INTRODUCTION
CHAPTER I

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A. PREFACE

The district of Kutch in Gujarat, western India, is well-known for its fossiliferous Mesozoic and Cenozoic marine successions. The ammonoids constitute the most dominant group of fossils in the Mesozoic part while the foraminiferids are the most abundantly occurring marine fossils in the Cenozoic rocks. The earliest monographic publication on organic remains of the Indian Subcontinent was from this Meso-Cenozoic succession of Kutch (Sowerby, 1840). Overlying the Deccan Trap, sediments ranging in age from Palaeocene to Recent are well-exposed here along the coast of Kutch Mainland. The Lower Tertiary part of the sequence forms a belt extending from Lakhpat in the northeast to Goyela in the southeast. Numerous stream, nala and road sections permit detail examination and collection of fossiliferous samples from the succession. It is the only area in India where fossiliferous marine sediments ranging in age from Palaeocene to Late Oligocene are well-exposed.

Foraminifera which constitute the dominant group are represented by larger as well as smaller foraminifera. In the Eocene-Oligocene part of the succession larger foraminifera occur as rock-forming elements at several horizons. Loose specimens of larger foraminifera are found scattered over the greater part of the Tertiary outcrop belt. Since early sixties Dr. B.K. Samanta and his students in the Geology Department of the University of Calcutta are carrying on field and laboratory investigations on the stratigraphy and foraminifera of this Lower Tertiary Succession of Kutch. A research project entitled "Study of foraminiferal biofacies and
MAP OF WESTERN INDIA SHOWING THE
STUDY AREA

FIG. 1
microenvironments of Palaeogene sediments of Western Kutch, Gujarat" financed by KDMIPE, Oil and Natural Gas Commission (ONGC), Dehra Dun was started in 1981 in this department under the supervision of Dr. Samanta. In course of this project work systematic collection of samples were made along selected traverses in Western Kutch followed by a thorough study of the contained larger foraminifera. In the present dissertation, which forms a part of this project, an account of the stratigraphy and larger foraminifera of the Lower Tertiary rocks exposed between Kapurasi in north and Harudi in south is provided.

B. GENERAL INFORMATION

The area of the present study is located in the northwestern part of Kutch District, Gujarat, western India. It extends from Kapurasi (23°42'26"N : 68°38'24"E) in the north to Harudi (23°30'30"N : 68°41'10"E) in the south. Bhuj, the district headquarter is 2500 km. away from Calcutta (Fig. 1) and connected by rail as well as air which in turn, linked with Narayan Sarovar (23°40'30"N : 68°37'30"E), a pilgrimage, by motorable metal roads, one via Naliya (23°15'00"N : 68°50'10"E) and another via Matanomadh (23°32'30"N : 68°59'10"E). The road via Naliya is of 'all-weather' in nature. All the traverses in the mapped area are easily approachable as in-between places are connected by roads or foot-tracks. Specially, the type sections of Naredi and Harudi Formations are located by the side of Naliya-Narayan Sarovar road. Communications between different camps in the field were made by bus and bullocks cart.

The Kori Creek, an inlet of Arabian Sea, forms a long, conti-
MAP OF KUTCH MAINLAND SHOWING THE OUTCROP
PATTERN OF CENOZOIC MARINE SEDIMENTS

INDEX
QUATERNARY
NEOGENE
PALEOGENE
DECCAN TRAP
MADE AREA

FIG. 2

INDIA
PAKISTAN
LAKHPAT
NARAYAN SADAR
MALIYA
GANDHIDHAM
BHUIJ

KMS.
200
10
0
nuous tidal plane in the north-western part of the mapped area. Excluding the south-eastern portion around Nareda-Baranda area, which is made up of highly rugged terrain with a number of small mounds or hillocks, the rest of the country shows a vast flat terrain gradually dipping towards the coast representing the coastal strip of Kutch Mainland. The maximum altitude in the present area is 304 m. Three major streams, the Kakdi Nadi, the Guvar Stream and the Matiwariwali Nadi which run into the sea constitute the main drainage system of this area. They are fed by rain waters only. The combination of the Kakdi Nadi and Matiwariwali Nadi represents the longest river flowing from south to north having an artificial water reservoir covering 5.86 sq. km. area at their junction, just north of Godhatad (Pl. 10, Fig. 1). The Guvar stream flows from east to west. The general drainage pattern is dendritic formed by numerous gullies and nalas on subhorizontal beds.

The climate is typically arid with negligible rainfall. There is not much vegetation - cover over the greater part of the study area. The low dipping beds form wide outcrop over the rather flat terrain permitting collection of larger number of fossiliferous samples. The summer months are not suitable for field. The period from November to March is most suitable for carrying out systematic field work in this arid region.

C. PREVIOUS WORK

There are numerous publications on the geology and palaeontology of Kutch, Gujarat. There are monographic publications on megainvertebrates of the Mesozoic of this region. The Tertiary part
of the succession had received special attention rather recently in connection with the search for petroleum. However, detail account of the dominant fossil group in the Tertiary rocks of Kutch, namely, the foraminifera is still lacking. Here, mainly the significant contributions on the lithostratigraphy, biostratigraphy and larger foraminifera of the Lower Tertiary of the Kutch with particular reference to the Guvar-Nareda area are reviewed.

a. Lithostratigraphy

The earliest geological map of the present area was provided by Grant (1840) who recognised the 'Nummulitic limestone and marl' and the 'Tertiary strata' as the fifth and sixth units respectively of his stratigraphic succession of Kutch. Later, Wynne & Fedden (1869) of the Geological Survey of India published a geological map of the whole of the Mainland of Kutch showing the distribution of the different formations. In this Memoir, Wynne presented for the first time a detailed account of the geology of Kutch. The Tertiary succession was considered by him to range from Eocene to Pliocene. The total thickness was estimated to be 1600' to 2600'. He proposed the following geological sequence of Kutch:

<table>
<thead>
<tr>
<th>Formations</th>
<th>Subdivisions</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent</td>
<td>Alluvium, blown sand and sub-recent deposits (m-n)</td>
<td>Pleistocene</td>
</tr>
</tbody>
</table>

(Contd....)
<table>
<thead>
<tr>
<th>Formations</th>
<th>Subdivisions</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tertiary</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Upper Tertiary)</td>
<td>F(1)</td>
</tr>
<tr>
<td></td>
<td>(Upper Jurassic Group)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Dogger)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Syenite)</td>
<td></td>
</tr>
</tbody>
</table>

He classified the Tertiary part of the sequence of Kutch in detail as follows:

(Stratigraphic Order)

? *Pliocene*  
*Variable and inconstant deposits, including*
*concrete beds of great thickness*

? *Miocene*  
F *Soft sandstones, shelly, calcareous and quartzose grits, gravels and conglomerates with trap pebbles and agates*
*Brown sands and sandstones with fossil timber*  
*200'-500'*
Miocene or E
Upper Eocene

---------Unconformity---------

A great thickness of clays & shales alternating with sandy shales & Harder bands of shelly limestone or marls; a few nodular clay & conglomerate beds

In the upper part fossils most abundant, often forming whole beds.

The lower part often rusty brown & sandy, with ferruginous & lateritic bands and some conglomerates. Some of the sands richly mottled & in parts white, some large bones etc., in one of the lower conglomerates.

Mottled, white, iron stained, streaky, fine silty sandy shales, soft and friable, obliquely laminated, irregularly bedded & often lenticular; contain impression of leaves ... 100'

Dun coloured & blue silty clays & blue shales; contain the carapace of a minute crab, etc. ... ... ... ... ... 30'

Marly beds with a few fossil casts & Nummulites in lower part.

Nummulitic marls and limestones ... 700'

(? ) Operculina gypseous shales with nodular bands and laterite above and below. An oyster bed sometimes on this horizon ... 100'

Finely laminated shales, upper part rusty brown and friable; lower argillaceous and bituminous & Pyritous, with small lumps of mineral resin, butumen & c.

Small horny plates, possibly belonging to a crustacean and woody fragments and leaf impressions best preserved in the lower part.

Total : 1600'- 2600'
The subdivisions of the Cenozoic successions of Kutch proposed by Wynne were followed by Meddlicot & Blanford (1879).

The most detailed investigations on the rock-stratigraphy of the Tertiary of Kutch were carried out by the geologists of the Oil & Natural Gas Commission (ONGC) under the leadership of Dr. S. K. Biswas who along with Dr. S.N. Raju published for the first time a rock-stratigraphic classification following the Code of Stratigraphic Nomenclature (1971). They (Biswas & Raju, 1971, 1973) recognised eight formations in the Tertiary succession of Kutch estimated to be about 2000' thick.

<table>
<thead>
<tr>
<th>Formations</th>
<th>Members</th>
<th>Lithology</th>
<th>Thickness (in feet)</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandhan</td>
<td>sandstone, siltstone, marl</td>
<td>965</td>
<td>Pliocene</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Disconformity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vinjhan</td>
<td>Siltstone</td>
<td>siltstone, shale</td>
<td>425</td>
<td>Miocene</td>
</tr>
<tr>
<td>Shale</td>
<td>Chhasra</td>
<td>shale, claystone, argillaceous limestone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Khari</td>
<td>siltstone, claystone</td>
<td>240</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nadi</td>
<td>Ber Moti</td>
<td>sandstone, limestone</td>
<td></td>
<td>Oligocene</td>
</tr>
<tr>
<td></td>
<td>Coral</td>
<td>marl, limestone, claystone</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Limestone</td>
<td>claystone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maniyara</td>
<td>Lumpy Clay</td>
<td>claystone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fort</td>
<td>Basal</td>
<td>siltstone</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Paraconformity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fulra</td>
<td>Limestone</td>
<td>foraminiferal limestone</td>
<td>75</td>
<td>Middle</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Eocene</td>
<td></td>
</tr>
<tr>
<td>Harudi</td>
<td>shale, siltstone, marl</td>
<td>46</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Contd...)
b. Biostratigraphy based on larger foraminifera

The detail field mapping of the ONGC geologists was followed by systematic laboratory investigations on microfossils for biostratigraphic classification and age determination of the succession.

The findings of these investigation were summarised by Raju (1970, 1971) who proposed the following biostratigraphic subdivision based on microfossils:

<table>
<thead>
<tr>
<th>Formations</th>
<th>Members</th>
<th>Biostratigraphic units (Zones)</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandhan</td>
<td></td>
<td>Disconformity</td>
<td>Pliocene</td>
</tr>
<tr>
<td>Vinjhan</td>
<td>Siltstone</td>
<td>No microfauna, Ammonia assemblage</td>
<td>Miocene</td>
</tr>
<tr>
<td>Shale</td>
<td>Chhasra</td>
<td>M. excentrica/ M. globulina</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>M. globulina - tani</td>
<td></td>
</tr>
</tbody>
</table>

(Contd....)
Samanta (1978) recognised two larger foraminiferal zones, *Discocylinia sowerbyi* Zone followed by *Discocylinia omphalus* Zone, in the Fulra Limestone of Kutch.
c. Lower Tertiary larger foraminifera

The earliest record of the larger foraminifera from the Indian subcontinent was by Sowerby (1840), who described from Kutch the following new species: Fasciolites (Parkinson) elliptica, Lyco-

phris dispansus, L. ephippium, Nummularia acuta, N. obtusa and N. exponens.

In the monograph by D'Archiac & Haime (1853) there was reference to the occurrence of several species of Nummulites and Assilina in the Tertiary succession of Kutch.

During the same time Carter (1853, 1861) published on larger foraminifera from different localities of western India including Kutch and discussed a number of species of larger foraminifera occurring in Kutch.

The collections of type fossils from Kutch deposited in the Geological Survey of India were examined by Vredenburg (1906) who reported a number of species of Nummulites including a new species N. vredenburgi.

Nuttall (1925–26) in an attempt to study the larger foraminifera of Kutch and Pakistan, identified the following species from Kutch: Actinocyclina alticostata sp. nov., Alveolina elliptica (Sowerby), Assilina exponens (Sowerby), Dictyoconoides cooki (Carter), Discocyclina dispansus (Sowerby), D. javana (Verbeek), D. javana (Verbeek) var. indicus nov., D. sowerbyi nom. nov., Nummulites acutus (Sowerby), N. clipeus sp. nov., N. fichteli Michelotti, N. intermedius d'Archiac, N. maculatus sp. nov., N.
obtusus (Sowerby), N. perforatus (de Montfort), N. stamineus sp. nov. and N. sub-clipeus sp. nov.

Tewari (1956) described a new species Spiroclypeus ranjanae from the Spiroclypeus-Bed of northwestern Kutch.

Tandon (1962) reported Assilina daviesi Cizancourt, A. granulosa, A. spinosa Davies, A. subspinosa Davies and Nummulites atacicus Leymerie from the Lower Eocene sequence of Nareda-Harudi area.

Sen Gupta (1963, 1965) redescribed supported by photomicrographs the following larger foraminifera: Asterocyclina alticostata (Nuttall), Discocyclina dispansa (Sowerby), D. sowerbyi Nuttall, Nummulites acutus (Sowerby), N. bengalensis Verbeek, N. beaumonti d'Archiac and N. perforatus (de Montfort).

Mohan and Gupta (1968) reported the occurrence of Assilina leymeriei, Lockhartia tipperi (Davies) and Nummulites subatacicus from the Gypseous Shale of Nareda - Baranda area.

Tandon (1970) provided an account of the Oligocene larger foraminifera from the southwestern Kutch supported by description and illustration of Eulepidina dilatata (Michelotti), Heterostegina kohlii sp. nov., Nummulites fichteli Michelotti.

Raju (1971) made significant contributions on the larger foraminifera from the Late Oligocene - Early Miocene succession and published a monograph of Miogypsinidae.

Nummulites pengaronensis Verbeek was reported from the Fulra Limestone of northwestern Kutch by Samanta & Samaddar (1974).

The four species of Nummulites - N. acutus (Sowerby), N.
maculatus Nuttall, N. obtusus (Sowerby) and N. vredenburgi Prever, originally described from Kutch, were reexamined by Samanta (1981, 1982).

Recently, Samanta & Lahiri (1985) provided a detailed account of eleven species of *Discocyclina* namely, *D. adamsii* sp. nov., *D. assamica* sp. nov., *D. augustae* Weijden, *D. dispansa* (Sowerby), *D. haynesi* sp. nov., *D. praeomphalus* sp. nov., *D. sella* (d'Archiac), *D. sowerbyi* Nuttall, *D. sp. var. A*, *D. sp. var. B* and *D. sp. var. C* occurring in the Middle Eocene rocks while Samanta et al. (1985) recorded for the first time three Indo-Pacific species of *Borelis* from the Oligocene rocks of northwestern Kutch.

D. PRESENT WORK

The field work was carried out for a total period of about twenty weeks during 1981 and 1981-82 field season in the Guvar-Nareda region of northwestern Kutch, Gujarat. An area of about 257 sq. km. demarcated by Kapurasi (23°42'26"N : 68°38'14"E) in north, Guvar (23°38'20"N : 68°32'26"E) in west, Nareda (23°34'30"N : 68°39'00"E) in the central part and Harudi (23°30'30"N : 68°41'10"E) in south was mapped geologically (Fig. 4). The field photographs (Plates 1-16) show the characteristic outcrop appearance of different rock units. The Guvar stream section exposing the most complete stratigraphic succession was examined in detail. Special attention was paid to the type sections of Naredi and Harudi Formations (Biswas & Raju, 1971) which are located in the area of study. The following four traverses (Fig. 3) were selected for systematic collection of rock samples at regular intervals:
1. Traverse I (T_I) : It is along Naliya-Narayan Sarovar Road and extends from a locality about 1 km. SE of Baranda (23°33′24″N : 68°40′39″E) to a locality about 2 kms. NW of Harudi (see Fig. 3). This traverse includes the type section of the Harudi Formation. In general, it covers the upper part of the Matanomadh Formation, the Naredi Formation, the Harudi Formation and the basal part of the Fulra Limestone (Fig. 5). The rocks of Harudi Formation is continuously exposed in a roadside escarpment. Here, the succession is as follows:

<table>
<thead>
<tr>
<th>Fulra Limestone</th>
<th>Harudi Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dis conformity</td>
</tr>
<tr>
<td>Naredi Formation</td>
<td>Unconformity</td>
</tr>
<tr>
<td>Matanomadh Formation</td>
<td></td>
</tr>
</tbody>
</table>

2. Traverse II (T_{II}) : It is along the Kakdi Nadi about 0.75 km. west of Nareda village (see Fig. 3). It is the type section of Naredi Formation. The traverse covers the Deccan Trap Formation and the overlying Gypseous Shale Member as well as the Assilina Limestone Member of the Naredi Formation (Fig. 6). The cliff section shown in Pl. 2, Fig. 1 is capped by the hard Assilina-bearing limestone. The Upper Ferruginous Limestone Member and its lower contact with the Assilina Limestone Member is not exposed here. The succession here is as follows:

<table>
<thead>
<tr>
<th>Naredi Formation</th>
<th>Assilina Limestone Member</th>
<th>Gypseous Shale Member</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-conformity</td>
<td></td>
</tr>
<tr>
<td>Deccan Trap Formation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. Traverse III (T_{III}) : It is along the Guvar stream flowing east to west (Fig. 3). Rocks are continuously exposed in the Cliff sections along the stream. The stratigraphic succession exposed is as follows (Fig. 7):

<table>
<thead>
<tr>
<th>Maniyara Fort Formation</th>
<th>Ber Moti Member</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coral Limestone Member</td>
<td>Lower Member</td>
</tr>
<tr>
<td>Paraconformity</td>
<td>---</td>
</tr>
</tbody>
</table>

---

Fulra Limestone

---

Harudi Formation

---

Disconformity

---

Ferruginous Claystone Member

---

Naredi Formation

---

Assilina Limestone Member

---

Gypseous Shale

4. Traverse IV (T_{IV}) : It is along Matiwarwali Nadi flowing inbetween Godhatad (23°39'00"N : 68°39'34"E) and Kapurasi. Rocks are exposed in the cliffs exposed along the stream (Fig. 3). The following stratigraphic succession is recognised (Fig. 8):

<table>
<thead>
<tr>
<th>Maniyara Fort Formation</th>
<th>Coral Limestone Member</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Member</td>
<td>Lower Member</td>
</tr>
<tr>
<td>Paraconformity</td>
<td>---</td>
</tr>
</tbody>
</table>

Fulra Limestone

Systematic collection of samples was made only from the Naredi Formation, Harudi Formation, Fulra Limestone and Maniyara Fort Formation from unweathered in situ rocks. Whenever available collection of free specimens of larger foraminifera was made for
preparing oriented sections. A total of 229 samples were collected from these four formations. Processing of these samples was carried out by the author in the laboratory of the Geology Department of the Calcutta University. To start with two to four thin sections of rocks per sample was prepared to check the larger foraminiferal assemblage present. A total of 45 samples were boiled in water with soda. Isolated specimens of larger foraminifera picked from these washed residues and the free specimens collected from the outcrops were used for preparation of oriented sections. A total of 650 oriented sections of larger foraminifera were examined. In addition, matrix-free specimens of three stratigraphically significant taxa, *Nummulites obtusus*, *N. vredenburgi* and *Spiroclypeus ranjanae* from their respective type localities in Kutch were also used as they were not represented by adequate well-preserved isolated specimens in the present collection.

The Kakdi Nadi section near Nareda village, the type section of the Naredi Formation and the escarpment exposed along Naliya - Narayan Sarovar Road (T_1) which has been designated as the type section of the Harudi Formation by Biswas & Raju (1971) are located in the present area of study. The stratigraphy and larger foraminifera of these two sections have been studied in detail.

Four lithostratigraphic units, Naredi Formation, Harudi Formation, Fulra Limestone and Maniyara Fort Formation, are described and discussed systematically. Attempts have been made to identify all the larger foraminifera occurring in the four traverses (see Figs. 9-12). These foraminifera whose identification needs an
examination of the internal structures of the test are included here under *Larger Foraminifera*. The biostratigraphic breakdown of the succession was carried out with the help of the ranges of the stratigraphically significant taxa (see Figs. 13-14). The biostratigraphic zones recognised in the present area are described and discussed. Correlation of the present larger foraminiferal zonal sequence with those described from other localities in India and adjacent region is discussed. On the strength of this correlation the geological age of the Palaeogene succession is determined (see Fig. 15).

All the larger foraminifera recognised are described, discussed and illustrated (see Plates 17-64). The descriptions are supported by photomicrographs and camera lucida sketches. Measurements of the essential morphological features of those taxa are provided in Tables 1-136. Some of these measurements are plotted graphically to show the range of variations and fields of distribution of different taxa. The collection of samples with field and their processing in the laboratory including the preparation of all oriented sections and camera lucida sketches have been carried out by the author.

E. ACKNOWLEDGEMENTS

The present dissertation which forms a part of the research project "Study of foraminiferal biofacies and microenvironments of the Palaeogene sediments of western Kutch, Gujarat" was carried out in the Micropalaeontology Laboratory of the Geology Department of the Calcutta University under the supervision of Dr. Bimal Kumar Samanta. I wish to express my sincere gratitude to Dr. Samanta for
his support, guidance and advice during all phases of this investigation. All identifications have been checked by him and the manuscript has been revised following his suggestions. Special thanks are due to the authorities of the University of Calcutta for providing laboratory and library facilities.

The financial support received from the Oil & Natural Gas Commission, Dehra Dun for field work is gratefully acknowledged. Dr. S.K. Biswas, General Manager, KDMIPE, ONGC provided valuable information on the geology of Kutch and helped with maps, traverse sheets etc.

It is a pleasure to acknowledge with thanks the help and assistance received from Mr. P. Bhatti in organising the field work, Dr. A. Lahiri, a research fellow in the Kutch Project, during the field work, Mr. R. Ghosh during the laboratory work, Mr. N. Roy for photomicrography, Mr. R. Bhar for SEM photography and Mr. N.N. Bhaduri for preparing and numbering the plates.