$ : In assemblages with values of  $\bar{V}$  less than 40, there is a fairly good positive correlation (fig. 32), in which values of  $\bar{\gamma}$  increase with increase of  $\bar{V}$  and vice versa. In the assemblages with values of  $\bar{V}$  greater than 80, the values of  $\bar{\gamma}$  decrease rapidly with increase of  $\bar{V}$ . This is in accordance with theoretical considerations (Drooger, 1963, p. 325): "Theoretically, one would expect that  $\bar{\gamma}$  values would again decrease to about 0 on approaching the complete symmetry of both spirals, as such a position would be in accordance with the direction of maximum equatorial growth".

Neither in the  $\bar{X} - \bar{\gamma}$  nor in the  $\bar{V} - \bar{\gamma}$  data there are reasons to suppose that the Indian Miogypsinidae would belong to different stocks.

5) The relation between  $\bar{I}$  and  $\bar{X}$ ;  $\bar{I}$  and  $\bar{V}$ : The values of the mean diameter of the protoconch have been plotted against the corresponding

values of the  $\bar{X} - \bar{V}$  scale for all the assemblages studied (fig. 33). This figure brings out some interesting groupings among the assemblages of *Miogypsinoides*, *Miogypsina* s.s. and *Lepidosemicyclina*. All the assemblages of *Miogypsinoides*, with the exception of the two assemblages of *M. cf. bermudezi* from the Waior section, occupy a distinctly separate strip in the lower right of the scatter field. Within this strip there is a good correlation between  $\bar{X}$  and  $\bar{I}$ .

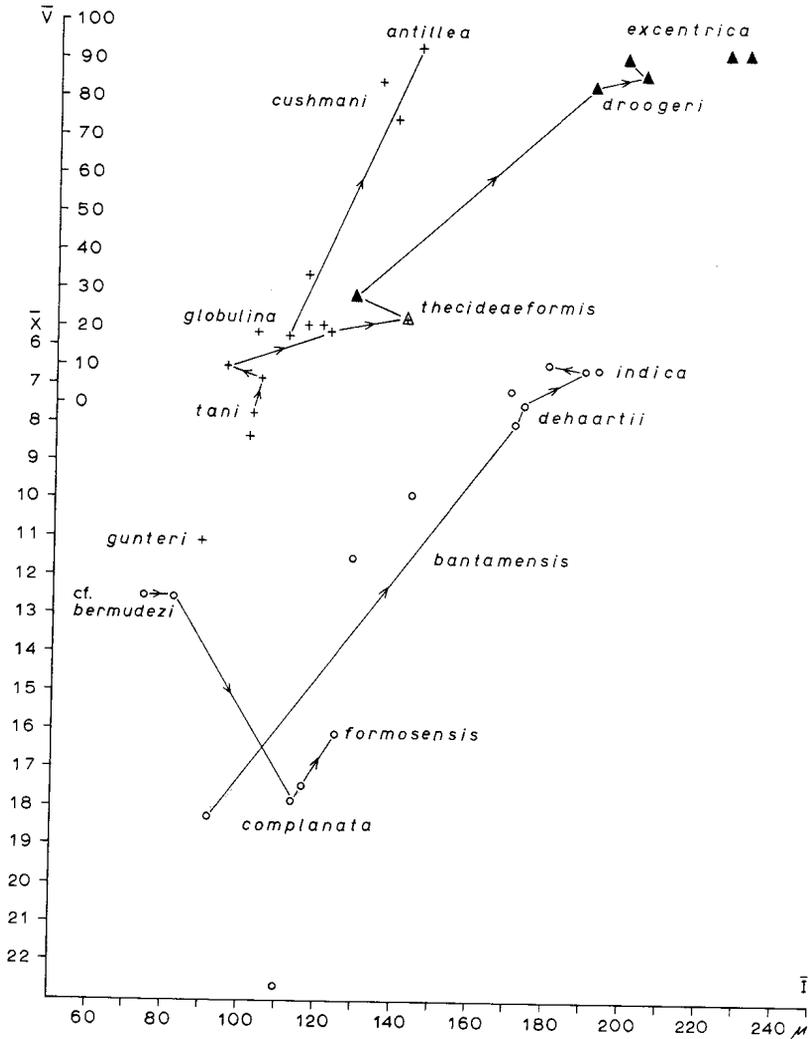


Fig. 33 Relation between  $\bar{I}$  and  $\bar{X}$ ,  $\bar{I}$  and  $\bar{V}$  for the assemblages of Miogypsinidae from India.

All the assemblages of *Miogypsina* s.s. together with the *M. cf. bermudezi* assemblages, occupy an elongate but narrow field at the left hand side of the scatter. Again there is a fairly good positive correlation between  $\bar{X}$  and  $\bar{I}$ , and  $\bar{V}$  and  $\bar{I}$ . Relative to the *Miogypsinoides* assemblages  $\bar{I}$  is distinctly smaller.

Early assemblages of *Lepidosemicyclina* (with values of  $\bar{V}$  less than 50) occupy a field close to that of *Miogypsina* s.s., but slightly towards the right. This is rather expected because some of these assemblages are transitional between *Lepidosemicyclina* and *Miogypsina* s.s. Morphologically advanced assemblages of *Lepidosemicyclina* occupy a distinctly separate field in the upper right corner of the scatter. Two assemblages of *M. excentrica* from Madanam well-1 are even in an extreme upper right position. This implies that after the two protoconchal nepionic spirals attained near-symmetry, further development had been in the growth of the embryonic apparatus (embryonic acceleration because of high  $\bar{II}/\bar{I}$  values) coinciding with the increase in number of the accessory auxiliary chambers.

Differentiation of the Indian Miogypsinidae into three groups, which fairly well correspond to the three (sub)genera, is best visualized by the relation between  $\bar{I}$  and  $\bar{X}-\bar{V}$ . Whether these three groups still fit in with the idea of a single evolving stock, will be discussed in the later parts of this chapter.

Speculations on environmental influences on  $\bar{I}$  have been elaborated in a recent paper by Drooger and Raju (1973).

#### STRATIGRAPHIC OBSERVATIONS IN SUPPORT OF THE SUCCESSION OF MIOGYPSINIDAE

As described in the preceding chapter, some 14 specific units of the Miogypsinidae could be determined from the sections in three areas in India. The high number of specific units gives the impression that nearly complete successions of *Miogypsinoides*, *Miogypsina* s.s. and *Lepidosemicyclina* have developed within the Indian subcontinent.

However, if we place all the present data in the numerical scale, it soon becomes evident that we are dealing with a discontinuous record. There are some five major gaps in our present record. At least some of these gaps might be due to either unfossiliferous intervals or even diastems in the sections from Kutch, or to wide stratigraphic gaps between our samples from the deep well sections in the Cauvery basin.

The following general framework of the succession of Indian species of Miogypsinidae could be reconstructed from the available data from Kutch, Saurashtra and Cauvery basin.

In Kutch, *M. cf. bermudezi* is stratigraphically the oldest species and it is succeeded by *M. complanata* and *M. formosensis*. The assemblage of *M. complanata* with the highest  $\bar{X}$  value (= 22.6) from the Thirupundi well cannot be placed with certainty in the succession of the *M. complanata* group. On the basis of the nepionic acceleration principle it would be older than the assemblages of *M. complanata* from Kutch. In the Khari Nadi section, the development of *Miogypsinoides* and also of early *Miogypsina* s.s. and *Lepidosemicyclina* is in full accordance with the principle of nepionic acceleration. On the basis of the same principle the Cauvery basin assemblages of *M. bantamensis* and *M. gunteri* from Madanam well and of *M. ex.interc. bantamensis-dehaartii* and *M. tani* from Karaikal well-4, may be safely placed in the general framework in between *M. complanata* and *M. dehaartii* of Kutch. Two levels from Saurashtra, one with *M. dehaartii* plus *M. globulina* and the other with *M. indica* plus *M. thecideaeformis* could be satisfactorily placed in relation to the succession from the Khari Nadi section in Kutch.

Thus in *Miogypsinoides*, we seem to have a succession of *M. cf. bermudezi*, *M. complanata*, *M. formosensis* (close to the limit with *M. complanata*), *M. bantamensis*, *M. dehaartii* and *M. indica*.

In the Khari Nadi section, we have a succession of three species of *Lepidosemicyclina*, from bottom to top, *M. thecideaeformis*, *M. droogeri* and *M. excentrica*. This succession is again in accordance with the principle of nepionic acceleration. Considering the level of embryonic-nepionic development, both assemblages of *M. excentrica* from Madanam well-1 represent the highest evolutionary stage in our *Lepidosemicyclina* samples and thus they are likely to be younger than the assemblages of *M. excentrica* from sample KR 36 in the Khari Nadi section.

The assemblages of *M. cushmani* and *M. antillea* in the Karaikal and Madanam wells are distinctly younger than those of *M. excentrica*, and hence *Miogypsina* s.s. ranges higher than *Lepidosemicyclina*.

As a result we have a broad framework in India from stratigraphically the oldest species, *M. cf. bermudezi*, to the youngest, *M. antillea*.

#### POSSIBLE INTERREGIONAL RELATIONS OF MIOGYPSINIDAE

It is clear from the above record that the succession of Indian *Miogypsinidae* is more akin to that from other areas within the Indo-Pacific province than to those of the Mediterranean and America. Each of these major regions has its own species and side branches from the main lineages.

Restricted to the American province are the *Heterosteginoides* lineage (*M. thalmani*, *M. panamensis*, *M. ecuadorensis*) and the *Miogypsinita* group of species (*M. bronnimanni*, *M. mexicana*). The Mediterranean province has its *Miolepidocyclus* offshoot with *M. socini*, *M. burdigalensis* and *M. negrii*. The peculiar groups of *Lepidosemicyclus* and advanced conical *Miogypsinoidea* are especially known from Indonesia. Their presence in India places this part of southern Asia in the miogypsinid Indo-Pacific province.

On the other hand, some of the species are known with certainty from all three regions: *M. complanata*, *M. gunteri*, *M. tani* and *M. globulina*. Since these forms are steps on the main line of Miogypsinidae development their presence in all three regions might as well be due to parallel evolution as to repeated migrations.

As a whole, the available data suggest that the Miogypsinidae of the Indo-Pacific had only a limited exchange with those from the Mediterranean and American provinces. It is worth mentioning that there are some more points of resemblance with the American than with the Mediterranean province. *M.* (cf) *bermudezi* has so far only been found in India, and in the Caribbean and the Gulf Coast. The end member of the *Miogypsina* s.s. lineage is *M. antillea* both in America and in the Indo-Pacific, whereas it is *M. mediterranea* in the Mediterranean region. It is remarkable that along the former Tethys belt, with supposedly shallow water conditions all along, there evidently was some effective Oligo-Miocene faunal barrier between the Indo-Pacific and Mediterranean. Unpublished data on Miogypsinidae from Iran, found in the Utrecht Institute, suggest that such a barrier might have been situated somewhere in the area of Iran, the majority of the species in this region being Mediterranean rather than Indo-Pacific.

Because of the presence of *M.* cf. *bermudezi* and *M. complanata* in America and in the Indo-Pacific with the Pacific and/or the Atlantic-Indian Ocean barriers in between, this geographic distribution invokes some important questions about possibilities of miogypsinid migration. In 1955 Drooger attempted to answer two questions, which are quoted below:

1) How far could a species spread under favourable conditions, that is in an environment of warm and shallow water?

2) Did at any time individuals or groups cross ocean barriers?

Some of the single, provincial species of *Miogypsina* have a geographic distribution over thousands of kilometers. For instance, *M. dehaartii* is distributed over a distance of more than 15,000 km. (Iran to Midway Atoll) and its conical variety over a distance of more than 7,000 km. (Kutch to Solomon Is.). Evidently there is no limit to distance if environmental conditions are continuous.

Regarding the ocean barriers, recent data on the presence of *M. dehaartii* and possibly also *M. bantamensis* (but no *Miogypsina* s.s.) in the Midway Atoll (Cole, 1969) is particularly significant. It makes clear that under favourable circumstances, individuals of the Miogypsinidae have successfully crossed the deep ocean barrier between the West Pacific coast and the Mid-Pacific atoll during the Early Miocene. Another interesting aspect is that in this case only individuals of *Miogypsinoides* succeeded in crossing the ocean barrier, while individuals of *Miogypsina* s.s. did not. It suggests that such events were rather accidental.

The mode of migration of these benthonic foraminifera across the ocean barriers could be by means of either a pelagic larval stage or by rafting. Although some juvenile individuals of *M. globulina* are known to have extremely thin side walls and a light test (Gulf Coast, Akers & Drooger, 1957; Cauvery basin) we do not know whether the Miogypsinidae had any pelagic larval stage, sufficiently prolonged to overcome the ocean barriers before settling. As already suggested by Drooger (1955) and Cole (1969) we may conceive that individuals of the Miogypsinidae had crossed the ocean barriers by means of rafting.

Anyhow, we have to accept that early *Miogypsinoides* of *M. bermudezi* or *M. complanata* level did cross the Atlantic and Pacific barriers, unless we claim the family to be polyphyletic. Such distribution across oceans is much more difficult to prove for later forms (such as *M. globulina*) because their presence in different provinces might be due to parallel evolution.

#### EARLY MIOGYPSINOIDES

If we now start our discussion of the details of the Indian succession of species, the first problem arises at the very beginning of the group.

Previous authors (Tan Sin Hok, 1936, 1937; Barker & Grimsdale, 1937; Drooger, 1955, 1963) agree that *Miogypsinoides* evolved from a *Rotalia*-like ancestor (*Pararotalia* or *Neorotalia*), because of certain similarities between the individuals of *M. complanata* and associated *Pararotalia*. Also in the Indian material small individuals of both *M. cf. bermudezi* and *M. complanata* show several morphological characteristics – ornamentation, trochospiral stage, umbilical plug – similar to those of associated individuals of *Pararotalia*. These data leave little doubt that early *Miogypsinoides* evolved from a *Pararotalia* ancestor.

The recorded succession in one outcrop of early *Miogypsinoides*, i.e., *M. cf. bermudezi* and *M. complanata* from the Waior section, allows for

different explanations concerning the origin and relationship of these species. The problem is accentuated by the absence of intermediate assemblages between *M. cf. bermudezi* and *M. complanata* in this section.

In 1951 and 1952 Drooger considered *M. bermudezi* from Cuba to be the oldest species because of the extreme thinness of the side walls. Thick-walled *Miogypsinoides* such as *M. complanata* would be younger, though stratigraphic proof for this idea was lacking. This caused him to suggest that the principle of nepionic acceleration might not be applicable to every detail of the development of the Miogypsinidae and he even introduced the term nepionic retardation. This concept of nepionic retardation was substantiated by data on *Miogypsinoides* from Puente Viejo, Spain, where in three samples the  $\bar{X}$  values would increase from the oldest to the youngest sample. Later, Drooger (1956) re-examined the Miogypsinidae from the Puente Viejo section and came to the conclusion that the assemblages are displaced elements in turbidites. Thus the major evidence in favour of nepionic retardation was contradicted.

On the basis of additional observations on *M. cf. bermudezi* from the Gulf Coast, Akers and Drooger (1957) and Drooger (1963) started to doubt the significance of the character of the side wall thickness. Thus, the question of nepionic retardation in early *Miogypsinoides* remained unsolved.

The only later indication that thin-walled *Miogypsinoides* with short spirals preceded thick-walled (and longer-spiralled?) *Miogypsinoides*, was forwarded by Gordan (1959) who recorded *M. bermudezi* and *M. complanata* from successive levels of the San Sebastian Formation in Puerto Rico. However, this record is not accompanied by any description or data on  $\bar{X}$  and  $\bar{Y}$ , of the taxa involved.

The superposition found in the Waior section is beyond doubt, so that now we are forced to speculate on the evolution of these early *Miogypsinoides* species. Different explanations could be:

1) Nepionic retardation: Assuming a monophyletic development of the Miogypsinidae, we are apt to consider that *M. complanata* has directly evolved from *M. (cf.) bermudezi*. To explain this we have to accept that the evolutionary features of spiral length of the nepionic stage ( $\bar{X}$ ,  $\bar{Y}$ ,  $\bar{Z}$ ) increased rapidly, or abruptly, from *M. cf. bermudezi* to *M. complanata*, i.e., this is "proof" of nepionic retardation. After the long-spiralled stage of *M. complanata* had been reached, the well known principle of nepionic acceleration started the gradual reduction of X, Y and Z. In the absence of intermediates between the assemblages of these two species even in the single cliff section of the Waior, this explanation of nepionic retardation has no sound basis. We certainly need a series of intermediates to single out this

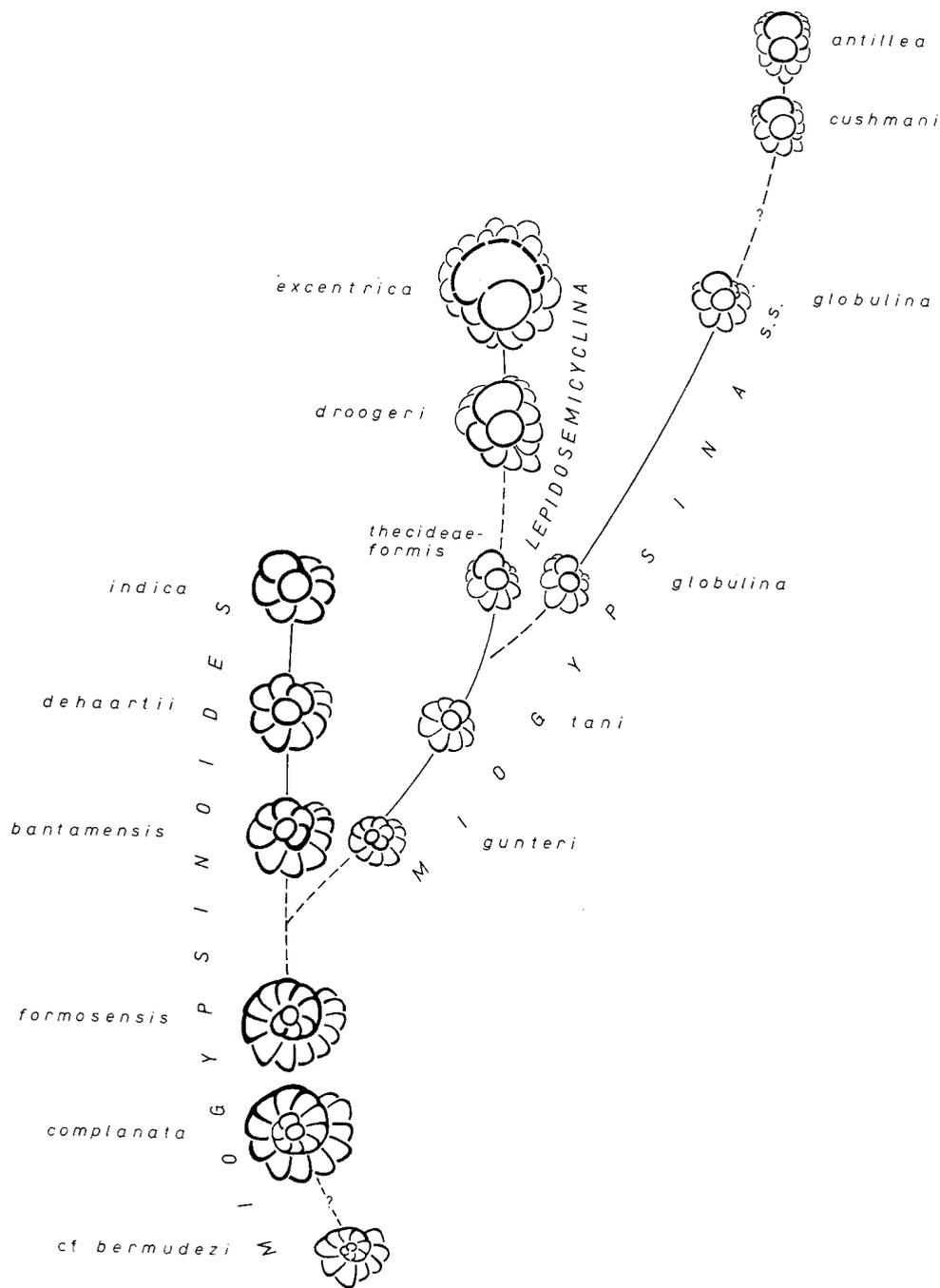


Fig. 34 Tentative phylogenetic scheme of the Indian Miogypsinidae.

explanation as the best one.

2) Polyphyletic origin: If we discard the monophyletic evolution, *M.* (cf.) *bermudezi* and *M. complanata* might belong to two different lineages. In this case, we have to assume that *M.* (cf.) *bermudezi* and *M. complanata* have derived from different "Pararotalia" ancestors. The first wave of *M. bermudezi* might have had no further issue, the actual Miogypsinidae starting with *M. complanata*. Yet another line of thought is possible in connection with this second hypothesis.

If the mean diameter of the protoconch has any genetical significance as a characteristic of population groups, we might presume that *M. cf. bermudezi* is the direct ancestor of *M. gunteri* (see fig. 33). These species then would be unrelated with the lineage of the *M. complanata* group. The *M. complanata* group itself would be a different lineage which, at least in India, would not lead to *Miogypsina* s.s. It is worth noting that in the Louisiana well from which Akers & Drooger (1957) described their *M. cf. bermudezi* the next higher species they reported actually is *M. gunteri*. However, if we accept this explanation, it is remarkable that there are so far no records of long-spiralled *M. complanata*, together with either *M. bermudezi* or *M. gunteri*.

3) Ecophenotypical variation: A third possible explanation might be that the *M. complanata* group had at any time environmentally controlled populations which apart from developing very thin walls, ran ahead in nepionic configuration. Again there is no clear evidence that *Miogypsinoides* showed random fluctuations in  $\bar{X}$  and  $\bar{Y}$ , whenever populations are found in stratigraphic superposition. With the exception of the *M. bermudezi* occurrences, the general record of *Miogypsinoides* seems to be in accordance with the principle of nepionic acceleration.

#### YOUNGER MIOGYPSINOIDES

The later development of Indian *Miogypsinoides* shows a remarkable gap in the record, which problem is much less embarrassing than that of *M. bermudezi*. The combined record of the Khari Nadi section and the Karaikal and Madanam wells, makes it fairly certain that *M. complanata* and primitive *M. formosensis* were followed by the species series *M. bantamensis*, *M. dehaartii* and *M. indica*. The lack of data between the assemblages with  $\bar{X}=16.2$  and  $\bar{X}=11.5$  does not necessarily mean a break in the evolution. Intermediate forms are thought to be present in the Indo-Pacific province, so that such intermediates may turn up in India as soon as the amount of data

increases. Whether such evolution in between was relatively more rapid cannot be concluded from our sections.

An interesting feature of *Miogypsinoidea* in the Indo-Pacific is the sustained development contemporaneous with *Miogypsina* s.s. up to the level of *M. globulina*.

The end members of *Miogypsinoidea*, *M. dehaartii* with its *cupulaeformis* variants and *M. indica*, are well represented in the samples from the Khari Nadi section in Kutch, and also from Saurashtra. Evidence from stratigraphically successive samples clearly indicates that the evolutionary trend in these end members is in accordance with the principle of nepionic acceleration.

Some of the changes are: reduction in  $\bar{X}$  and  $\bar{Y}$ , progressive increase in  $\bar{\gamma}$  values from negative to positive, and fairly rapid increase, except for minor setbacks, in the size of the protoconch.

The most remarkable trend in the development of the end members is the acquirement of subconical tests, at about the middle part of the range of *M. dehaartii*. Although the percentage of conical individuals increases towards higher levels such forms remain associated with relatively small and flat individuals. The trend of development of conical forms is associated with a shift in the position of the embryonic apparatus away from the periphery, and growth of the median layer also in anti-frontal direction. In extreme, conical individuals the embryonic apparatus occupies a nearly central position, from which growth of the median layer continued uniformly downwards in all directions. This development gave room to the growth of slightly more nepionic chambers than in the accompanying, relatively flat individuals. However, when we consider parameter  $\bar{Y}$ , this development does not suggest a nepionic retardation.

As already suggested by Dröoger (1955, 1963) this trend is one of the ways that leads towards better radial symmetry.

#### SEGREGATION OF MIOGYPSINA S.S. AND MIOGYPSINOIDES

In our samples, the earliest assemblage of *Miogypsina* s.s. is one of *M. gunteri*, which is associated with *M. (Miogypsinoidea) bantamensis*. At this stage, *M. gunteri* differs from *M. bantamensis*, apart from the presence of distinct lateral chambers, in having smaller protoconch and deutoconch. Although both assemblages appear to have been diversified with respect to the embryonic stage and the characters of lateral walls, a complete morphological break in embryonic-nepionic features is not evident. In  $\bar{X}$ ,  $\bar{Y}$  and  $\bar{\gamma}$  the assemblages of both species cannot be proved to be different and

in I the total variation is continuous or nearly so. If compared with assemblages considered to be homogeneous, this total variation in protoconch diameter would not be exceedingly wide for a single homogeneous population. If we may consider the miogypsinids of this well sample to be on the threshold from *Miogypsinoides* to *Miogypsina* or slightly beyond, we might speculate on how segregation of both lineages took place. One might suppose that differentiation was not necessarily due to wide geographic separation, but rather to differences in adjoining habitats within each province or subprovince. The assumption of ecoraces (or microgeographic races) as the beginning of *Miogypsina* s.s. would easily explain that such development took place at many places of the globe at strongly different  $\bar{X}$  levels.

As a next higher stage we have *M. tani* associated with a *M. (Miogypsinoides) dehaartii* assemblage ( $\bar{X} = 9.8$ ), which is close to the limit with *M. bantamensis*. Here again the assemblage of *Miogypsina* s.s. has a relatively smaller protoconch. The difference in I is slightly greater than in the previous case (fig. 33). With respect to the features of the nepionic stage, the differences are not yet prominent, but nepionic acceleration seems to have had more effect on *M. tani*. The morphological gap is apparent now.

A still wider morphological break between the assemblages of *Miogypsina* and *Miogypsinoides* is recognizable at the stage where the subconical *cupulaeformis* variants of *M. dehaartii* come into the picture (sample G 1448, Khari Nadi section, overlying a level with *M. tani* alone). At this stage *M. dehaartii* (with var. *cupulaeformis*) has already developed a large embryonic apparatus compared to that of *M. tani*. With reference to the features of the nepionic stage ( $\bar{X}$ ,  $\bar{Y}$ ,  $\bar{\gamma}$ ) *M. dehaartii* is distinctly lagging behind *M. tani*. At a later stage of *M. dehaartii* (samples G 1421 and Jagatia well) and in *M. indica* (G 1417 and G 1415) the morphological break between the assemblages of *Miogypsinoides* and of *Miogypsina-Lepidosemicyclina* remains clearly recognizable. The last forms co-occurring with *M. indica* already belong to *Lepidosemicyclina: M. thecidaeiformis*. In *Miogypsinoides* a gradual increase in the size of the protoconch, with minor setbacks, continued up to the highest occurrence.

The trends in the evolution of *Miogypsinoides* and *Miogypsina* s.s., at least during the interval from *M. bantamensis* to *M. dehaartii*, appear to suggest continued diversification between the two groups (see fig. 33). The separation of the two groups is possibly related to a basic divergence in habitat and mode of life. The succession from the Khari Nadi section seems to render some support toward such explanation 1) Presence of assemblages of *Miogypsina* s.s. alone in samples KR 155 and G 1437, while assemblages of both *Miogypsinoides* and *Miogypsina* s.s. are present in G 1448. 2) Differ-

ences in state of preservation between the individuals of the assemblages of *Miogypsinoides* and *Miogypsina-Lepidosemicyclina* in samples G 1421, G 1417 and G 1415.

The development trends in both groups are in accordance with the principle of nepionic acceleration. With respect to the trends in the nepionic stage, evolution of both groups is parallel. At any stratigraphic level, the assemblages of *Miogypsinoides* are less developed than those of *Miogypsina* s.s.

However, in respect to the size of the embryonic stage, the final assemblages of *Miogypsinoides* and those of *Lepidosemicyclina thecidaeiformis* appear to converge again.

#### THE LEPIDOSEMICYCLINA LINEAGE

Although the distinction of *Lepidosemicyclina* from *Miogypsina* s.s. has been usually based on the presence of predominantly hexagonal equatorial chambers, the main justification for separating this lineage lies in the high relative rate of embryonic-nepionic development.

Relative to the lineage of *Miogypsina* s.s., the following major events in the development of *Lepidosemicyclina* are recognizable.

1) *Lepidosemicyclina* has derived from *Miogypsina* s.s. The changes leading to the origin of *Lepidosemicyclina* appear to begin at some level of a very early stage of *M. globulina*, approximately at a stage with values of  $\bar{V}$  between 10 and 20. Our present record of several assemblages transitional between *Miogypsina* s.s. and *Lepidosemicyclina* leads to the assumption that the origin of this lineage could well have taken place in the region of the Indian subcontinent.

2) Up to the last representatives of the lineage, *M. excentrica*, *Lepidosemicyclina* is found in association with *M. globulina*.

3) At the stages of *M. droogeri* and *M. excentrica*, a wide morphological gap has been recognized between *Lepidosemicyclina* and *Miogypsina* s.s. (= *M. globulina*), so that there is little doubt that we are dealing with separate, contemporaneous populations.

4) In our present samples or in the few studied by Mohan (1958) assemblages of *Lepidosemicyclina* with values of  $\bar{V}$  roughly in between 45 and 80, have not been found. Future studies on assemblages from adjacent sections may fill this gap. However, if we consider the Khari Nadi section alone, *M. droogeri* appears to be an immigrant.

The missing stages probably developed in some other geographical area,

but it is also possible that the development of assemblages transitional between *M. thecideaeformis* and *M. droogeri* took place in a different environment, which is not represented in our present samples.

In the course of the evolution of the Indian *Lepidosemicyclina* lineage, from *M. thecideaeformis* to *M. excentrica*, the following morphological changes are recognized.

- a. The mean values of the diameter of protoconch and deutoconch increase rapidly, with some minor fluctuations. In the end member, *M. excentrica*, the deutoconch usually strongly embraces the protoconch.
- b. Beginning development of hexagonal equatorial chambers shifts from a position of about 10–12 rows away from the embryonic-nepionic stage, to the first row adjoining the nepionic stage.
- c. There is a general trend towards increase of size of the test, and particularly of lengthening of the test. The maximum diameter in successive assemblages from the Khari Nadi section increases from about 4.5 mm to 8 mm. However, in the youngest assemblage of *M. excentrica* (from Madanam well, core 2) the length of the test appears to be reduced again. These values could not be quantified more accurately as part of the test on the side of the frontal margin is broken in too many specimens.
- d. There is a distinct shift in the position of the embryonic apparatus, particularly so in the end member, from a peripheral position to a place at a certain distance from the apical periphery.
- e. Associated with the shift in position of the embryonic apparatus there is a distinct trend towards development of more than two stolons from the embryonic apparatus. *M. excentrica* is characterized by the usual presence of several accessory auxiliary chambers, an evolutionary stage not attained by any other species of the Miogypsinidae. In a few specimens there is even an extra stolon from the protoconch leading to an accessory auxiliary chamber. As noted already by Tan Sin Hok, a complicated system of stolons connects the equatorial chambers.

Once more considering the evolution of *Lepidosemicyclina*, it may be noted that its first member, *M. thecideaeformis* was widespread in the Indo-Pacific province. Possibly this trend was the regular continuation of *Miogypsina* s.s. following early *M. globulina*. Theoretically the Indonesian *M. thecideaeformis* evolves to the extreme forms *M. polymorpha* and *M. bifida*, in which the embryonic chambers strongly increase in size, and the hexagonal equatorial chambers show extreme length, but which seem to be arrested at low  $\bar{V}$  values. Whether such forms, reported by Mohan, really are present in India, cannot yet be established. An assemblage from Saurashtra described by Mohan (1958) as *M. polymorpha* appears to be distinctly

*M. thecideaeformis*. The strongly undulated frontal margin of their test is considered here not to be diagnostic of *M. polymorpha*. Because of their peculiar features it is likely that neither *M. polymorpha* nor *M. bifida* lead to the younger *Lepidosemicyclina*. As in India, *Lepidosemicyclina* with  $\bar{V}$  values between 45 and 80 have not yet been found in Indonesia. Wherever in the Indo-Pacific the intermediates developed, their final result *M. excentrica* is found again in Indonesia and India, in the latter region preceded by *M. droogeri*. It is likely that the evolution of  $\bar{V}$  in this lineage proceeded very rapidly, since in both areas the contemporaneous *Miogypsina* s.s. lineage did not proceed beyond the stage of *M. globulina* (or *M. kotoi*).

#### THE PROBLEM OF *M. GLOBULINA*

It has been suggested that the  $\bar{V}$  evolution in *Lepidosemicyclina* moved so fast that its complete development took place in the life span of *M. globulina* of the *Miogypsina* s.s. lineage. In this line of reasoning it is assumed that *M. globulina* evolved rather slowly to its successor *M. intermedia*. A similar process is accepted for the evolution of the *Miolepidocyclina* lineage in the Mediterranean, equally within the life span of *M. globulina* (Drooger, 1954, 1963). The data from India cast serious doubt on the idea of sustained change in *M. globulina*. The assemblages we found together with *M. droogeri* and *M. excentrica* show no change at all. They give the impression that *M. globulina* staggered on at the evolutionary level of its early representatives with frequent recurrence of *thecideaeformis* features. The same may be true for the forms from Indonesia, where *M. kotoi* is reported to occur together with *M. excentrica* in the island of Madura (Tan Sin Hok, 1937). We might very well be dealing with a *Miogypsina* stock with arrested evolution at the level of *M. globulina* over most of the Indo-Pacific province.

Several assumptions may be advanced about the origin of this immovable *M. globulina* stock. It might have split off from early *M. thecideaeformis* in the Indo-Pacific itself. Of course we may consider these later *M. globulina* as immigrants in India from some remote corner of the Indo-Pacific or even from another province. The regular reappearance of some hexagonal equatorial chambers in these later *M. globulina* assemblages seems to plead against a provenance from outside the Indo-Pacific.

Anyway the assumption of arrested evolution seems reasonable. It might even explain the presence of *M. globulina* together with its theoretical descendant *M. cushmani* in Karaikal well no. 6, if we wish to exclude the possibility of reworking to explain the latter combination of species.

Yet another problem that cannot be solved is the probable presence of two *M. globulina* populations in some single samples, one of which is sometimes *M. thecidaeiformis* like. For the moment the assumption of different environments would give the easiest explanation.

THE YOUNGEST MIOGYPSINA S.S.

In Cauvery basin there is ample proof that the final stage of *Lepidosemicyclina*, *M. excentrica*, is followed by a final wave of *Miogypsina* s.s., i.e., *M. cushmani* and *M. antillea*. Any proof of the normal evolution via *M. intermedia* is lacking, and the same seems to be true for Indonesia. Yet it is not necessary to assume that these forms have migrated from America; they might well have arisen in some ill known subprovince of the Indo-Pacific, such as New Zealand.

MICROSPHERIC GENERATION

Rare specimens of the microspheric generation are found in most of the assemblages investigated. They are relatively frequent in only three assem-

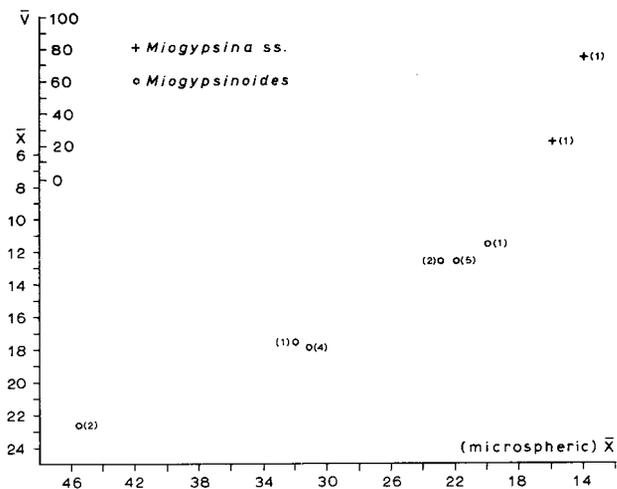


Fig. 35 Relation between the total number of spiral chambers in microspheric individuals and the  $\bar{X}$  or  $\bar{V}$  values of the accompanying macroscopic assemblages. Numbers between brackets indicate the number of specimens.

blages: *M. cf. bermudezi* (KR 330), *M. complanata* (KR 11) and *M. cushmani* + *M. globulina* (201–204 m, Karaikal–6). In assemblages of early *Miogypsinoides* there is very little difference in the size of the individuals of microspheric and macrospheric generations. In assemblages of *M. globulina*, *M. thecideaeformis* and *M. excentrica*, microspheric individuals are distinctly larger. In assemblages of *M. cushmani* and *M. globulina* from Karaikal 6, there is again very little difference in size between the individuals of both generations.

In all the sectioned microspheric specimens the nepionic chambers belong to a single spiral. In many of the sections it is difficult to establish their exact number. Available data (fig. 35) suggest that nepionic acceleration is also valid for the representatives of the microspheric generation. The picture as a whole is similar to the one documented by Drooger (1963, fig. 23).

#### RATE OF ACQUISITION OF NEW FEATURES

Because of their usage in taxonomic classification, and by many authors in chronostratigraphic correlation, we may briefly discuss the rates of acquisition of some of the new features during the development of the *Miogypsinidae*.

1) **Lateral chambers:** All available evidence suggests that lateral chambers (which characterize the subgenus *Miogypsina* s.s.) have developed at different  $\bar{X}$  values in the *Miogypsinoides* group.

2) **The second principal auxiliary chamber:** It begins as a small indistinct chamber in a few individuals of assemblages at a stage of *M. gunteri* (Drooger, 1952) or *M. tani*. The percentage of individuals with a second principal auxiliary chamber increases very gradually in successively younger populations. Even in assemblages of *M. globulina* found in association with *M. excentrica*, there are still individuals without a second principal auxiliary chamber. If we consider the time duration, from the stage at which a few individuals acquire the second principal auxiliary chamber to the stage at which entire populations had two principal auxiliary chambers, this acquisition is a slow process.

3) **Hexagonal equatorial chambers:** Their introduction evidently is a deuterogenetic process. It is typical for *Miogypsinidae* in the Indo-Pacific province. As a whole the rate of development of such chambers seems to be a rather irregular process, both in ontogeny and in phylogeny.

Drooger (1963) discussed in detail the possible rates of nepionic acceleration in different lineages of the Miogypsiniidae, with the main *Miogypsina* lineage as the basis of reference. Whether rapid or slow this author considers nepionic acceleration to be present throughout all lineages. In view of our present data, this theory has to be slightly revised. First of all it appears very likely that nepionic retardation did occur in the early history of the family (*M. cf. bermudezi* to *M. complanata*). Second we are confronted with another clear case of lack of change during a long time, in *M. globulina*, which species seems to be overtaken by one of its theoretical descendants, *M. cushmani*.

Furthermore there are now examples of different rates of nepionic acceleration.

In the Indian succession, the younger members of *Miogypsinoidea*, *M. bantamensis* to *M. indica*, show a trend parallel to that of local *Miogypsina* s.s., but the rate in the latter group is somewhat faster. Higher up in the succession we see that *Lepidosemicyclina* underwent very rapid nepionic acceleration relative to the *Miogypsina* s.s. stock, irrespective of the ways we wish to manipulate migrations of different groups.

As associations of planktonic foraminifera are considered to have changed rapidly, we may consider them for a further estimate of rates of evolution. Associated planktonic foraminifera from Cauvery basin (details given in next chapter) suggest that the development of the succession of *Miogypsina-Lepidosemicyclina* from the stage of *M. tani* ( $\bar{X} = 8.33$ ) to the stage of *M. excentrica*, is well within an interval between the uppermost part of the *G. kugleri* Zone (= Zone N4 of Blow) and the lower part of the *G. insueta* Zone (= lower part of Zone N7 of Blow). Within this interval the rate of nepionic acceleration appears to be so rapid that the ranges of planktonic species (which modestly reflect stages of recognizable morphological development) cannot be confidently used to verify the successive zones based on nepionic acceleration in the Miogypsiniidae. It appears that, at least within this interval, the rate of evolution in *Miogypsina-Lepidosemicyclina* is much faster than in planktonic foraminifera, or any other group.

Due to the lack of planktonics at other levels of our sections, similar comparisons cannot be made for early *Miogypsinoidea* or younger *Miogypsina*.

## Chapter VII

### ECOLOGY

The probable habitats of the Miogypsinidae may be guessed from gross lithological characters and faunal associations.

Both in Kutch and in Saurashtra abundant Miogypsinidae are usually found in marly limestone and calcareous clay; they are rare in calcareous fine grained sandstone. They usually occur in association with various molluscs – *Pecten*, *Ostrea*, *Turritella* – echinoids, ostracoda and other foraminifera. A few of the records are from shell beds. They are absent in beds of well laminated, variegated or mottled, gypsiferous clay alternating with silt. In Cauvery basin, Miogypsinidae from core no. 3 of Karaikal well-4 and from core no. 5 of Madanam well-1, were obtained from alternating thin beds of highly fossiliferous clayey limestone and fine grained calcareous sandstone. All the available evidence from the associated faunas suggests that the Miogypsinidae lived in shallow marine environments.

On the other hand, the *M. globulina* assemblages from core no. 2 of Karaikal –4, and core no. 3 of Madanam-1, are associated with numerous planktonic foraminifera, *Uvigerina*, *Bolivina* and other forms which are suggestive of deeper marine conditions. Moreover, the nature of preservation of the very thin tests and the occurrence of several small juvenile forms of *Miogypsina* suggest that these assemblages lived under quieter marine conditions. Also the assemblages of *M. excentrica* from core no. 2 of Madanam –1 are associated with numerous planktonics and *Uvigerina*.

Thus it appears that Miogypsinidae thrived under variable conditions usually in shallow water with frequent high energy conditions and more rarely in deeper or at least quieter marine environments.

Some specific cases from Kutch and Saurashtra are discussed below. Among the early *Miogypsinoides* the assemblages of *M. cf. bermudezi* were obtained from lumpy clay and thin-bedded calcareous fine-grained sandstone containing a few planktonics while benthonics predominantly belong to *Nonion*, *Elphidium* and *Pararotalia*. These thin walled *Miogypsinoides* seem to have lived under shallow, relatively quiet, conditions. On the other hand, *M. complanata* and *M. formosensis* were recorded from highly fossiliferous

marly limestone with a well diversified fauna. These assemblages possibly thrived in more turbulent water.

Younger *Miogypsinoides* are relatively rare or absent in limestone beds with numerous mollusc shells, in which contemporaneous assemblages of *Miogypsina* s.s. are abundant.

The predominance of strongly undulated tests of the elongate individuals of *M. thecideaeformis* from the lumpy calcareous clay of sample SG 4, Saurashtra, seems to be related to soft bottom conditions. The well preserved assemblage of *M. excentrica* (sample KR 36) from lumpy calcareous silty clay is associated with a high percentage of *Ammonia* (nearly 50%), *Elphidium*, miliolids, *Chara* fruits and very rare, small *Archaias*. We may infer that this assemblage lived in shallow water without strong turbulence, thus under low energy conditions. Assemblages of *M. droogeri* are very rare, poorly preserved and worn, while specimens of *M. globulina* are very abundant and well preserved in the highly fossiliferous limestones of samples G 1406 and G 1401, which contain well diversified assemblages of foraminifera including several large *Archaias*. In the case of these two samples, specimens of *Lepidosemicyclina* may have been brought in by wave and current action. These few observations suggest that *Lepidosemicyclina* probably favoured a soft bottom with low energy conditions, whereas contemporary assemblages of *Miogypsina* s.s. apparently tolerated turbulent high energy conditions. The occurrence of *M. excentrica* in core no. 2, Madanam well-1, also points to quiet water, but this time in a deeper habitat.

## Chapter VIII

### BIOSTRATIGRAPHY

#### GENERAL REMARKS

As already mentioned in the introduction, one of the main aims of this study of the Miogypsinae has been to refine the biostratigraphic subdivision of the Oligo-Miocene sediments in India and to attempt a detailed inter-basinal correlation. It has to be realized that biostratigraphic correlation based on successive steps in a rapidly evolving lineage of a single group of fossils is more precise than that by means of any succession of unrelated groups of organisms. To this extent *Miogypsina* are thought to be of unique value. As discussed in the previous chapters the evolutionary trends in *Miogypsina* could be fairly well reconstructed. Further, it is of the greatest advantage that each of the specific units within the evolving lineages of *Miogypsina* can be defined numerically so that there can be little ambiguity regarding the morphological limits of the specific units. This approach also facilitates comparison of populations from different regions.

Apart from cases of arrested evolution and possible nepionic retardation, encountered especially in Indian Miogypsinae, the principle of nepionic acceleration appears to be useful for detailed correlation.

#### CORRELATION OF SECTIONS IN INDIA

From the discussions on the Khari Nadi section, it is evident that within each of the lineages of the Miogypsinae, significant steps smaller than the specific units may be recognized. For instance, assemblages with values of  $\bar{X}$  below 9 and negative  $\bar{\gamma}$  have been placed under *M. tani*, whereas we know that within this range the assemblage with  $\bar{X} = 7.77 \pm 0.169$  is stratigraphically older than the one with  $\bar{X} = 6.88 \pm 0.133$ , because their means are significantly different. It appears, from such examples, that an ultimate refinement, for the purpose of chronostratigraphic correlation, may be attained by refining the numerical scales in terms of  $\bar{X}$ ,  $\bar{V}$ ,  $\bar{\gamma}$  in combination



with other parameters. For the purpose of correlation the greatest advantage of such scales would be that one needs not have to resort to lengthy discussions on taxonomy, species concept etc. From the available evidence it seems possible that the numerical scale can be satisfactorily used for chronostratigraphic correlations within a single basin and/or sections from adjacent basins, in which the lineages are similar in every respect. Further it appears to be an advantage to consider independently the scales of lineages of *Miogypsinoidea*, *Miogypsina* s.s. and *Lepidosemicyclina* as this procedure will provide a further verification.

Considering the gaps in our present data and other factors like small samples and poor preservation, relatively wide limits within the *Miogypsina* scale are favoured for our zonation. The following range zones (= phylozones = lineagezones) can be recognized for the succession known from India. The limits of these zones coincide with those set in defining the respective species. Possible major gaps in the record are mentioned.

1) *M. complanata* Zone: This zone is defined by the range of *M. complanata*. In the succession underlying this zone, a *M. cf. bermudezi* Zone may possibly be recognized.

Further investigations are required to clarify the succession between the *M. complanata* Zone and the next higher zone. The possible second zone will not be defined here.

3) *M. gunteri* Zone: This zone is defined by the range of *M. gunteri*. *M. bantamensis* may occur in this zone.

4) *M. tani* Zone: This zone is defined by the range of *M. tani*. *M. dehaartii* may be present. Conical variants of the latter start to occur in the upper part of this zone.

5) *M. globulina-thecidaeformis* Zone: This partial range zone is defined by that part of the *Miogypsina* succession which leads from the early stages of *M. globulina* to *M. thecidaeformis*. The assemblages are usually represented by transitional forms. The upper limit of this zone is provisionally defined by the appearance of *M. droogeri*. Because of the stagnant evolution in *M. globulina* it may be difficult to recognize this zone when *M. droogeri* is absent from the succession. The youngest stages of *M. dehaartii* and *M. indica* occur in this zone and provide an additional means of recognition.

6) *M. droogeri* Zone: This zone is defined by the range of *M. droogeri*. *M. globulina* may continue in this zone.

7) *M. excentrica* Zone: This zone is defined by the range of *M. excentrica*. *M. globulina* may still occur in this zone.

A further study of additional sections is necessary to characterize the interval between the occurrence of *M. excentrica* and *M. cushmani*, in order to define zone 8).

9) *M. cushmani-antillea* Zone: This zone is defined by the combined ranges of *M. cushmani* and *M. antillea*. Possibly *M. globulina* is still present.

A proposed correlation of the stratigraphic sections from Kutch and Cauvery basin is shown in fig. 36.

All the known *Miogyopsina* assemblages from Saurashtra, from two localities described in this paper and from six localities described by Mohan (1958) belong to the *M. globulina-thecidaeformis* Zone. The sample localities include, Nandana section, Jagatia shallow well, loc. Vwl., loc. F, D and B, loc. Vf and loc. H (reference is made to Mohan, 1958, for details of the latter six localities).

The *Miogyopsina* assemblage from Kimamlee, Surat-Broach area, Cambay basin, described by Mohan (1958) also belongs to the *M. globulina-thecidaeformis* Zone.

#### ASSOCIATED FORAMINIFERA

The details of the distribution of some of the foraminifera, that are found either in *Miogyopsina* samples or in adjacent levels are briefly given below.

1) *Benthonic foraminifera*. Although several benthonic foraminifera, including *Lepidocyclina*, *Austrotrillina*, *Archaias*, *Taberina*, *Spiroclypeus*, *Operculina*, *Gypsina*, are found in some of our samples, detailed investigations are not yet complete. As such, in the absence of satisfactory data on evolutionary trends and/or well determined ranges of species of several of the associated larger foraminifera from our sections, we cannot, at present, use these forms for detailed correlations or to verify relative rates of evolution in the *Miogyopsinidae*.

It may be worth noting that the stratigraphic level of the first appearance of the *Miogyopsinidae* in Kutch is distinctly above the extinction level of the reticulate *Nummulites* (*fichteli-intermedius* group).

2) *Planktonic foraminifera*. In Kutch, most of the samples studied lack planktonic foraminifera. However, two samples, KR 19 and KR 330 from Waior section, contain poorly developed assemblages of planktonics in association with *M. cf. bermudezi*. They include very rare forms of *Globorotalia opima nana*, *G. cf. permicra* and some species of the genus *Globigerina*, including *G. praebulloides leroyi*, *G. cf. officinalis*, *G. angustum-bilicata* and *G. cf. obesa*. *Globigerinoides* was not found. These assemblages are not indicative for any particular planktonic zone. At best we may conclude that they are suggestive of the *G. opima* Zone or *G. ciperoensis* Zone, i.e. they are

below the *Globigerinoides* datum level.

In Cauvery basin, planktonic foraminifera are very abundant, particularly so in the Paleogene subsurface sequence. Late Eocene to Early Miocene planktonics from a few wells were described already by Raju (1971). During the present study some planktonics that occur within the interval of *Miogypsina* have been determined.

The results, in relation to *Miogypsina*, are given below.

*Madanam well from bottom to top:*

Core-5 (1040.27 – 1043.27 m.): *M. gunteri* and *M. bantamensis*.

Core-4 (874 – 877 m.): No *Miogypsina*. Planktonics include *Globoquadrina praedeformans*, a few juvenile forms which resemble *Globigerina binaiensis*, *Globigerinoides trilobus*, *G. altiapertura*, and *Globorotalia siakensis*.

Core-3: (631 – 637.5 m.): Rare specimens of *M. globulina*. Planktonics include *Globoquadrina altispira*, transitional forms between *Globigerinoides primordius* and *G. trilobus*, *G. altiapertura*, transitional forms between *G. altiapertura* and *G. subquadratus*, *Globorotalia* cf. *siakensis*, *G. (Clavatorella) bermudezi* and *Globigerina obesa*.

Core-2 (484 – 487 m.): *M. excentrica* and very rare specimens of *M. globulina*. Planktonics include *Globigerinoides trilobus*, *G. sacculiferus*, *G. altiapertura*, *G. subquadratus*, *Globoquadrina altispira*, *Globorotalia* cf. *siakensis* and *Globigerina obesa*.

All three cores, 4, 3 and 2 contain *Globigerinoides altiapertura* which has been considered to range from the *G. dissimilis* Zone to the *G. stainforthi* Zone by Bolli (1957) and from Zone N5 to the lower part of Zone N7 by Blow (1969). However, the zonal markers for this interval, *G. dissimilis*, *G. stainforthi* and *G. insueta* are not present in our samples. Furthermore, representatives of the *Globigerinoides sicanus-Orbulina universa* lineage are lacking, even in the highest core studied. This evidence, partly negative, suggests that all three cores might belong to an interval between the *G. dissimilis* Zone and *G. stainforthi* Zone of Bolli or to an interval between Zone N5 and the lower part of N7 of Blow.

On the basis of these associations, cores 4 and 3 may be referred to the *G. dissimilis* Zone or Zone N5. For reasons already mentioned above, core-2 could be referred to an interval of the *G. stainforthi* Zone of Bolli (Zone N6, or lower part of Zone N7 of Blow).

A few specimens of *G. (Clavatorella) bermudezi* are also found in core-3. According to Blow (1969) this species would appear first in Zone N8. However, the occurrence of other planktonics in this core does not support

this assumption. *G. bermudezi* was also found in association with *Globorotalia kugleri* and *Globigerinoides primordius* (suggestive for Zone N4) in core samples from Karaikal well-2 (unpublished). These observations clearly suggest that *G. bermudezi* has a long range, at least as far as Indian sections are concerned.

*Karaikal well-4 from bottom to top:*

Core-5 (1160 m.): A *Globorotalia kugleri* – *Globigerinoides primordius* assemblage (Zone N4) has been described by Raju (1971).

Core-3 (810.14–813.14 m.): *M. dehaartii* and *M. tani*.

Core-2: *M. globulina*. Planktonics include *Globigerinoides primordius*, *G. trilobus*, *G. sacculiferus*, *G. altiapertura*, forms transitional to *G. subquadratus*, *Globorotalia* cf. *siakensis* and *Globoquadrina* sp. Here again, the assemblage does not clearly indicate any particular zone. For similar reasons as mentioned for the previous core samples, this assemblage may be referred to Zone N5 of Blow or the *G. dissimilis* Zone of Bolli.

*Conclusions:* The following conclusions could be drawn from the available data from Kutch and Cauvery basin.

1. In Kutch, *M. cf. bermudezi* occurs below the *Globigerinoides* datum.

2. In Cauvery basin, *M. globulina* ( $\bar{V} = 17$ ) occurs together with planktonics which suggest Zone N5 of Blow, or the *G. dissimilis* Zone of Bolli.

From considerations of stratigraphic superposition, core 3 with *M. tani* and *M. dehaartii* might be equivalent to an interval from the upper part of Zone N4 to the lower part of Zone N5 of Blow.

3. In Cauvery basin, *M. excentrica* occurs together with planktonics, which suggest an interval of Zone N6 or the lower part of Zone N7 of Blow or the *G. stainforthi* Zone of Bolli.

#### CORRELATION OF THE SECTIONS IN THE INDO-PACIFIC AND THE "LETTER CLASSIFICATION"

From the considerations of distribution and phylogeny, all three lineages, *Miogypsinoides*, *Lepidosemicyclina* and *Miogypsina* s.s. in the Indo-Pacific offer a basis for detailed correlation.

In the Indo-Pacific province, the "letter classification" is in wide usage as a framework for chronostratigraphic classification and correlation. From the discussion presented by Adams (1970) and previous authors, the main difficulties in the application of the letter classification appear to be: a. No type sections were recognized. Controversies over "stage" boundaries cannot

be verified with reference to any particular standard section; b. Although the letter stages are meant as chronostratigraphic units, they are defined purely on the basis of assemblages of larger foraminifera. The ranges of most of the genera and species are dubious. Much of the published data on their distribution is from isolated sections; c. The basic problem which underlies most of

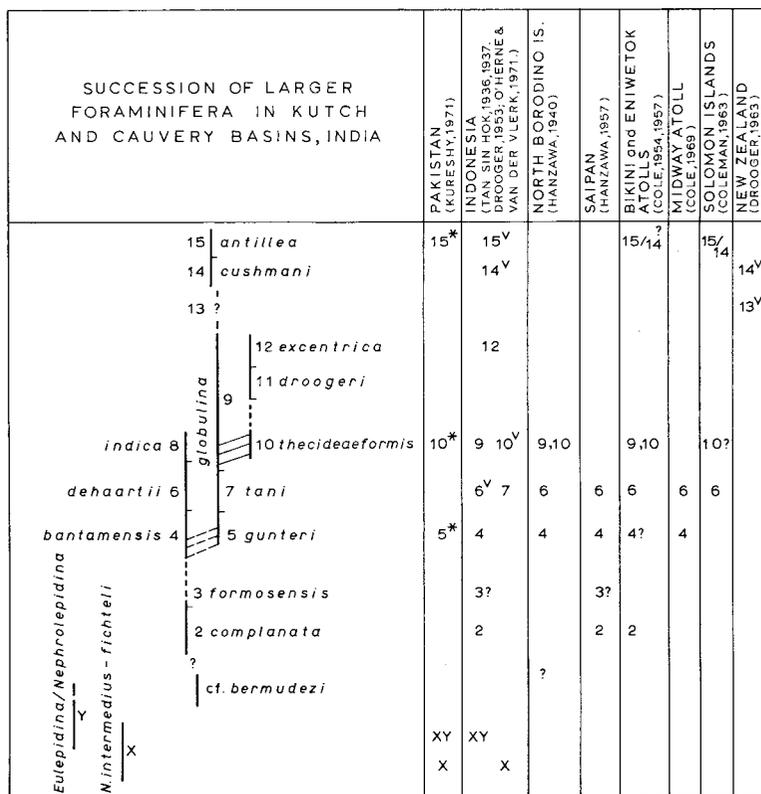


Fig. 37 Distribution of Miogypsinidae in the Indo-Pacific province. Evaluation of the specific units from outside India is based on a few pictured thin sections and needs to be considered subjective and approximative. Symbol V points to data on assemblages studied by Drooger (1953, 1963); the asterisk indicates specific units reported without accompanying description or figures.

the controversies about stratigraphic ranges, appears to stem from the widely different species concepts of authors. Under these circumstances, there seems to be little use to place our arguments of correlation in terms of the letter classification.

Any detailed correlation of our sections with those from other areas in the Indo-Pacific is difficult as most of the previous determinations of the Miogypsinidae have been based on typological species concepts, which again varied from one author to the other. The known distribution of the Miogypsinidae in some of the areas in the Indo-Pacific is summarized in fig. 37. The source of information for respective areas is given in the figure itself. In several cases, the specific names given by the original authors had to be changed for the purpose of this figure. For example, values of  $\bar{X}$  and other parameters are taken into consideration when 3 or 4 equatorial sections have been pictured from a single sample (Cole, 1969). In any case, the evaluation and relative position of the specific units shown in this figure, have to be considered as subjective and approximative.

#### CORRELATION OF THE INDIAN SUCCESSION WITH THE EUROPEAN STRATOTYPES

Following the classical works of the last century, the European stage nomenclature has become well entrenched in the geological literature, as a standard chronostratigraphic classification. Recent detailed investigations showed that many of the type deposits of the so-called standard stages do not contain diagnostic foraminifera, found to be reliable in correlation of sections elsewhere. As a consequence, the usage of the stage names and the attempted chronostratigraphic correlation with reference to European stages frequently has little bearing to the actual stratotypes. Indian stratigraphy is no exception, since several of the sections had been stamped as Aquitanian, Burdigalian, often with very little evidence.

From these considerations, the presence of Miogypsinidae in the stratotypes of the Aquitanian and Burdigalian in southwestern France (Drooger, 1955) and also in the recently designated stratotype of the Chattian in western Germany (Anderson et al., 1971) is of great importance in our attempts of chronostratigraphic correlation.

Correlation is not impeded by different concepts of species, because the Miogypsinidae from the type localities of these three stages have been investigated quantitatively (Drooger, 1955, 1960). According to Drooger (1966), the distribution of *Miogypsina* species in the stratotypes is as follows:

- Type Burdigalian: *M. intermedia* in uppermost beds.  
*M. globulina* in major part of the type deposits from the base onwards.  
*M. burdigalensis* in basal beds.
- Type Aquitanian: *M. tani* in middle and upper parts of the type deposits.  
*M. gunteri* in beds, considered to correspond to the lower part of the type Aquitanian, from a locality near Labrède.
- Chattian (Doberg): *M. septentrionalis*.

More recent ideas (Drooger and Marks, MS., personal communication) include to drop the term "Helvetian" and to extend the upper range of the Burdigalian to include also the succession underlying the *Orbulina* datum, hence, up to the base of the Langhian. Accepting this, younger members of Mediterranean *Miogypsina*, *M. cushmani* and *M. mediterranea*, are brought within the scope of the Burdigalian.

In order to get some insight into the problem involved in correlation, the following similarities and differences in the distributions and the implications of the assumed phylogenetic trends are taken into consideration:

1) *M. gunteri*, *M. tani* and *M. globulina* occur in both India and SW France. From the available data from India and Indonesia, *M. globulina* appears to become stagnant or it had a very low rate of development, whereas in the Aquitaine basin *M. globulina* gave rise to *M. intermedia*. This suggests that the upper limit of *M. globulina* cannot be used satisfactorily in interregional correlation between the Indo-Pacific and Europe.

2) In *Miogypsinoidea* the series from *M. complanata* to *M. bantamensis* is more or less well known from both areas, developing into *Miogypsina* s.s. Younger representatives of *Miogypsinoidea* are not known from the Aquitaine basin. If we exclude the possibility of reworking, *Miogypsinoidea* appears to be stagnant at the stage of *M. bantamensis* in some areas of the Mediterranean since it is reported from samples with *M. globulina* or *M. intermedia* (Bronnimann, 1940, Souaya, 1961). On the other hand, in India the development into the younger *Miogypsinoidea*, up to the stage of *M. indica* is parallel to that of the members of *Miogypsina* s.s. Under these circumstances the succession of younger *Miogypsinoidea* alone cannot be used satisfactorily.

3) The development of *Miogypsina* s.s. from *Miogypsinoidea* apparently took place at different  $\bar{X}$  levels — *M. septentrionalis* in northern Europe, *M. basraensis* in North Africa, *M. gunteri* in India and SW France. As such the succession of *Miogypsina* s.s. older than the level of *M. gunteri* cannot be used for direct correlations.

4) The youngest member of *Miogypsina* s.s. in the Mediterranean is *M. mediterranea* while it is *M. antillea* in India, but in both areas it is preceded by *M. cushmani*.

These considerations certainly contain the warning that not every stage of the development of the Miogypsinidae successions from different provinces can be used for precise chronostratigraphic correlations. However, we may as well take account of other aspects also. We are able to acknowledge these limitations simply because a vast amount of data on the Miogypsinidae, particularly from Europe, had been well documented. The gloomy picture presented above is not to show that the Miogypsinidae cannot be reliably used in interregional correlations. If we had to rely on the trends in the accompanying fauna of our sections, the situation would be much worse.

If we consider the rates at which the development of the Miogypsinidae took place and the possibility of parallel trends in some of the lineages, the limitations enumerated above appear exaggerated and the Miogypsinidae are

ZONES	RANGES OF OTHER SPECIES	KUTCH STAGES	EUROPEAN STAGES
<i>M. cushmani-antillea</i>			.....?.....
		-----?	
<i>M. excentrica</i>			
<i>M. droogeri</i>		VINJHAN	BURDIGALIAN
<i>M. globulina-thecidaeiformis</i>	<i>indica</i>		.....
<i>M. tani</i>	<i>dehaartii</i>		.....
<i>M. gunteri</i>	<i>bantamensis</i>	AIDA	AQUITANIAN
	<i>formosensis</i>		.....
<i>M. complanata</i> ( <i>M. cf. bermudezi</i> )		WAIOR	CHATTIAN
<i>N. intermedius-fichteli</i> / <i>Eulepidina</i>		RAMANIA	.....

Fig. 38 Interrelation between Indian larger foraminiferal zones, local stages of Kutch, and the European stages.

still reliable for detailed chronostratigraphic correlation. For the very reasons of the rapid rate of nepionic acceleration, Miogypsinidae might be more reliable than planktonics for certain intervals. The following reasoning could be used in our correlations.

1) Both in the Indian succession and in that of the Aquitaine basin, Europe, *M. gunteri* gave rise to *M. tani* and furthermore *M. tani* gave rise to *M. globulina*, the trends of both cases being in accordance with the principle of nepionic acceleration. There is hardly any evidence we could gather to show that these parallel trends are heterochronous. This leads us to the conclusion that our levels with *M. gunteri* and *M. tani* are equivalent to the Aquitanian. The beginning of *M. globulina* might well mark the beginning of Burdigalian time.

2) In the Indian succession, the trend of the development of *Miogypsinoides* from *M. bantamensis* to *M. dehaartii* is parallel to that of *M. gunteri* to *M. tani* and to the early stage of *M. globulina*, hence of Aquitanian-Early Burdigalian Age. The succession from *M. cf. bermudezi* to *M. complanata* and *M. formosensis* is older than *M. bantamensis*. In Europe *M. septentrionalis* is considered to be distinctly older than *M. gunteri* on the basis of the principle of nepionic acceleration (Drooger, 1963, 1966). On these considerations, we may assign our succession of *M. complanata-formosensis* to the Chattian.

3) Because of the more complex development of the Indian succession above the level of *M. tani* we may turn our attention to the associated planktonic foraminiferal assemblages. Planktonic foraminifera found in association with *M. excentrica* are suggestive of the *G. stainforthi* Zone or the lower part of the *G. insueta* Zone, thus distinctly below the *Orbulina* datum level. To this extent our succession with *M. thecideaeformis*, *M. droogeri* and *M. excentrica* appears to be well within the limits of the Burdigalian. In our samples planktonic foraminifera are not found in samples with *M. cushmani* or *M. antillea*. However, in several well sections examined during routine work *Orbulina* is not found in association with *Miogypsina*. It may be possible that the youngest members of *Miogypsina* s.s. from India may be well within the extended Burdigalian as well. In any case it will be difficult at present, to place the upper limit of the extended Burdigalian in our succession. The proposed correlations are summarized in fig. 38.

Van der Vlerk and Postuma (1967) reported the occurrence of a solitary specimen of *Orbulina* in sample Bg 296 from the Kombangan section in Madura. According to O'Herne and Van der Vlerk (1971) *Miogypsina* assemblages from samples Bg 295–Bg 297 gave a  $\bar{V}$  value of 81.2, which indicates the specific unit *M. cushmani* according to the  $\bar{V}$  scale. If the evidence of a

solitary specimen is taken into consideration the end members of *Miogyopsina* s.s. — *M. cushmani* and *M. antillea* — in Indonesia might be of post-Burdigalian (Langhian) Age. Whether such a situation is valid for the Indian succession as well, in view of its close affinity to that of Indonesia, cannot be evaluated at present. Other reported co-occurrences of *Orbulina* and *Miogyopsina* from the Eastern Indo-Pacific (such as Clarke & Blow, 1969; Coleman & McTavish, 1964), often lack published evidence, but they emphasize that in this part of the world *Miogyopsina* may have ranged higher than elsewhere.

In the light of these correlations we may evaluate the position of the local stages of Kutch, proposed by Biswas (1965, 1970). The stratotype of the Waior Stage with *M. cf. bermudezi*, *M. complanata* and an early stage of *M. formosensis* appears to be equivalent to the Chattian. The stratotype of the Aida Stage, in the Khari Nadi section, with *M. tani* appears to be equivalent to the Aquitanian. The lower part of the Aida Stage does not contain any diagnostic fauna. A para-stratotype of the Vinjhan Stage, in the Khari Nadi section, with *M. indica*, *M. thedeaeformis*, *M. droogeri* and *M. excentrica* may be referred to the Burdigalian.

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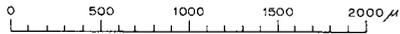
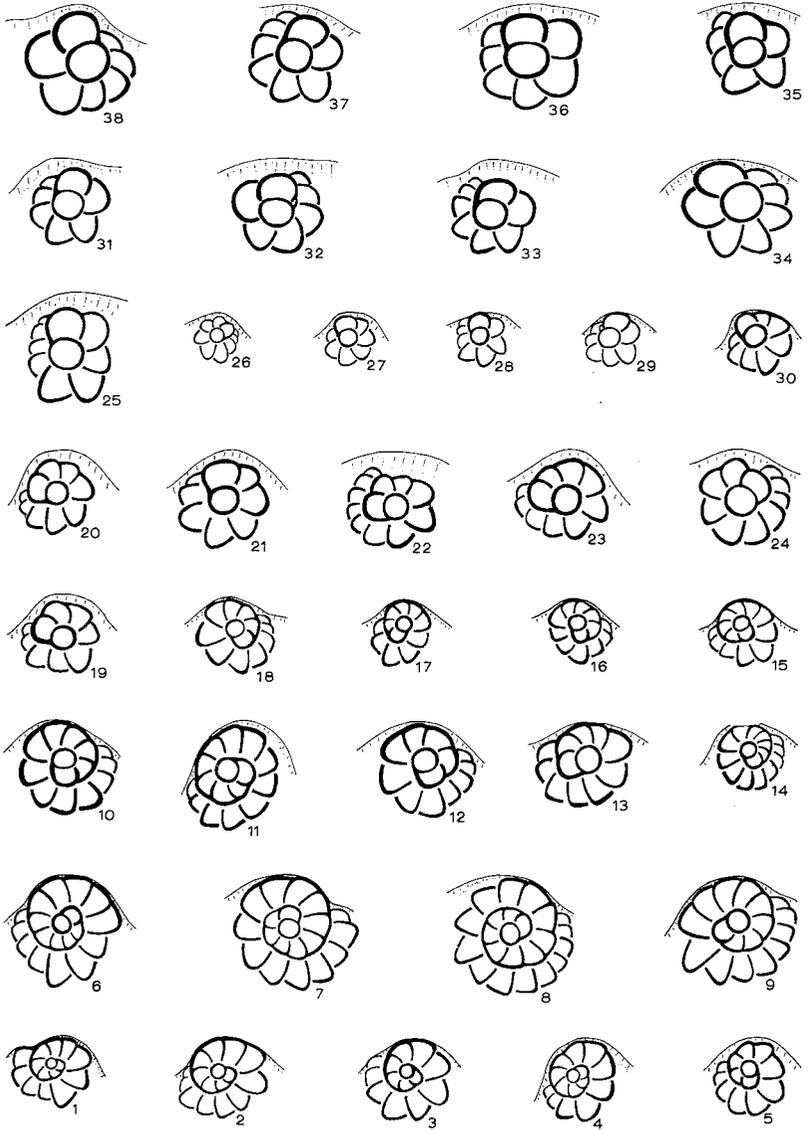
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PLATE 1

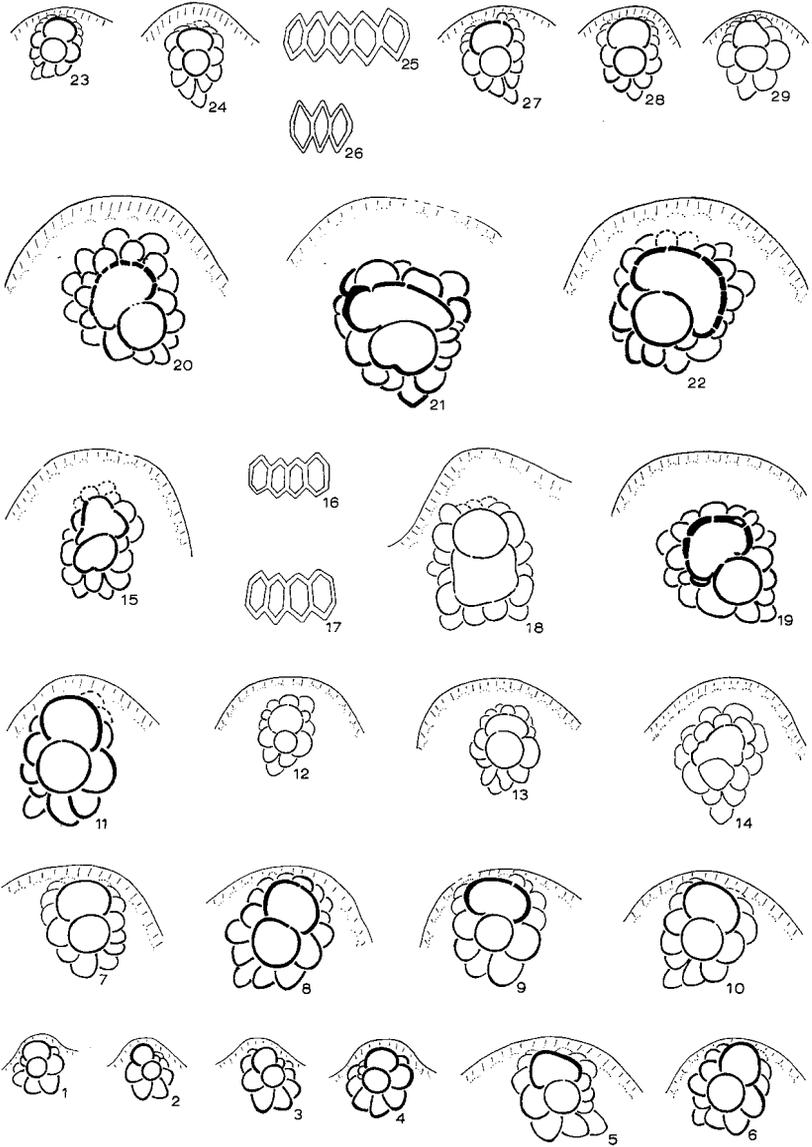


## Plate 1

Drawings of the embryonic-nepionic stage in median sections of *Miogypsina* specimens. The position of the apical periphery is shown. Stolons are slightly exaggerated.

- Figs. 1–5 *Miogypsina (Miogypsinoidea) cf. bermudezi* Drooger from sample KR 19, Waior section, Kutch.
- Figs. 6–9 *Miogypsina (Miogypsinoidea) complanata* Schlumberger from sample KR 11, Waior section, Kutch.
- Figs. 10–13 *Miogypsina (Miogypsinoidea) bantamensis* (Tan Sin Hok) from core no. 5, Madanam well-1, Cauvery basin.
- Figs. 14–18 *Miogypsina (Miogypsina) gunteri* Cole from core no. 5, Madanam well-1, Cauvery basin.
- Figs. 19–25 *Miogypsina (Miogypsinoidea) dehaartii* Van der Vlerk from sample G 1448, Khari Nadi section, Kutch. Figs. 22–25 are conical *cupulaeformis* variants.
- Figs. 26–30 *Miogypsina (Miogypsina) tani* Drooger from sample G 1448, Khari Nadi section, Kutch.
- Figs. 31–38 *Miogypsina (Miogypsinoidea) indica* Raju. Figs. 31–34 after specimens from G 1417, Khari Nadi section, Kutch; figs. 35–38 from sample SG 4 (type sample), Nandana section, Saurashtra.

PLATE 2

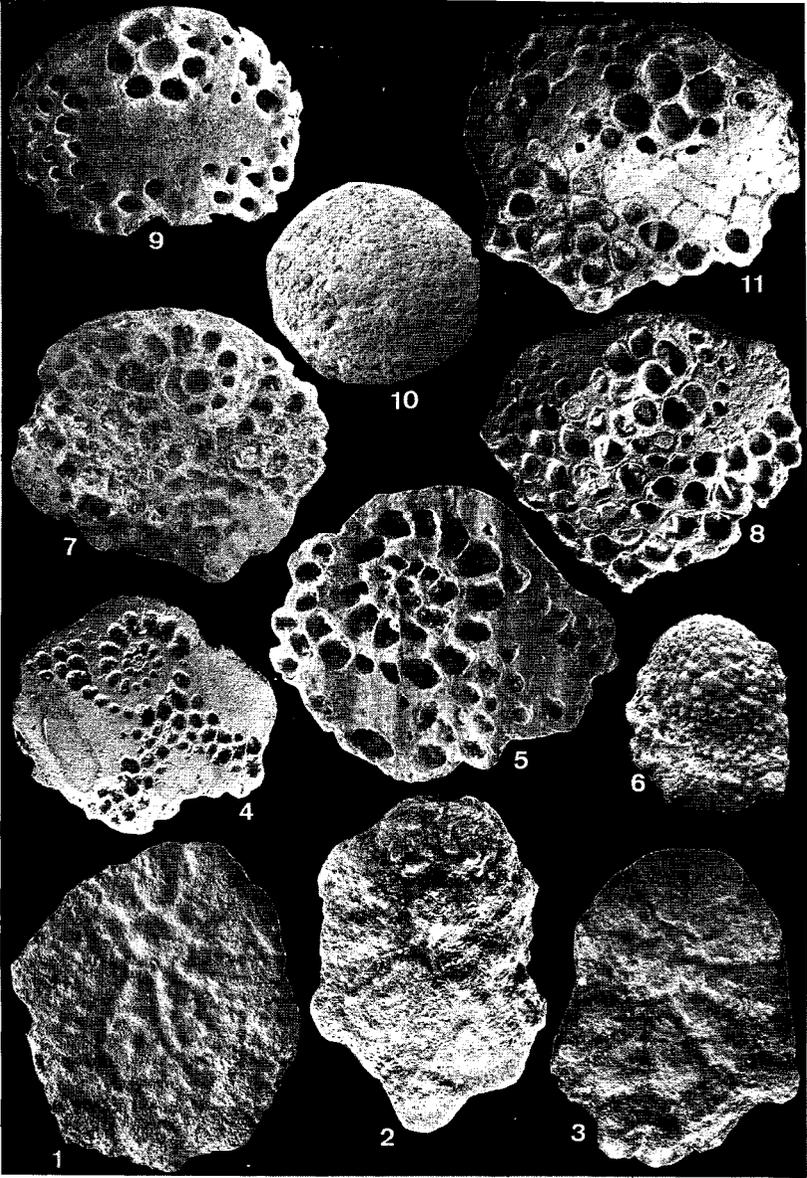


## Plate 2

Drawings of the embryonic–nepionic stage and of equatorial chambers in median sections of *Miogypsina* specimens. The position of the apical periphery is shown. Stolons are slightly exaggerated.

- Figs. 1–4      *Miogypsina (Miogypsina) globulina* (Michelotti) from core no. 2, Karaikal well 4, Cauvery basin.
- Figs. 5–11    *Miogypsina (Lepidosemicyclina) droogeri* Mohan & Tewari, figs. 5–9 from sample G 1406 and figs. 10, 11 from sample G 1401, Khari Nadi section, Kutch.
- Figs. 12–22   *Miogypsina (Lepidosemicyclina) excentrica* (Tan Sin Hok), figs. 13, 14, 16, 17, 18, 20 from sample 10–16 cm., and figs. 12, 15, 19, 21, 22 from sample 103–109 cm. of core no. 2, Madanam well 1, Cauvery basin. Figs. 16, 17 show the shape of elongate-hexagonal equatorial chambers after 3 to 4 rows away from the nepionic stage.
- Figs. 23–29   *Miogypsina (Miogypsina) antillea* (Cushman) from cuttings 246–252 m., Karaikal well 4, Cauvery basin. Figs. 25, 26 show the shape of maximal elongate-hexagonal equatorial chambers, observed in a few relatively large specimens, 10 or 11 rows away from the nepionic stage.

PLATE 3

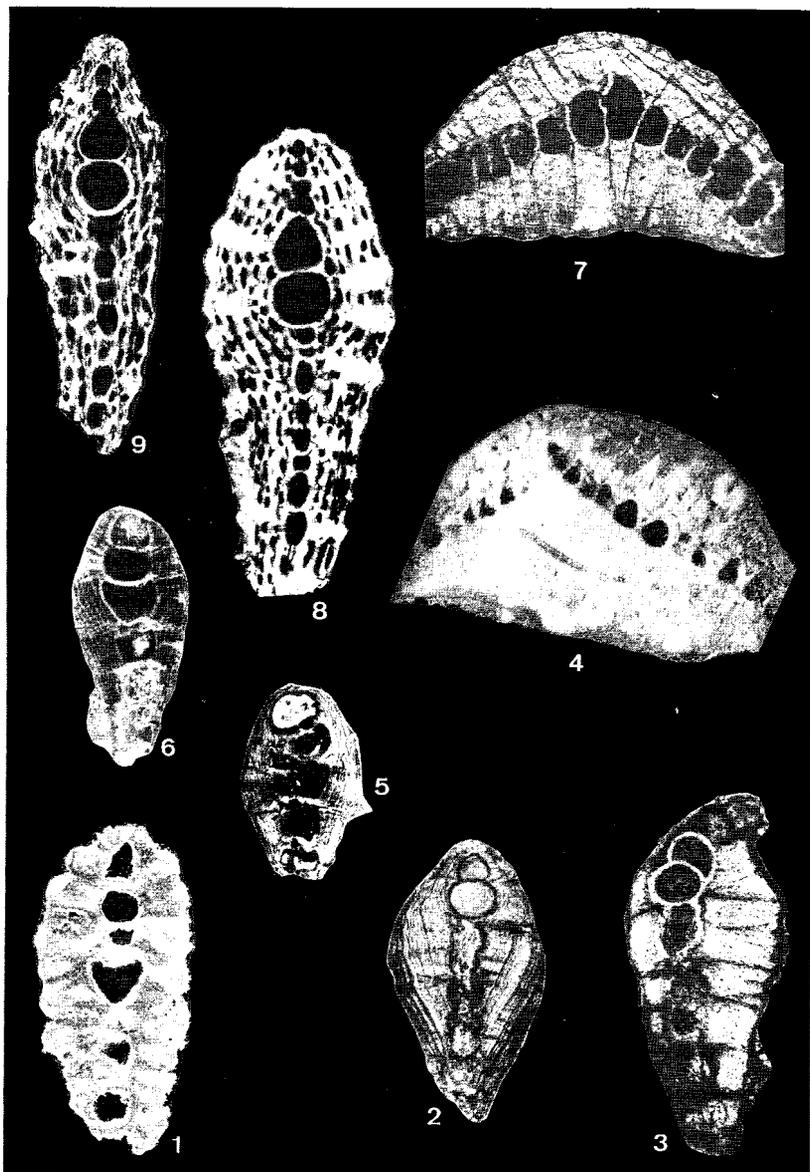


### Plate 3

#### External views and median sections.

- Figs. 1, 2      *Miogypsina (Miogypsinoidea) cf. bermudezi* Drooger from sample KR 19, Waior section, Kutch. Fig. 1,  $\times 105$ ; fig. 2,  $\times 130$ .
- Figs. 3–7      *Miogypsina (Miogypsinoidea) complanata* Schlumberger. Fig. 3,  $\times 70$  from sample KR 140, Khari Nadi section, Kutch. Figs. 4–6 from cuttings 888–879 m. Thirupundi deep well, Cauvery basin, fig. 4,  $\times 24$ , microspheric, 5,  $\times 22$ , and 6,  $\times 20$  external view. Fig. 7,  $\times 35$  from sample KR 123, Walasara section, Kutch.
- Fig. 8          *Miogypsina (Miogypsinoidea) dehaartii* Van der Vlerk var. *cupulaeformis* Zuffardi-Comerci, subconical form from sample G 1448, Khari Nadi section, Kutch.  $\times 35$ .
- Figs. 9–11     *Miogypsina (Miogypsinoidea) indica* Raju. Fig. 9,  $\times 30$ , holotype, and fig. 10,  $\times 20$ , paratype, external view of conical form (see pl. 4, fig. 7 for transverse section of this specimen) from sample SG 4, Saurashtra. Fig. 11,  $\times 35$ , from sample G 1417, Khari Nadi section, Kutch.

PLATE 4

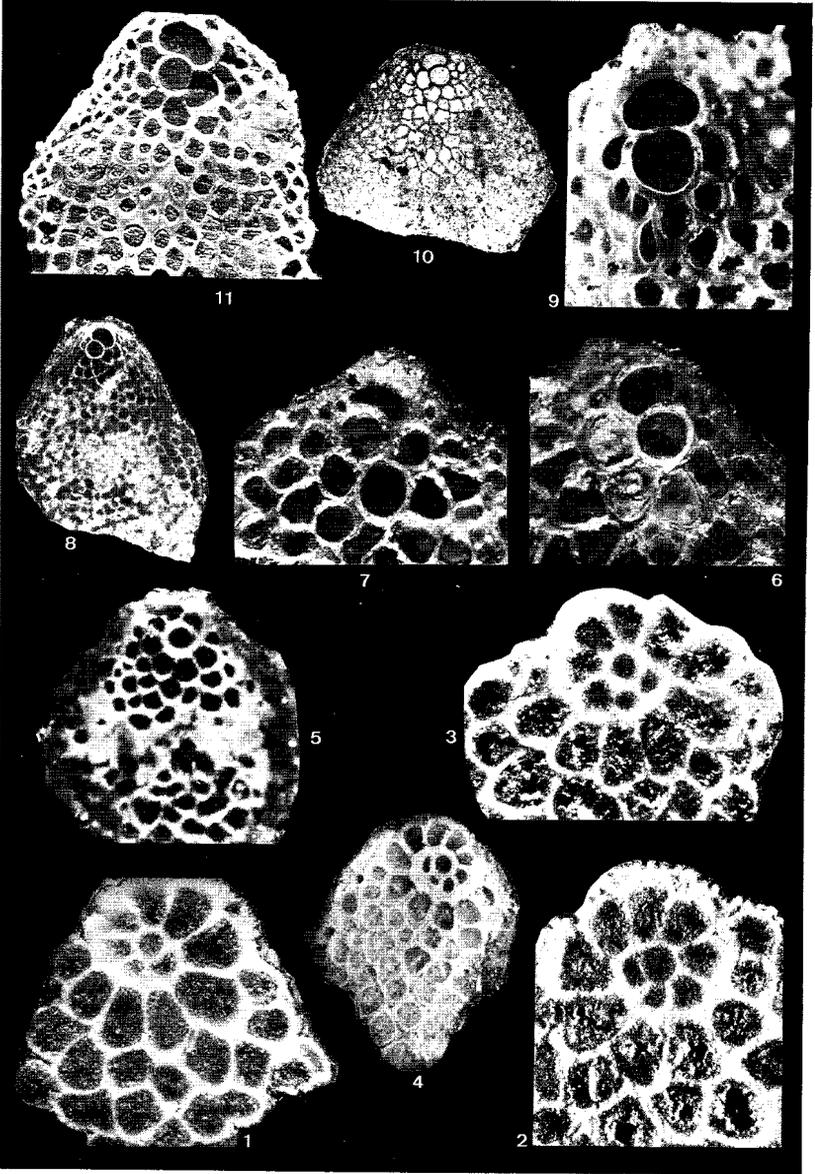


## Plate 4

### Transverse sections.

- Fig. 1 *Miogypsina (Miogypsinoides) formosensis* Yabe and Hanzawa from sample KR 332. Waior section, Kutch. x40.
- Figs. 2-4 *Miogypsina (Miogypsinoides) dehaartii* Van der Vlerk. Fig. 2, x38, flat form and fig. 4, x38 conical microspheric form from Jagatia shallow well, Saurashtra, Fig. 3, x42, subconical form from sample G 1448, Khari Nadi Section, Kutch.
- Figs. 5-7 *Miogypsina (Miogypsinoides) indica* Raju. Fig. 5, x35, from sample G 1417 and fig. 6, x35, from sample G 1415, Khari Nadi section, Kutch. Fig. 7, x38, paratype, conical form from sample SG 4, Saurashtra (see pl. 3, fig. 10 for external view of this specimen).
- Figs. 8, 9 *Miogypsina (Lepidosemicyclina) excentrica* (Tan Sin Hok) from core no. 2, Madanam well-1, Cauvery basin. x36.

PLATE 5

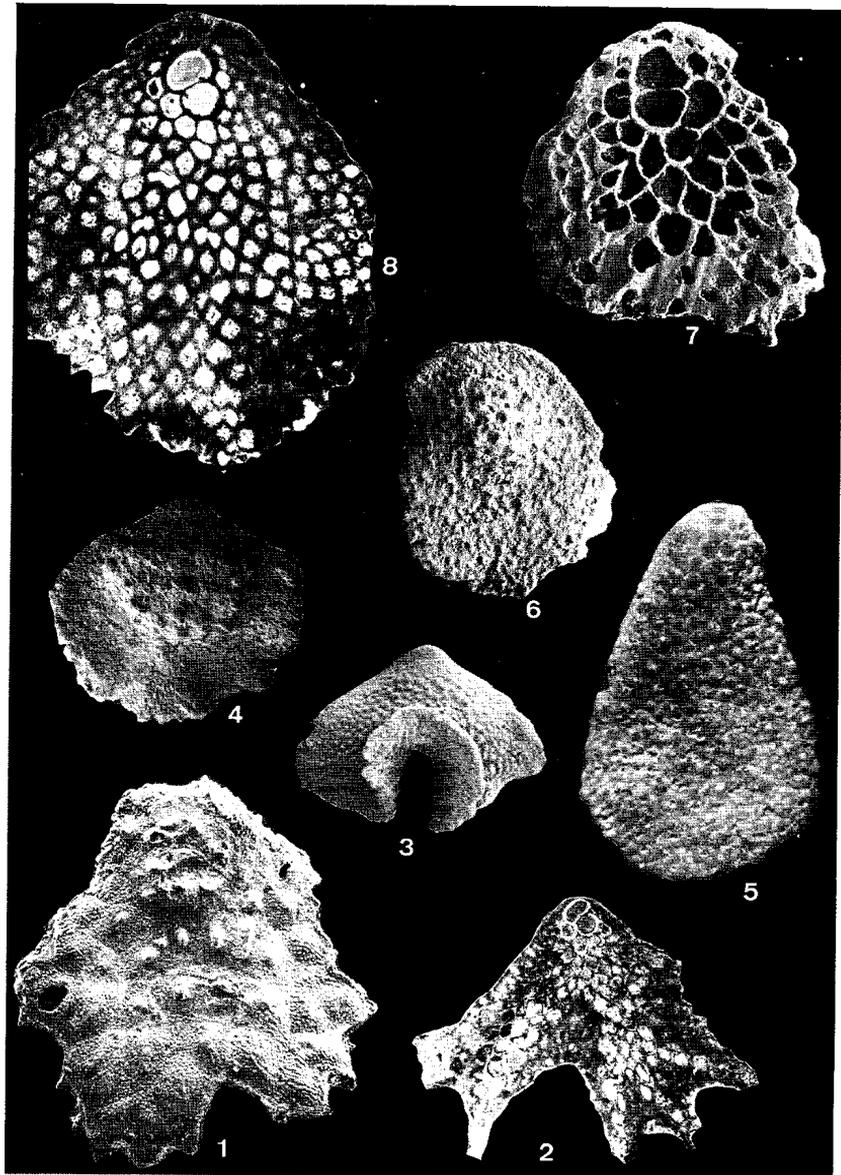


## Plate 5

### Median sections.

- Fig. 1–3 *Miogypsina (Miogypsinoidea) cf. bermudezi* Drooger from sample KR 19, Waior section, Kutch. x75.
- Fig. 4 *Miogypsina (Miogypsinoidea) bantamensis* (Tan Sin Hok) from core no. 5, Madanam well 1, Cauvery basin. x34.
- Fig. 5 *Miogypsina (Miogypsina) tani* Drooger from core no. 3, Karaikal well 4, Cauvery basin. x38.
- Fig. 6, 7 *Miogypsina (Miogypsina) globulina* (Michelotti) from core no. 2, Karaikal well 4, Cauvery basin. x75.
- Figs. 8, 10, 11 *Miogypsina (Lepidosemicyclina) droogeri* Mohan & Tewari from sample G 1406, Khari Nadi section, Kutch. Figs. 8, 10, x16; fig. 11, x30.
- Fig. 9 *Miogypsina (Miogypsina) antillea* (Cushman) from cuttings 246–252 m., Karaikal well 4, Cauvery basin. x85.

PLATE 6



## Plate 6

External views and median sections.

- Fig. 1 *Miogypsina (Miogypsina) globulina* (Michelotti), external view of a juvenile form without lateral chambers, from core no. 2, Karaikal well 4, Cauvery basin. x115.
- Figs. 2–4 *Miogypsina (Lepidosemicyclina) thecideaformis* (Rutten). Fig. 2, x20, equatorial section and fig. 3, x14, external view, from sample SG 4, Saurashtra. Fig. 4, x14, from sample G 1415, Khari Nadi section, Kutch.
- Figs. 5–6 *Miogypsina (Lepidosemicyclina) excentrica* (Tan Sin Hok). Fig. 5, x20, from core no. 2, Madanam well 1, Cauvery basin. Fig. 6, x14, from KR 36, Khari Nadi section, Kutch.
- Figs. 7, 8 *Miogypsina (Miogypsina) antillea* (Cushman) from cuttings 246–252 m., Karaikal well 4, Cauvery basin. Fig. 7, x48; fig. 8, x35.

PLATE 7

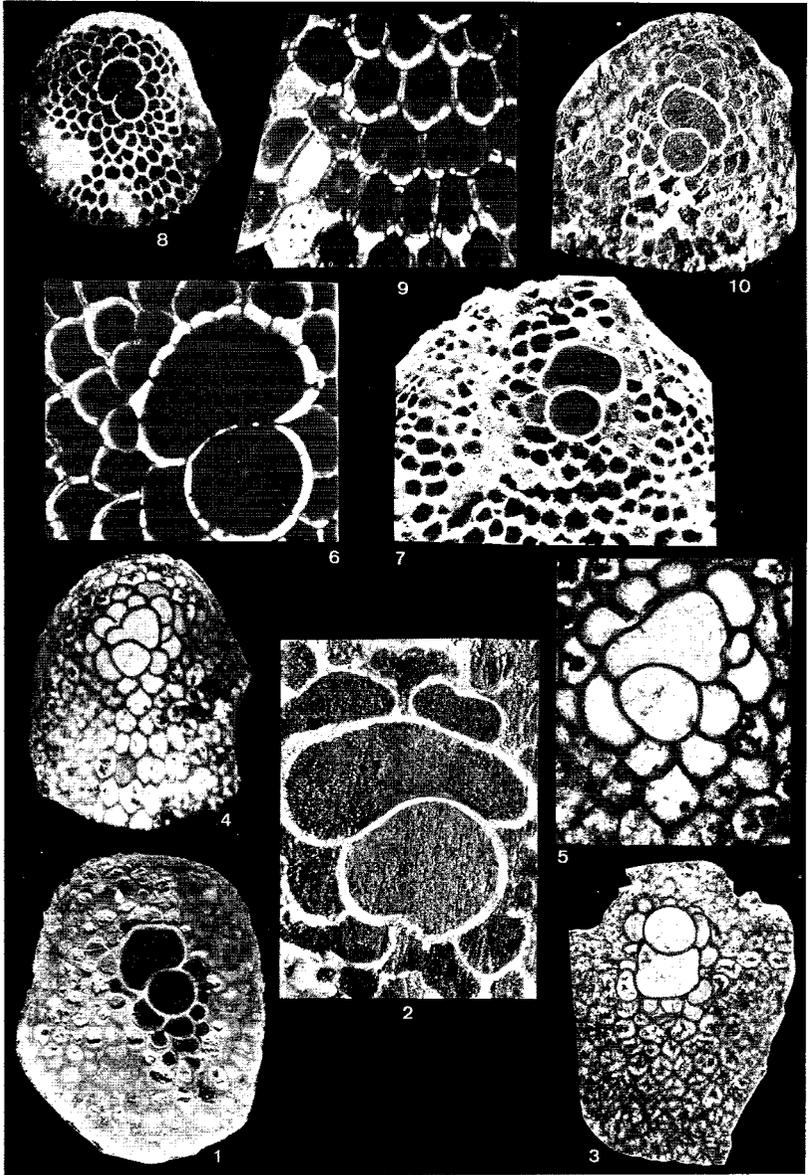
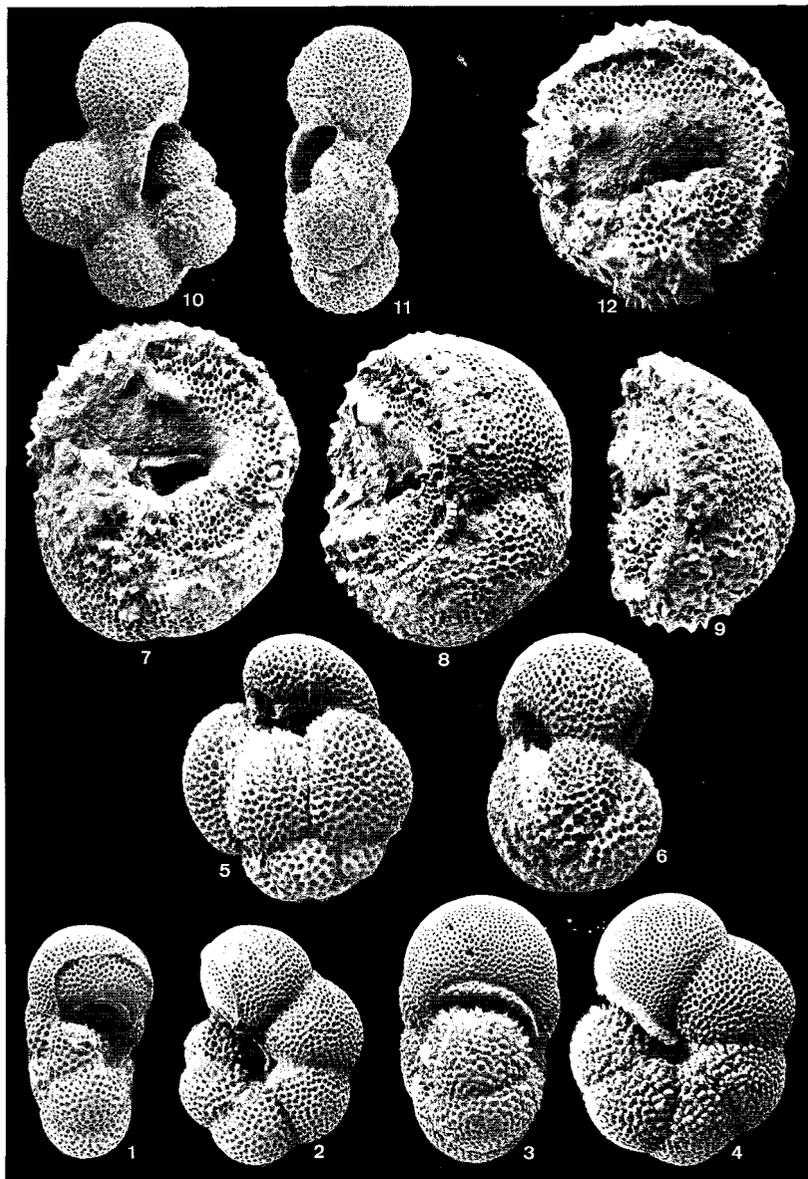


Plate 7

Figs. 1–10 *Miogypsina (Lepidosemicyclina) excentrica* (Tan Sin Hok). All equatorial sections of specimens from core no. 2, Madanam well 1, Cauvery basin. Figs. 4, 5, 6, 8, 9 from 10–16 cm., and the others from 103–109 cm. Figs. 1, 3, 4, 7, 10, x30; figs. 2, 5, 6, 9, x72; fig. 8, x18. Fig. 5, enlargement of the embryonic-nepionic stage of fig. 4. Fig. 6 enlargement of the embryonic-nepionic stage, and fig. 9 enlargement of the equatorial chambers of fig. 8.

PLATE 8



## Plate 8

### Planktonic foraminifera.

Figs. 1–9, 12, x100; figs. 10, 11, x130.

- Figs. 1, 2        *Globorotalia siakensis* LeRoy from core no. 3, Madanam well 1, Cauvery basin.
- Figs. 3, 4        *Globorotalia* cf. *siakensis* LeRoy from core no. 3, Madanam well 1, Cauvery basin.
- Fig. 5            *Globoquadrina altispira* (Cushman and Jarvis) from core no. 3, Madanam well 1, Cauvery basin.
- Fig. 6            *Globigerinoides altiapertura* Bolli from core no. 3, Madanam well 1, Cauvery basin.
- Figs. 7–9, 12    *Globoquadrina praedeheiscens* Blow and Banner from core no. 4, Madanam well 1, Cauvery basin. Figs. 9 and 12 show a specimen, the final one or two chambers of which have broken off; it resembles *Globigerina binaiensis* Koch.
- Figs. 10, 11     *Globorotalia (Clavatorella) bermudezi* (Bolli) from core no. 3, Madanam well 1, Cauvery basin.

SAMPLE	X			Y			Z			Y*			I <sub>μ</sub>		II <sub>μ</sub>		DETERMINATION		
	N	Range	Mean ± σ <sub>w</sub>	N	Range	Mean ± σ <sub>w</sub>	N	Range	Mean ± σ <sub>w</sub>	N	Range	Mean ± σ <sub>w</sub>	N	Range	Mean ± σ <sub>w</sub>	N		Range	Mean ± σ <sub>w</sub>
KR 123	25	14-21	1742 ± 0.35	25	6-12	95 ± 0.31	21	8-14	110 ± 0.35	22	-405 - -180	-316 ± 12.96	18	75 - 184	116 ± 65	15	90 - 184	112 ± 75	<i>complanata</i>
KR 332	25	14-21	1612 ± 0.4	25	6-11	86 ± 0.24	22	9-15	110 ± 0.36	25	-405 - -220	-280 ± 97	21	84 - 150	125 ± 39	17	100 - 159	127 ± 42	<i>formosensis</i>
KR 11	25	15-22	178 ± 0.36	25	8-13	972 ± 0.27	23	6-16	1226 ± 0.35	25	-445 - -260	-327 ± 956	24	76 - 150	114 ± 34	19	92 - 167	118 ± 42	<i>complanata</i>
KR 330	20	11-15	1255 ± 0.27	20	3-9	635 ± 0.27	18	7-11	88 ± 0.27	17	-320 - -120	-229 ± 132	118	67 - 117	82 ± 3	14	58 - 117	80 ± 43	<i>cf. bermudezi</i>
KR 19	25	9-16	1252 ± 0.37	25	4-10	666 ± 0.28	25	7-13	88 ± 0.3	25	-365 - -155	-248 ± 475	25	50 - 92	74 ± 17	18	50 - 92	76 ± 28	<i>cf. bermudezi</i>

Table I Results of counts and measurements on assemblages of *Miogypsinoides* from sections Waior and Walasara, Kutch.

SAMPLES	X	Y	Z	Y*	I <sub>μ</sub>	II <sub>μ</sub>
KR 19 KR 330	0.06	0.78		1.55 <sup>k</sup>	2.64	0.84
KR 19 KR 11	10.35	7.81	7.51	7.4	11.55	8.76
KR 19 KR 332	6.67	5.21	4.71	3.79	13.63	9.47
KR 330 KR 332	7.09	6.24	4.75	3.74	8.78	7.17
KR 11 KR 332	3.15	3.06	2.52	2.79	2.17	1.42
KR 11 KR 123	0.76	0.53	2.55	0.69	0.29	0.74
KR 11 KR 140	0.85	2.01	0.59	3.25	4.59	2.79
KR 123 KR 140	1.67	2.49	2.04	3.43	3.43	
KR 123 KR 332	2.46	2.28		1.69	1.26	1.71

Table V t values of characteristics for pairs of early *Miogypsinoides* assemblages from sections Waior, Walasara and Khari Nadi, Kutch.

SAMPLES NUMBER	GROUP	X	Y	Y*	V	I
KR 155		3.88	3.49	4.22		0.58
G 1448	B					
G 1448	B	3.58	5.83	4.04		2.13
G 1437						
G 1448	A+AF	1.63				3.36
G 1421	A					
G 1417	A	3.49		3.91		
G 1437					4.98	5.03
G 1421	B					6.97
G 1421	B				0.47	1.75
G 1417	B				1.56	3.81
G 1417	B					2.11
G 1415	B					
G 1406	A				3.86	2.75
KR 36	A					0.82
G 1401	B+AB				0.92	0.74
KR 36	B					1.52

Table VI t values of several characteristics for pairs of some *Miogypsinoides*, *Miogypsinina* s.s. and *Lepidosemicyclina* assemblages from section Khari Nadi, Kutch.

SAMPLE	GROUP	X			Y			Z			Υ*			V			I <sub>μ</sub>			II <sub>μ</sub>			Σ <sub>T</sub>	DETERMINATION		
		N	Range	Mean ± σ <sub>M</sub>	N	Range	Mean ± σ <sub>M</sub>	N	Range	Mean ± σ <sub>M</sub>	N	Range	Mean ± σ <sub>M</sub>	N	Range	Mean ± σ <sub>M</sub>	N	Range	Mean ± σ <sub>M</sub>	N	Range	Mean ± σ <sub>M</sub>				
KR 36	B	20	5-7	6.0 ± 0.072						20	-20 - +45	-18.3 ± 36.3	20	0 - 292	187 ± 164	20	84 - 125	103 ± 34	20	84 - 159	116 ± 42	1126	<i>globulina</i>			
	A									27	-65 - +35	5.0 ± 38.6	27	762 - 988	907 ± 140	27	25 - 268	199 ± 55	27	159 - 334	268 ± 78	1347	<i>excentrica</i>			
G1401	B+AB	39	5-7	6.21 ± 0.091						39	-40 - +50	-13.84 ± 29.3	39	0 - 409	205.2 ± 156	39	67 - 217	116 ± 59	39	75 - 259	131 ± 69	1134				
	B	21	5-7	6.23 ± 0.117						21	-40 - +35	3.8 ± 35.1	21	0 - 295	154.2 ± 161	21	67 - 125	89 ± 27	21	75 - 125	98 ± 3	1096	<i>globulina</i>			
	AB	18	5-7	5.16 ± 0.145						18	+10 - +50	-25.55 ± 31.0	18	10 - 409	264.6 ± 208	18	100 - 217	47 ± 72	18	117 - 259	170 ± 75	1160	<i>globulina</i>			
	A									9	+5 - +50	-23.33 ± 45.6	10	763 - 968	865 ± 195	10	150 - 292	204 ± 118	10	208 - 334	281 ± 117	1382	<i>droogeri</i>			
G1406	B AB	41	5-7	5.98 ± 0.088						41	-30 - +45	-12.68 ± 28.9	41	0 - 428	204.6 ± 134	41	67 - 200	120 ± 64	41	84 - 242	142 ± 79	1183				
	B	20	5-7	6.2 ± 0.116						20	-30 - +45	+10 ± 40.6	20	0 - 25.6	15.6 ± 185	20	67 - 100	82 ± 2	20	84 - 117	94 ± 26	1155	<i>globulina</i>			
	AB	21	5-7	5.76 ± 0.117						21	0 - +45	-23.0 ± 22.3	21	0 - 42.8	25.52 ± 115	21	125 - 200	157 ± 41	21	159 - 242	188 ± 47	1198	<i>globulina</i>			
	A									20	0 - +70	-26.3 ± 37.3	20	577 - 95.7	837 ± 227	20	142 - 292	91 ± 85	20	169 - 342	249 ± 96	1304	<i>droogeri</i>			
G1415	B (H2O)	35	5-7	6.17 ± 0.086						35	-5 - +55	-18.5 ± 24.4	35	196 - 389	288 ± 086	35	84 - 168	129 ± 32	35	100 - 208	157 ± 46	1217	<i>thecideaeformis</i>			
	A	12	5-7	6.42 ± 0.190	12	0-1	0.50 ± 0.106	12	1-3	1.91 ± 0.259	13	-5 - +45	-6.23 ± 35.3						13	134 - 225	180 ± 73	12	168 - 225	195 ± 49	1083	<i>indica</i>
G1417	B	25	5-7	6.04 ± 0.107	22	0-1	0.05			25	-10 - +40	-24.2 ± 26.7	25	104 - 42.9	22.6 ± 150	25	92 - 208	142 ± 58	23	100 - 242	169 ± 69	1190	<i>globulina-thecideaeformis</i>			
	A	17	6-8	6.58 ± 0.149	17	0-1	0.47 ± 0.079	14	1-3	1.78 ± 0.193	18	-30 - +45	-16.66 ± 43.1						18	142 - 250	189 ± 64	18	176 - 268	218 ± 65	1153	<i>indica</i>
G1421	B	33	6-7	6.36 ± 0.084	31	0-1	0.09			32	-30 - +55	-21.9 ± 37.9	33	0 - 271	191.2 ± 102	33	84 - 159	122 ± 33	33	84 - 217	141 ± 51	1156	<i>globulina</i>			
	A	11	7-9	7.45 ± 0.207	11	0-2	1.18 ± 0.121	8	2-4	3.37 ± 0.245	11	-35 - +15	-9.54 ± 48.9						11	142 - 200	173 ± 57	11	159 - 234	194 ± 77	1126	<i>dehaartii</i>
G1437	B	28	6-7	6.32 ± 0.089	24	0-2	1.08 ± 0.064	23	3-4	3.13 ± 0.064	27	-40 - +37	-2.3 ± 30.3	28	0 - 293	95.5 ± 168	28	84 - 134	95 ± 24	27	84 - 134	101 ± 25	1063	<i>globulina-tani</i>		
G1448	B	25	6-8	6.88 ± 0.133	25	0-3	1.98 ± 0.139	21	2-5	3.55 ± 0.161	25	-65 - +30	-20.2 ± 47.7						25	75 - 150	104 ± 36	23	75 - 142	111 ± 38	1067	<i>tani</i>
	A AF	40	7-11	7.98 ± 0.161	40	1-4	2.11 ± 0.084	36	2-5	3.98 ± 0.096	40	-95 - 0	-35.1 ± 37.5						40	133 - 217	171 ± 32	40	125 - 217	178 ± 31	1041	<i>dehaartii</i>
	AF	25	7-8	7.44 ± 0.101	25	1-3	2.08 ± 0.094	23	3-5	4.0 ± 0.117	25	-70 - 0	-32.2 ± 36.3						25	133 - 208	171 ± 4	25	133 - 217	177 ± 37	1035	<i>dehaartii s.s.</i>
	A	15	7-11	8.82 ± 0.273	15	2-4	2.17 ± 0.160	13	2-5	3.96 ± 0.173	15	-95 - 0	-38.3 ± 89.9						15	133 - 217	170 ± 54	15	125 - 217	179 ± 56	1053	<i>dehaartii var cupulaeformis</i>
KR155		35	6-10	7.77 ± 0.169	33	1-4	2.62 ± 0.120	29	3-7	4.31 ± 0.176	34	-130 - 0	-51.62 ± 58.4						35	75 - 125	102 ± 19	33	75 - 125	106 ± 25	1039	<i>tani</i>
KR140		25	16-21	18.2 ± 0.31	25	8-13	10.5 ± 0.25	16	6-14	11.97 ± 0.3	23	-455 - -270	-374 ± 1109						22	67 - 125	92 ± 36	20	67 - 130	92 ± 84	100	<i>complanata</i>

Table II Results of counts and measurements on assemblages of *Miogypsinoidea*, *Miogypsina s.s.* and *Lepidosemicyclina* from section Khari Nadi, Kutch.

