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TERTIARY STRATIGRAPHY OF KUTCH*

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PROLOGUE

I am thankful to the Palaeontological Society of India for giving this honour of delivering the prestigeous M.R. Sahni Memorial Lecture before this august body of eminent Palaeontologists and Stratigraphers.

I have selected this topic on the Tertiary Stratigraphy of Kutch for a special reason. Pioneering work on the Micropalaeontology and Tertiary Stratigraphy of Kutch was carried out by Dr. B.S.Tiwari in this University and presented under the auspices of the Paleontological Society of India. Picking up thread from there, I worked on the Tertiary of Kutch for many years during the early part of my career as a professional geologist. I started my work in Kutch with the Tertiary rocks and my first publication is on this subject. Though many papers were published on various aspects of the Tertiary stratigraphy, a comprehensive and complete account of this was lacking as also the detailed descriptions of the stratotypes. I will try to unfold how the stratigraphy, originally classified and sequence described, was progressively refined as the modern concepts evolved and more and more studies done over the last three decades.

INTRODUCTION

Kutch basin is a peri-cratonic rift basin in the western margin of India which has preserved almost a complete sequence form Triassic to Recent punctuated by several stratigraphic breaks between transgressive cycles. The basin extends far to the west over the present continental shelf. The Tertiary sediments are developed in the western part of this basin with major part occurring in offshore region extending up to the present continental shelf. A condensed section of the Tertiary is exposed in the western part of onland Kutch (Fig. 1) The unique feature of this area is a near complete sequence ranging from Paleocene to Pliocene developed within a 900 metre thick section (Fig. 2). The Palaeogene part constitutes only 100 metres of this sequence signifying that the main subsidence during Tertiary took place in Neogene times. Tertiary is exposed mainly in the narrow coastal plains of Kutch Mainland and in the peripheral plains of other 'highlands'. Tectonically less disturbed Tertiary sediments wrap around the highs formed by the Mesozoic structures. Obviously the synclinal lows formed narrow embayments during the Tertiary excepting in Miocene when a highstand of the sea flooded most part of the basin. Most of the sedimentation during the Tertiary thus took place in shallow marine peri-tidal environments.

The type sections/stratotypes of the Tertiary rocks are seen in South-Western Kutch mainland (Fig. 3). In Southern and Eastern Kutch including Eastern Mainland, the Neogene rocks occur overlapping the Palaeogene strata. There is a general eastward overlap of Neogene strata indicating west to east transgression of the Tertiary sea into the Kutch embayment basin.

Since the British geologists first studied these rocks, the Tertiary rocks of Kutch were considered as the extension of the Tertiary rocks of Sindh-Baluchistan region and were referred to by the same nomenclature. However, the Tertiary rocks of Kutch were deposited in a different tectonic regime and constitute sediments during a specific geologic events related to the evolution of the western continental margin of India. With its well developed fossiliferous, Tertiary sequence, it merits to be considered as a Tertiary stratotype for shallow marine sediments in India. Realising this the task of classification of these sediments was taken up based on detailed mapping and biostratigraphic studies. A chrono-stratigraphic classification proposed earlier (Biswas 1965) was subsequently modified (Biswas, 1973b). It has how been possible to identify the chrono-stratigraphic units and map them in the field in view of the excellent development of continuously recognisable bands of key-biostratigraphic horizons indicating time boundaries. Subsequently, rock stratigraphic classification of these sediments was evolved (Biswas & Raju, 1973). Due to the well developed and easily recognisable fossiliferous beds, it became easier to map the chrono-stratigraphic boundaries for most part of the Kutch mainland. The mapping of litho- and chrono-stratigraphic units of this basin revealed that the boundaries of litho-, bio-, and chrono-stratigraphic units are seldom mutually transgressive. This indicates a very stable shelf condition of deposition with a low profile of provenance due to which sedimenta-

* Official spelling of Gujarat and Central Governments has been maintained. Further, author feels that same spelling is entrenched in geological literature and it is not desirable to use the new spelling, i.e.Kachchh.

tion was mainly mud and carbonate.

Stratotypes of litho-stratigraphic, biostratigraphic and chrono-stratigraphic units had been identified and described earlier in various publications. This task of providing detailed description and synthesis of various categories of stratotyes became all the more necessary as a wealth of data emanated from the wells drilled by O.N.G.C. It has helped in working out a high resolution stratigraphic sequence. The stratigraphic frame work of a basin is complete when it is studied in all the three aspects, i.e. litho-, bio and chrono-stratigraphic, synthesised and correlated in a mutually aggreable pattern which brings out the basin history. This provides a basic framework for all subsequent stratigraphic analysis (Fig. 1). Published and a few unpublished reports of ONGC have been freely used.

PREVIOUS WORK

The first detailed classification of the Tertiary sediments of Kutch was presented by Wynne (1872). Wynne classified the Tertiary sediments into six groups.

(6) Recent-Upper Tertiary

(5) Argillaceous Group

(4) Arenaceous Group

(3) Nummulitic Group

(2) Gypseous Shales

(1) Sub-Nummulitic

Wynne gave a bed by bed description of some of the sections. However, his classification lacked precise definition of the units ('groups').

Later workers have used various classifications and terminologies. They either used Wynne's (1872) classifications without redefinition or used the terminology of the Sind - Baluchistan region of Pakistan, viz., Laki, Kirthar, Nari, Gaj, etc. Poddar(1959) presented a classification combining the Wynne's terminology and that of Sind-Baluchistan without offering a proper review. Tewari and co-workers (1952-1969) used the Pakistan terminologies and described the sequence from each traverse under informally

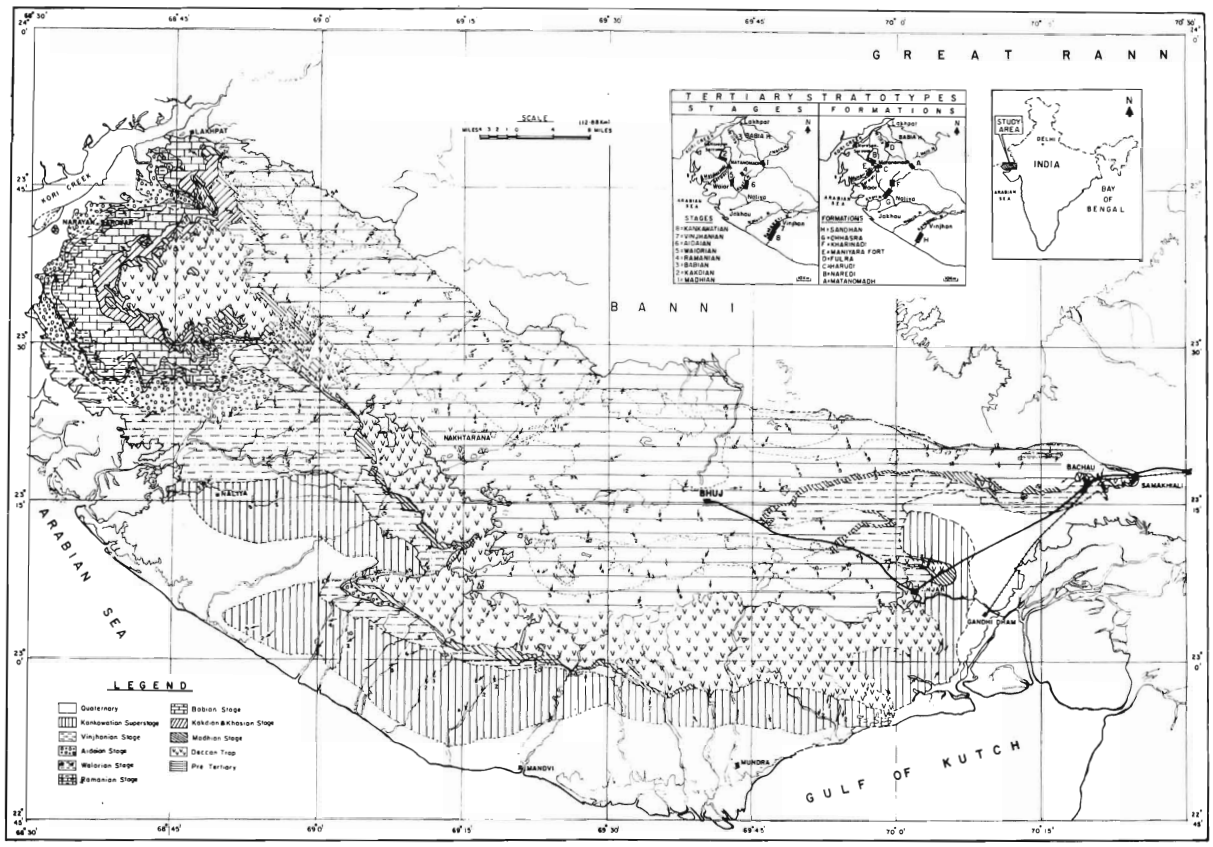

Fig. 1 : Tertiary Stages of Kutch Mainland

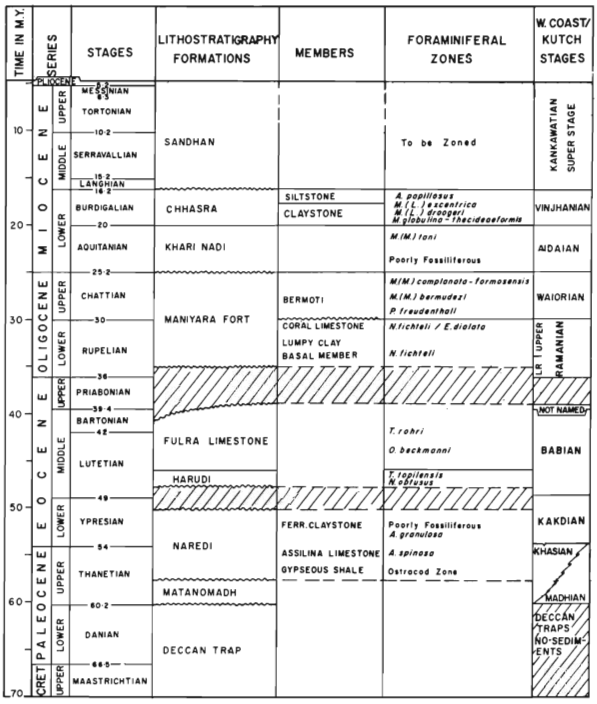

Fig.2 : Stratigraphic classification of Tertiary sediments of Kutch.

numbered beds. These beds vary in thickness from I feet to 900 feet and the limits of the individual beds are undefined.

Biswas (1965) proposed a new Time-Stratigraphic classification of the Tertiary sediments of Kutch based on chrono-stratotypes and detailed mapping of the time-rock units. This was the first attempt in Indian stratigraphy to establish a formal chronostratigraphic classification applying modern concepts. The classification was later modified (Biswas 1971, 1973b). Subsequently, Biswas and Raju (1971, 1973) proposed a lithostratigraphic classification of Tertiary sediments of Kutch introducing a small change of nomenclature.

Biostratigraphic zonal schemes were proposed by many palaeontologists. Sen Gupta (1963) described the Tertiary strata of Lakhpat area under 7 biostratigraphic zones. This was followed by Raju (1974a), Pandey (1982), Samanta and Lahiri (1985) and many others.

LITHOSTRATIGRAPHY

The Tertiary sequence Kutch consisting of limestones, shales and sandstones could be grouped into discrete mappable formations based on vertical differentiation of gross lithology and unconformities recognisable in the field. Distinctive lithologic association was taken into consideration in identifying formations which could further be divided into members. While the nomenclature of the formations have been formalised, the members have described as informal units since these units have not been mapped separately. Due to stable shelf environment the formations have remarkable lateral continuity and could be mapped throughout the extent of the Tertiary outcrop. Unconformities, mostly disconformities, generally marked by lateritised undulating surfaces or by bioturbated cut and fill structures and regional overlaps, are extensive and can be recognised in the field. These unconformities could be detected also in the drill holes which indicate their extension to offshore areas over the continental shelf. The litholostratigraphy described here is the elaboration of the frame work described earlier by Biswas and Raju (1971,1973). In order to avoid synonimity in

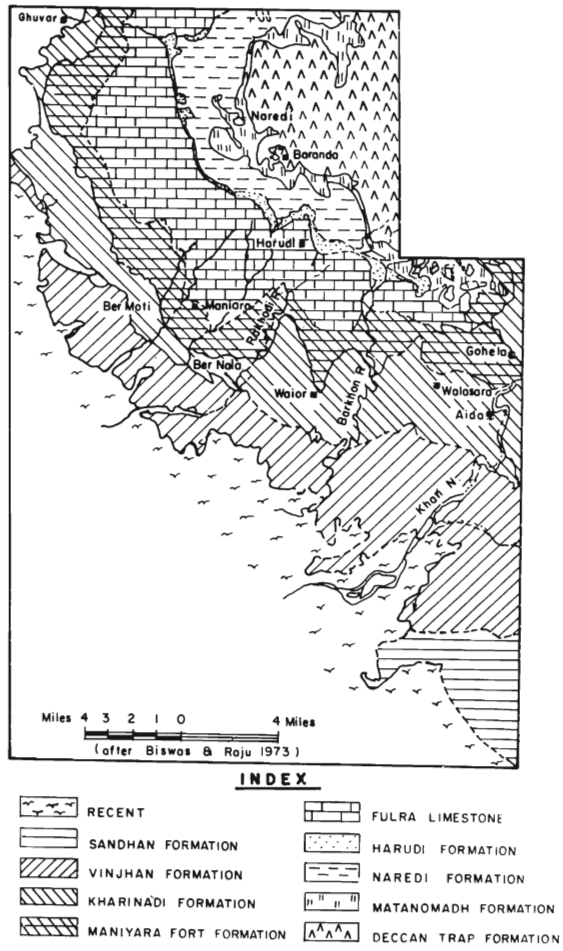

Fig. 3 : Geological Map of the South-western Kutch.

different categories of stratigraphic nomenclature, it is felt necessary to change the stratotype name prefix in one case. The formation named as the Vinjhan Shale in the earlier proposed classification, is changed here as the Chhasra Formation after the type section which is now redesignated to the Khari Nadi section in the vicinity of the Chhasra Village. The stratotype described earlier in Kankawati Nadi section is now considered as a reference section for this formation.

Detailed descriptions of the formations are given below. The locations of the respective stratotypes of formations are shown in Fig. 1, and lithological successions are shown in Figs. 4 to 5.

Matanomadh Formation

Authors : Biswas & Raju (1971).

Further references : Biswas & Raju (1973).

Definition : A variety of rock types consisting of Trap derivatives, pyroclastics and clastic sediments in various degrees of admixture constitutes a distinctive type of brightly coloured litho-unit named here as the Matanomadh Formation after its type section.

Related names : Sub-Nummulitic (Wynne, 1872); laterite and lateritic clays (Poddar, 1959); Also 'Supra-Trappeans' by various authors; Madh Series (Biswas 1965).

Type section : This Formation is named after Matanomadh village (Lat. 23°32'30"; Long. 68°57'10") in Western Kutch. The type section is exposed in Bhuj-Lakhpat road section east of Matanomadh, in the badlands around the village, and in the Madhwali Nadi section to the south of the village.

Distribution and Occurrence : The formation is exposed extensively in the mainland of Kutch bordering consistently the outcrop of Tertiary rocks. It also occurs as outliers in the Trap or Jurassic country occupying topographic depressions. It covers a widespread lateritised post-Trappean peneplaned surface and forms the floor of the Tertiary deposits.

Lithology : The lithologic succession is extremely variable and consists of a variety of brightly coloured rock types with different admixtures of clastics and volcanic materials. Trap derivatives give rise to a wide range of rocks from laterite to clays in the lower part of the formation. The common rock types are red

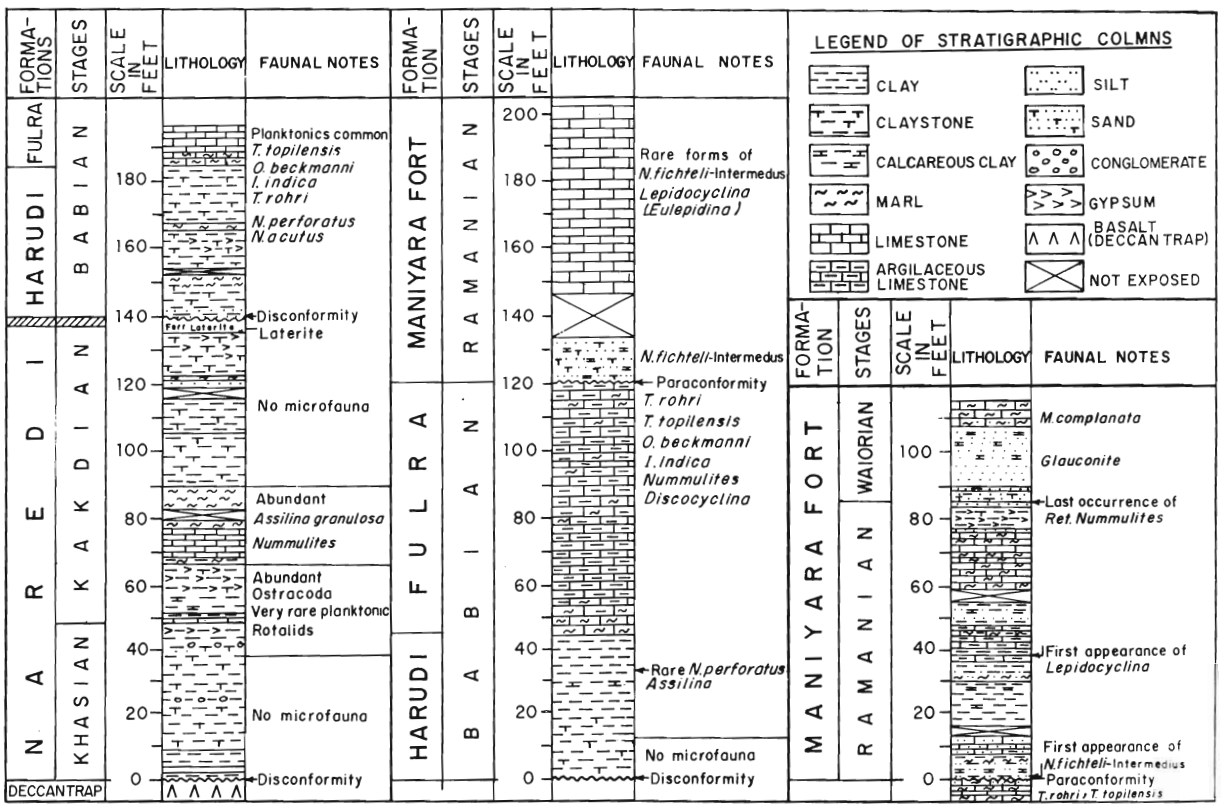

Fig.4 : Stratotypes of Naredi, Harudi, Fulra and Maniara Fort formations.

laterite, bauxite, lateritic Trap-pebble-conglomerate, Trap-wash/wacke, variegated plastic bentonitic clays, red and yellow ferruginous clays, grey and white tuffaceous shales and red, current bedded, tuffaceous sandstones and occasional layers of lignite.

Boundaries : The formation directly overlies the Deccan Trap Group and the contact is sharply defined by red laterites or Trap-pebble- conglomerates above the Deccan Trap. The upper contact marked by a lignite band in the type locality. Elsewhere, the contact is disconformable.

Thickness : The thickness of the formation is extremely variable. The Maximum thickness measured in the type area is 160ft. (49m).

Fauna and flora : This formation is generally barren of fossils but locally rich in microflora dicot leaf impressions, occasionally with fossil fruits and woods.

Environment of Deposition : The lithologic characteristics indicate that these volcanoclastic sediments were deposited during the waning phase of the Deccan volcanicity in different terrestrial environments. Pyroclastic and ash ejected from various volcanic centres (Biswas and Deshpande, 1973) were carried by wind. Volcanic debris were reworked and deposited alongwith clastics in fluvial and lacustrine environments. Abundance of fossil flora also supports this and further indicates a warm and arid climate which is responsible for the bright colour.

Age : The pollen-spore assemblage indicates a probable Palaeocene age (Mathur, 1966). This is supported by its occurrence above the Deccan Trap Group whose age in Kutch has been established as Late Cretaceous to Early Palaeocene (Mehrotra and Biswas, 1989).

Naredi Formation

Authors : Biswas & Raju (1971).

Further references : Biswas & Raju (1973); and Samanta (1989).

Related Names : "Gypseous shales" (Wynne 1872), Laki "Beds" (Tewari, 1957).

Definition : Overlying the brightly coloured lateritic volcanoclastic rocks of the Matanomadh Formation, occurs a dominantly agrillaceous formation which is named as the Naredi Formation after its stratotype in the cliffs of the Kakdi Nadi near the village of Naredi (23°39'49": 68°40'38").

Type section : The type section is exposed in the cliffs along Kakdi Nadi south of Naredi and partly (upper part only) along Guvar stream NNW of Naredi (Fig. 4).

Distribution and Occurrence : This formation is well developed only in Western Kutch. It occurs in a narrow sinuous belt of outcrop from Lakhpat in the north to Jhulrai in the south through Umarsar, Nareda and Naredi around the structural nose of Narayan Sarovar. A huge thickness of lignite bed has developed within this formation in the Babia syncline between Umarsar and Panadra. The lignite is being mined by the Gujarat Mineral Development Corporation.

Lithology : Three distinct members are recognised in the type locality:

i) *Gypseous shale member* : It is about 24m thick and consists of grey, brown and olive green glauconitic claystones and splintery shales with thin layers of gypsum, limonite and bands of sideritic concretions which occasionally contain fossils at the core-Veneri-cardia, Nautilus, etc.

ii) *Assilina-limestone member* : It is 6m thick and consists of bedded, dirty white limestone and yellowish grey marlite studded with *Assilina*.

iii) *Ferruginous claystone member* : It is about 15m thick and consists of grey and brown

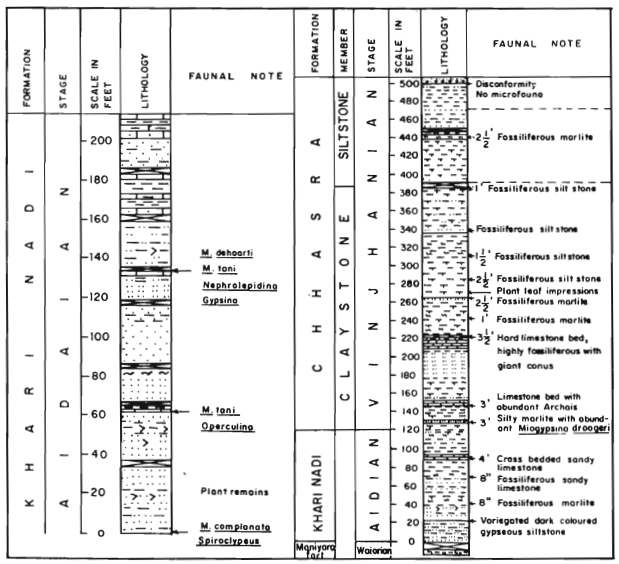

Fig. 5 : Stratotype of Khari Nadi and Chhasra Formations.

claystones with layers of gypsum and red ferruginous laminae. A red laterite bed caps the sequence and marks the unconformity above it.

The lower and middle members locally develop black shale facies comprising black pyriteous shales and lignite beds. In Panadra and Umarsar area in northwestern mainland, thick beds of lignite occurs overlying white, well sorted, fine grained, friable sandstones. The black shale facies is well developed around Jhulrai village.

Thickness : Maximum thickness measured in the type section is 130ft., 40m (+8ft. laterite fig.4). However, it is over 100m thick in the subcrops of Babia syncline (Panadra Mines).

Boundaries : In the type locality the Naredi Formation directly overlies the Deccan Trap Formation as observed in the nala 700m west of Naredi. In all other places, a well marked plane of disconformity separates this formation from the Matanomadh Formation. The upper contact with the Harudi Formation is also marked by another plane of disconformity. This plane of disconformity is characteristically marked by red ferricreted erosional surface covered by 'buck-shot' gravels well exposed in Waior-Baranda Road, 3 Km. south of Baranda. This surface occurs above the barren lateritic shales of the Ferruginous claystone member of the Naredi Formation in sharp contrast with the richly fossiliferous claystones of the overlying Harudi Formation.

Fauna : *Assilina spinosa*, *Lockhartia*, sp., *Nummulites* sp., *Globigerina* sp., and *Globorotalia* sp. Apart from microfauna, varieties of bivalves, gastropods and corals are seen.

Biofacies : Samanta (1989) recognised small granulate *Assilina* biofacies in Lakhpat area.

Environment of deposition : Environment of deposition of this formation varies from lagoonal to marine inner-shelf. The ferruginous claystone in the upper part indicates regression. The lithology and biota typify lagoonal and coastal marsh or back-swamp environment. The black shale facies developed in the restricted environments of coastal marsh or back swamp environments.

Age : The lower member may be of Late Palaeocene in age. The middle member with *Assilina* is considered to be Early Eocene in age. The upper member is barren and no definite age could be assigned.

Harudi Formation

Authors : Biswas & Raju (1971).

Further references : Biswas & Raju (1973); and Samanta (1989).

Related names : This formation corresponds to the upper part of the 'Gypseous Shales' of Wynne (1872).

Definition : A unit of grey calcareous highly fossiliferous shales above the Ferruginous claystone member of the Naredi Formation and below the scarp forming white nummulitic limestones, is named as the Harudi Formation after its type section near Harudi village (23°30'30" ; 68°41'10").

Type section : The formation is very well exposed in an impressive escarpment to the west of Harudi village. The type section is continuously exposed over a short distance of 300m along the escarpment at a locality about 2kms NW of Harudi, close to the Naliya-Narayan Sarovar road (Fig.4).

Distribution and occurrence : The formation outcrops throughout the Tertiary belt of western Kutch mainland bordering the extensive outcrop of the overlying nummulitic limestones. It is well developed in the low grounds south of Lakhpat Fort and on the south-western flank of Narayan Sarovar structural nose.

Lithology : The formation consists of green and greenish grey, splintery shale with yellow limonitic partings in the lower part and calcareous claystone and siltstone with occasional layers of gypsum and carbonaceous shale in the upper. A thin coquina bed occurs near the base. Occasionally concretionary and oolitic fossiliferous limestone bands are seen in the lower part. A 2 feet thick ferruginous, gypseous clayey marlite band studded with large (1 to 1.4mm diameter) *Nummulites obtusus* is a characteristic marker bed within the formation. This marker is popularly referred as *N. obtusus* band. The *Nummulites* are easily recognised by their doubly convex tablet shape and ornamented surface with curved sutures resembling that of a thumb impression. This bed occurs about 4.5m below the top of the formation. This bed is extensive and can be traced from Lakhpat in the north to Waghopadar in the south. However, its absence in Babia Hill area is conspicuous.

Thickness : The formation is about 14m thick. Its

thickness is more or less constant throughout the extent of its outcrop.

Boundaries : The lower contact is disconformable and is fixed on top of the laterite bed of the Naredi Formation. The upper contact is conformable and is placed at the base of the lowest massive foraminiferal limestone bed containing characteristic saddled to undulated *Discocyclina* . Samanta (1989) recognised a stratigraphic break (paraconformity) above the *N. obtusus* Band. The occurrence of ferruginous and gypseous layers above this band also suggests a diastem.

Fauna and Flora : *Truncorotaloides topilensis, Nummulites obtusus,* & *N. acutus* are characteristic fossils. Singh and Singh (1986) recorded nannoplankton species of *Brarrudosphaera biglowi, Dictyoccites bisectus* and *Discoaster barbadiensis* from the upper part of the Harudi Formation. The coquina bands near the base contains varieties of pelecypods, gastropods and corals. Giant gastropods e.g. *Bolis* and *Xancus,* are common at places, particularly in Barkhan river section. *Porocidaris* and *Cidaris* and spines are also very common in this.

Biofacies : Samanta (1989) recognised two biofacies, namely large complex *Nummulites* biofacies in the lower part and *Nummulites* peloid biofacies in the upper part.

Environment of deposition : Littoral to lagoonal in the lower part and inner-shelf in the upper part as indicated by the foraminiferal assemblage and general lithology. Sediments represent a transgressive phase of deposition.

Age : The foraminiferal assemblages indicate a definite Middle Eocene age.

Fulra Limestone

Authors : Biswas & Raju (1971).

Further reference : Biswas & Raju (1973), Samanta (1989); Singh and singh (1986).

Related names : Nummulitic Group (Wynne, 1872); Kirthar Series (Sen Gupta, 1964; Poddar, 1959; Tewari, 1957).

Definition : A thick sequence of bedded white foraminiferal limestone overlying the argillaceous formation forms a very distinct lithounit in the Tertiary of Kutch. This formation has been named as the Fulra Limestone after its designated type section near Fulra village (23°42'30"; 68°47'12") in Western Kutch.

Type section : The type section is best exposed in the southern flank of Babia hill, about 1.7 km sw of Fulra village. The upper part is also well exposed in the nala to the south of Fulra (Fig. 4).

Distribution of occurrence : This formation is well exposed only in the western part of Kutch around Narayan Sarovar, Dedhadi, and Lakhpat noses in a 6.5 to 10 km wide belt of outcrop. The outcrop belt is the widest and best exposed around Rodasar, Ber Nani, Khari, Harudi, Lakhmirani and Waghopadar. Near Waghopadar the formation is overlapped by the younger beds. About 30 m thick sequence of this formation also occurs near Matanomadh and around the Vinjhan nose in southern mainland.

Lithology : The entire formation is made up of massive to thickly bedded, white, and buff coloured foraminiferal limestone. The limestones are fossiliferous micrites, biomicrites and biomicrosparites locally silty (Hardas and Biswas, 1973). Large saddled to undulated *Discocyclina,* ellipsoidal *Fasciolites* are abundant and they give a characteristic appearance to this formation. The upper part contains a number of echinoides.

Thickness : The maximum thickness of this formation has been recorded in the Berwali stream section which is about 185 ft (60m). However, it is only 75ft (23m) thick in the type section.

Boundaries : The lower contact is conformable and is fixed at the base of the scarp forming massive foraminiferal limestone. The well exposed upper contact is paraconformable, but locally disconformable showing cut and fill structures and bioturbation.

Fauna : The planktonic foraminifera belong to two zones, namely, *Orbulinoides beckmanni* zone in the lower and *Truncorotaloides rohri* zone in the upper part. These zones are illustrated and described by Mohan and Soodan (1970). The Larger foraminifera belong to *Discocyclina sowerbyi* zone in the lower part and *Fasciolites elliptica* zone in the upper part. Singh and Singh (1986) recorded a number of species of nannoplankton from Fulra Limestone. These include forms like *Braarudosphaera biglowi.*

Besides the microfossils, a host of megafossils are present in this formation. Among them oysters, turritellids, *Pecten,* echinoids, corals and fossil crabs are very common. Sahni and Mishra (1975) have also reported vertebrate fossils—whales, sea cow and fish, from this formation.

Biofacies : Samanta, (1989) recognised eight biofacies in this formation in Lakhpat area. They are, from top to bottom:

(8) Large ellipsoidal *Alveolina* Biofacies.

(7) Small *Nummulites-Discocyclina-Alveolina* Biofacies.

(6) Large *Alveolina-Nummulites-Discocyclina* Biofacies.

(5) *Discocyclina-Nummulites* Biofacies

(4) *Asterocyclina-Discocyclina* Biofacies

(3) Large compressed lenticular *Assilina* Biofacies

(2) Large *Discocyclina-* radiate *Nummulites- Assilina* Biofacies

(1) Large, thick *Discocyclina* Biofacies.

Environment of deposition : Foraminiferal assemblages and lithology are characteristic of a low energy, clear waters probably under middle-shelf environment.

Age : The characteristic faunas indicate a Late Middle Eocene age equivalent to the tropical zones, *O.beckmanni* and *T.rohri* zones.

Maniyara Fort Formation

Authors : Biswas & Raju(1971).

Further references : Biswas & Raju (1973); Samanta (1989).

Related names : Nummulitic Group (Wynne, 1872); Nari Series (Nagappa, 1959; Chatterjee and Mathur, 1966).

Definition : A group of bedded, yellow to ochre coloured foraminiferal limestones with a basal greyish green glauconitic siltstone overlying the white Fulra Limestone, has been named as Maniyra Fort Formation after its designated type section. Ochre colour and green pellets of glauconite in all the rock types readily distinguish this formation.

Type section : This formation is named after Maniyara Fort (23°28'05" 68°37'00"). The type section is continuously exposed along Bermoti Nadi (stream) flowing between Maniyara Fort and Bermoti village (23°25'00";68°35'00") from a locality 1.6km NNE of Bermoti to a locality about 450m SE of the village (Fig. 5).

Distribution : Besides the type section, this formation is well exposed in Ramania stream, Waior stream, Berwali Nadi, Bermoti stream and also in the area around Lakhpat. The outcrop is fairly continuous along a 1.5-3.5 km wide belt wrapping around the Lakhpat and Narayan Sarovar structural noses.

Lithology : This formation is divided into four members:

1) *The basal member* is about 14 ft. thick and consists of alternating beds of foraminiferal, glauconitic, brownish to yellowish siltstone and calcareous, gypseous claystone. The occurrence of green pellets of glauconite readily distinguishes this member from the underlying Fulra Limestone. The glauconite gets locally concentrated in the cut and fills of the lower disconformable surface to form "green sands".

2) *The lumpy clay member* is about 15 ft. thick and consists of cement coloured to brownish calcareous, lumpy claystone, occasionally containing thin limestone and marlite beds.

3) *The Coral limestone member* is about 30 feet thick and consists of dirty white nodular limestone, which weathers in characteristic bouldery pattern, alternating with calcareous claystone in the lower part. The upper part comprises grey to dirty white massive limestone with abundant corals, frequently forming small bioherms. The limestones are glauconitic biomicrites and biosparites (Hardas and Biswas, 1973). All the above mentioned three members are very well exposed in the stream west of Ramania (23°00'28"; 68°47'50").

4) *The Bermoti member* is about 36 feet thick and is best developed in the stream SE of Bermoti and also NNE of Waior (23°05'002"; 68°41'45"). It is also well exposed on top of Maniyara Fort Hill. The lower part best exposed near Waior, consists of rusty brown, friable glauconitic argillaceous sandstone with pseudo- oolites. The upper part is composed of thinly bedded, very hard, grey to yellowish foraminiferal limestones (biomicrites) with interbeds of silty marlite full of *Spiroclypeus*.

Boundaries : The lower contact is paraconformable/locally disconformable as discussed earlier. Ochre colour and sudden appearance of glauconite pellets make it easy to recognise the boundary in the field. Cut and fill structures packed with glauconite, sometimes full of *Cidaris* spines (e.g. in Dedhadi nala section), mark the lower boundary very sharply at places.

The upper boundary is easily recognisable between the persistant blue clay at the base of the overlying formation and the limestone of the Bermoti member. A feeble erosional unconformity between the two is discernible by the regional overlap and occurrence of inliers of Bermoti member at many places. An erosional diastem between the coral limestone member and Bermoti member is clearly evident in the field by the erosion of the top 8 ft. sequence and occurrence of glauconitic sandstone full of fossil bones and other reworked fossils (Walasara water falls section at the head of the tributary of Ramania Stream).

Thickness : The formation is uniformly 115ft. (35m), thick.

Fauna : The formation is richly fossiliferous with varieties of echinoids, pelecypods, gastropods, corals and crabs. Vertical burrows are very common.

Vertebrate fossils are very common and characterise this formation. Well preserved skeletons of reptiles, whales, etc. are seen trapped between layers of foraminiferal limestone. *Nummulites* and *Miogypsina* are the characteristic foraminifera present.

Biofacies : Samanta (1989), recognised three biofacies in the basal member and four biofacies in the coral in the basal member and four biofacies in the coral limestone member in Lakhpat area. They are :

Coral limestone Member :

(4) Reticulate *Nummulites* — abundant coral Biofacies

(3) *Pararotalia* — Reticulate *Nummulites* — Molluscs Biofacies.

(2) *Pararotalia* — Porcellaneous foraminiferal Biofacies

(1) Reticulate *Nummulites* — *Operculina* — *Eulepidina* Biofacies

Basal member

(3) Reticulate *Nummulites* Biofacies

(2) Reticulate *Nummulites* — *Heterostegina* Biofacies

(1) Reticulate *Nummulites* — Algal Biofacies.

Three zones are recognised in the Bermoti Member:

(3) *Miogypsina (Miogypsinoides) complanta — formosensis* zone

(2) *M. (Miogypsinoides) bermudezi* zone

(1) *Planolinderina freudanthali* zone

A single zone, *Eulepidina dialata/Nummulites fichteli* zone is recognisable in the coral limestone member. *Nummulites fichteli* partial range zone is recognisable in the basal member.

Environment of deposition : Marginal marine, littoral to shallow inner-shelf. Marine transgressive, environment shifted from lagoonal to high energy open shelf environment when coral bioherms were formed.

Age : This formation can be dated on the basis of typical fauna as Oligocene. The basal, lumpy clay and Coral limestone members together are Early Oligocene(Lattorfian) and the Bermoti member is Late Oligocene (Chattian) in age.

Khari Nadi Formation

Authors : Biswas & Raju (1971).

Further references : Biswas & Raju (1973).

Related names : Arenaceous Group (Wynne, 1872); Gaj beds (Poddar, 1959; Mohan and Bhatt, 1968). Erroneously mapped in eastern and northern Kutch as Sub-Nummulitic Group by Wynne.

Definition : A distinctive sequence of fine grained to silty, variegated sandstones overlying the white foraminiferal limestones of the Fulra and Maniyara Fort formations, is defined here as the Khari Nadi Formation.

Type section : This formation is named after Khari Nadi. The type section is exposed along cliffs and banks of Khari Nadi between its confluence with Sugandhi Nadi (locality : 23°25'45" ; 68°49'40") near Goyela and the prominent elbow bend (23°23'00" ; 68°48'00") about 2 kms. north of Laiyari-Rampura cart-track (Fig. 5).

Distribution and Occurrence : The maximum development of the formation is seen on the southern flank of the Narayan Sarovar nose between Waior and Jangadia. Good exposures are seen in the high cliffs of the Waior, Barkhan, and Khari streams. It extends to the north up to Lakhpat in an extensive belt of outcrop. Around the peripheries of the Rann islands and Wagad highland, this formation occurs unconformably above the Jurassic rocks.

Lithology : The lithology consists predominantly of laminated to very thin bedded red and yellowish

mottled to variegated siltstone and very fine grained sandstones with occasional grey and brown gypseous claystone. A bluish grey claystone bed occurs consistently near the base in every section. Cross bedded, fine grained, micaceous sandstone is present in the middle part, while a few thin fossiliferous marl and limestone beds are present in the middle and upper part of the type section.

In Eastern Kutch (Rann islands and Wagad Highland), red lateritic conglomerate often with agate pebbles, purple ferruginous sandstones, white-felspathic and tuffaceous sandstones with laminated claystone bands constitute the lithology of the formation.

Bioturbation, particularly in the basal part, is very common which is responsible for its mottled variegated appearance. The vertical burrows are filled up with red hematite in contrast with the bright yellow colour of the burrowed siltstone.

Boundaries : The lower contact is generally conformable and is fixed on top of the *Spiroclypeus* limestone bed and at the base of the bluish grey claystone bed. However, a feeble erosional unconformity is indicated by transgressive overlap as mentioned earlier. The upper contact is also conformable and gradational. It is fixed at the base of a 4 feet thick marlite bed (full of *Turritella* & *Lepidocyclina*, and echinoids) exposed in the 10 m cliff of Khari Nadi at its prominent elbow bend, east of Laiyari. However, in Kankawati river section in southern Kutch, a 5 m red zone with gypseous and ferruginous bands suggests a break in the sedimentation.

Thickness : Maximum thickness encountered in the type section is 215ft., (65m). In Kankawati river section, it reduces to 47m, (165 ft.). In Rann islands, the thickness varies from 15 to 35m.

Fauna : The foraminifera include *Miogypsina (Miogypsina) tani, M. (Miogypsinoides) dehartii, Nephrolepidina & Austrotrillina.* Plant fossils are common in the lower part. Good dicot leaf impressions are often seen in shaly beds.

Turritella, Ostrea and echinoids are common mega fossils present. In Northern and Eastern Kutch the formation is barren of fossils.

Environment of deposition : Tidal flat, littoral, to shallow inner-shelf, in a slowly transgressive sea over a stable shelf.

Age : The lower part which is poorly fossiliferous may be equivalent to *M. (M.) gunteri* zone of lower Aquitanian. *M. (M.) tani* which is common in the middle and upper part indicates Late Aquitanian age.

Chhasra Formation

Authors : Biswas, new name.

Further references : Originally described as the Vinjhan Shale by Biswas & Raju (1971, 1973); Raju (1974b).

Related Names : Argillaceous Group (Wynne, 1972), Gaj series/beds (Tewari 1957; Poddar, 1959 ; Chatterjee and Mathur, (1966), Vinjhan Shale (Biswas and Raju, 1971).

Definition : In contrast with the underlying dominant arenaceous formation, a thick sequence of grey argillaceous beds has been defined here as the Chhasra Formation.

Type Section : This formation is named after Chhasra Village ($23^{o}21'20"$;$68^{o}46'40"$). The type section is exposed along Khari Nadi from the top of Khari Nadi Formation near Laiyari to a locality 1 km south of Chhasra village. A 4.5 km stretch in the Kankawati river between Khirasra and Vinjhan is the best reference section for this formation. (Fig.5).

Distribution and Occurrence : Extensively exposed in Southern and Eastern Kutch, also exposed as patchy outcrops in the low plains between the highlands. It overlaps all the Tertiary formations developed in Western Kutch mainland, progressively towards the east where it rests over the Mesozoic rocks, the Deccan Trap or the Matanomadh Formation. It also occurs as outlier in the peripheral structural lows of the mainland and Wagad highland.

Lithology : This formation consists of two distinct members :

(1) A lower claystone member, 265ft. (82m) thick, is best exposed in the type section and consists of grey and khaki coloured, laminated to splintery, gypseous shales and claystones with alternations of thin, hard yellowish, highly fossiliferous argillaceous limestones. Characteristic megafossils include *Turritella*, large *Ostrea*, giant *Conus* and others.

(2) An upper siltstone member 115ft.+(35m) is well exposed along the Kankawati river from a locality just east of Vinjhan to a locality 1 km south of Vinjhan. This member consists predominantly of alternating micaceous siltstone

and laminated silty shales of monotonous khaki colour. The upper part is reddish. A few thin fossiliferous marl beds are present.

Boundaries : The lower contact of the formation is generally conformable with the Khari Nadi Formation as described earlier. It is easily recognisable between the overlying khaki claystone and underlying variegated siltstones. The upper contact with the Sandhan Formation is marked by a prominent disconformity seen in all the major river sections in southern slopes of Kutch mainland.

Thickness : Maximum thickness encountered in the type section 380 ft. +(116m).

Fauna : The formation is very richly fossiliferous with varieties of fossils, e.g.

Gastropods : *Turritella, Murex, Natica, Cyprea, Trochus, Turbo, Physa, Conus* (giant forms) etc.

Lameilibranchs : *Ostrea latimarginata, O. gajensis, O.angulata; Pecten, Arca, Venus*, etc.

Echinoids : *Cidaris, Clypeaster, Scutella, Breynia, etc.*

Single form corals and bryozoa are also common. Trails and burrows are commonly seen.

Biozones : Three distinct zones are recognisable in the claystone member:

(3) *Miogypsina (Lepidosemicyclina) excentrica* zone

(2) *Miogypsina (Lepidosemicyclina) droogeri* zone

(1) *Miogypsina (Miogysina) globulina - thecideaeformis* zone

M. (Miogypsinoides) dehaartii and *M. (M.) indica* occur in the lower zone. *Austrotrillina howchini* and *Archaias malabarica* are common.

Guha (1961) recorded nine species of ostracoda from claystone member including *Cytherelloidea chaasraensis* Guha, and *Miocyprideis chaudhuryi* (Lubimova and Guha).

Envioronment of deposition : The rich biota and lithology clearly indicates deposition in sublittoral environment during the highest stand of the sea. Foraminifera suggest a fluctuating marginal marine to shallow inner-shelf conditions of deposition.

Age : Miogypsinidae assemblage suggests Burdigalian age.

Sandhan Formation

Authors : Biswas and Raju (1971).

Further references : Biswas and Raju (1973).

Related names : Upper Tertiary (Wynne, 1872), Manchhar Series (Poddar, 1959).

Definition : Overlying the Chhasra Formation, a dominantly sandstone formation which is the highest in the Tertiary sequence of Kutch, has been named here as the Sandhan Formation.

Type section : This formation is named after Sandhan village (23°01'15"; 68°59'35"). The type section is exposed along the Kankawati river from one km south of Vinjhan to south of Sandhan where it is overlain by Quaternary and Recent deposits.

Distribution and occurrence : This formation is exposed in a wide continuous belt of outcrops all along the coastal plain of South-Western, Southern and South- Eastern Kutch mainland from Naliya in the west to Anjar in the east. In the plainlands of the Eastern Kutch, this formation is also exposed in patchy outcrops overlying the Chhasra Formation.

Lithology : The lower part of the formation consists of well sorted, medium to coarse grained, massive, micaceous, quartzoze sandstones, overlain by clayey, laminated siltstones and topped by thin yellow fossiliferous limestone beds. The middle part comprises conglomerates and coarse grained sandstones with lenticular bodies of conglomerates. The upper part consists mainly of hard, calcareous grits, overlain by pink and grey mottled silty sandstone with calcareous nodules. A 2 ft. thick basal conglomerate containing pebbles and cobbles of older formations alongwith fossil wood pieces of varying sizes, occurs extensively, filling up the scoured channels in the underlying formation.

Boundaries : The lower disconformable contact with the Chhasra Formation is clearly seen in all the river sections of Southern mainland as undulating erosional surface with a basal conglomerate bed. The upper contact is not distinct. It grades into Quaternary/Recent beds with increasing calcareous nodules forming 'Kankars'. Along the southern slopes of the mainland it overlaps the Deccan Trap south of Anjar.

Thickness : The Maximum thickness developed in the type section in South-Western Kutch is over 965ft.+(294m). It thins down gradually towards the east.

Fauna and Flora : Foraminifera include *Ammonia* sp., *Pararotalia* sp., *Elphidium* sp. and miliolids. Fossil wood. *Dipterocarpoxylon malvaii* Ghosh is common in the basal conglomerate.

Mathur and Mathur (1969) described 21 species of the spores and pollens from this formation exposed in the vicinity of Naera (23°60';71°30') and Baraia (22°55';69°43'). Lenticular pockets of oyster debris ('shell gravels') and thin oyster bands (Oyster banks) are common in the upper conglomeratic sandstone. Several vertebrate fossils including Anthracotheroids and Suids have been reported by Prasad (1964, 1967) from this formation.

Environment of deposition : The basal conglomerate with fossil wood and channel fills over the underlying Vinjhan shales clearly suggest an erosional break in deposition followed by fluvial sedimentation. The sandstones appear to be the littoral sands of the advancing sea after a major regression. The depositional environment thus appears to be Supra-littoral to deltaic or fore-shore environment.

Age : In absence of diagnostic fauna, no definite age could be assigned. However, its occurrence above the Middle Miocene strata with a prominent break and from the affinity of foraminifera a tentative Pliocene age has been assigned to this formation.

BIOSTRATIGRAPHY

Major part of the Tertiary sequence of Kutch is rich in fossils. Larger foraminifera provide basis for biostratigraphic zonation, quite a few of which can be easily identified up to generic or specific level with hand lens in field itself. Mappability of many of these zones is a practical feature since their beds are traceable in the field for long distances and some zone boundaries coincide with the stage boundaries. Most of zones, though often named and semiprecisely defined in succession by different workers, are yet to be designated formally with type sections, faunal details and mappability. Nevertheless, the commonly used foraminifer zone-names of the Kutch Tertiary stratigraphy have been compiled in Table-1. The table provides, age-wise arranged zone names with author and other details. The faunal description and description of these biostratigraphic units are left to the biostratigraphers to resolve. Though preliminary, an idea about the definition of zones and the stratotypes and age is presented in the pages to follow.

Schizocythere spinosa Zone

Stratotype : Kakdi Nadi Section (Naredi Cliff), Kutch.

Definition : The zone is defined by the local abundance of Ostracode assemblage and marked by the range of the *Schizocythere spinosa* (Khosla and Pant, 1988)

Age : Khasian Stage (Thanetian), Palaeocene.

Related Stratigraphic Unit : This zone is recognised from the Gypseous Shale Member of Naredi Formation. The thin Zone falls within the Khasian Stage.

Assilina granulosa Zone

Stratotype : Kakdi River Section (Naredi Cliff), Kutch.

Definition : This Zone is defined by the local range of *Assilina granulosa* (Mohan and Soodan, 1970).

Age : Lower Eocene (Ypresian).

Related Stratigraphic Unit : This zone is recognised from the *Assilina limestone* member of Naredi Formation and from the middle part of Kakdian Stage.

Assilina granulosa-Nummulite obtusus Inter-biohorizon poorly fossiliferous Zone.

Definition : This zone extends from the top of *Assilina spinosa* Zone in the Naredi Formation to the base of *Nummulites obtusus* Zone in the Harudi Formation.

Age : Upper part of Lower Eocene to the Lower part of the Middle Eocene (Ypresian to Lutetian). This barren zone includes also a small hiatus at boundary of Lower and Middle Eocene (contact of Naredi & Harudi Formation).

Related Stratigraphic Unit : This Zone ranges from the Ferruginous Claystone member of Naredi Formation, referred to as upper part of Kakdian Stage, to the lower part of Babian Stage covering Harudi Formation.

Nummulites obtusus Zone

Stratotype : Guvar stream section, (fig. 1 of Raju, 1974b), given as *N. perforatus*).

Definition : Defined by the local range of *N.obtusus* stratigraphically below *T. topilensis* Zone.

Age : Lower part of Middle Eocene (Lutetian)

Related Stratigraphic units : Middle part of Harudi formation and lower part of Babian stage.

***Truncorotaloides topilensis* Zone**

Stratotype : Trinidad (=*Globorotalia lehneri* zone of Bolli, 1957).

Parastratotype : Guvar stream section (fig. 1 of Raju, 1974b)

Definition : Locally defined as the interval from *Nummulites obtusus* to initial appearance of *Orbulinoides beckmanni*

Age : Middle Eocene (Lutetian)

Related Stratigraphic Unit : Uppermost part of Harudi Formation and lower part of Babian Stage.

***Orbulinoides beckmanni* Zone**

Stratotype : Trinidad (Bolli, 1957)

Parastratotype : Berwali Nadi Section, Kutch (Mohan and Soodan, 1970, and Raju, 1974b).

Definition : This Zone is defined by the total range of *O.beckmanni*..

Age : Middle Eocene (Lutetian - Bartonian).

Related Stratigraphic Unit : This Zone is recognised from the lower part of Fulra Limestone and Middle part of Babian Stage.

***Truncorataloides rohri* Zone**

Stratotype : Trinidad (Bolli, 1957).

Parastratotype : Ramania area, Kutch (Raju, 1974b).

Definition : This Zone is defined as the interval from the last occurrence of *Orbulinoides beckmanni* to the last occurrence of *T.rohri.*

Age : Upper part of Middle Eocene to basal Upper Eocene(?), Bartonian- Priabonian).

Related Stratigraphic Unit : It is recognised in the upper part of Fulra Limestone and upper part of Babian Stage. The Zone extends in the basal Upper Eocene also when the *T.rohri* straddles the last *Assilina*-first *Pellatispira* boundary.

***Nummulites fichteli* Zone**

Stratotype : Bermoti stream section (Raju, 1974 b).

Definition : Defined as the interval from first occurrence of the nominate taxon to the initial occurrence of *Lepidocylina (Eulepidina) dialata.*

Age : Lower Oligocene

Related Stratigraphic Unit : Basal Member of Maniyara Fort Formation and lower part of Ramanian Stage.

***Nummulites fichteli — Lepiodyclina (Eulepidina) dialata* Zone**

Stratotype : Bermoti stream section (Raju, 1974 b)

Definition : This Zone is defined by the first appearance of *Lepidocyclina (Eulepidina) dialata* to the top of the *N. fichteli* in Kutch. *L.(E) dialata* is common in the lower part but rare to absent in the upper part.

Age : Lower Oligocene (Rupelian).

Related Stratigraphic Units : This Zone is recognised from coral limestone member of Maniyara Fort Formation and the Upper part of Ramanian Stage.

***Planolinderina freudenthali* Zone**

Stratotype : A small cliff section near Waior Village (Fig.1, Raju & Drooger, 1978).

Definition : The Zone is defined as the interval from the last occurrence of *Nummulites fichteli* to the first occurrence of *Migypsinoides.*

Age : Upper Oligocene (Chattian).

Related Stratigraphic Unit : The Zone is recognised from the Lowest part of Bermoti Member of Maniyara Fort Formation and the lower part of Waiorian Stage.

***Miogypsina (Miogysinoides) bermudezi* Zone**

Stratotype : Cliff section near Waior village (Fig. 7, Raju, 1974a).

Definition : The Zone is defined as the interval from the base of *M.(M.) bermudezi* to the base of *M .(M.) complanata.*

Age : Upper Oligocene (Chattian).

Related Stratigraphic Unit : The Zone is recognised from the Middle part of Bermoti Member of Maniyara Fort Formation and the middle part of Waiorian Stage.

***Miogypsina (Miogypsinoides) complanata — formosensis* Zone**

Stratotype : Cliff section near Waior village (Fig.7, Raju, 1974a).

Definition : The Zone is defined by the combined range of nominate taxa.

Age : Upper Oligocene. (Chattian).

Related Stratigraphic Unit : The Zone is recognised from the Upper part of Bermoti member of Maniyara Fort Formation and the upper part of Waiorian Stage.

***Miogypsina (Miogysinoides) complanata — Miogypsina (Miogypsina) tani* Interbiohorizon Zone.**

Definition : The interval from the top of *M.(M.) complanata formosensis* Zone to the base of *M.(M.) tani* Zone is poorly fossiliferous in Kutch outcrop area and designated as a zone.

Age : The regressive event of this Zone covers, in the offshore, post *M.(M.) complanata* range of *Spiroclypeus ranjanae* and associated shales. The Zone, according to stratigraphic position, ranges from upper Oligocene to basal lower Miocene (Chattian to base of Aquitanian).

Related Stratigraphic Unit : The Zone is recognised in the interval of the lower part of the Khari Nadi Formation and the lower part of Aidian Stage.

***Miogypsina (Miogypsina)tani* Zone.**

Stratotype: Khari Nadi Section, Kutch (fig. 9, Raju, 1974a).

Definition : The Zone is defined by the total range for nominate taxon.

Age : Lower Miocene (Aquitanian).

Related Stratigraphic Unit : The Zone is recognised in the upper part of Khari Nadi Formation and the upper part of Aidaian Stage.

***Miogypsina globulina - M. (Lepodosemicyclina) thecideaformis* Zone.**

Stratotype : Khari Nadi Section, Kutch (Fig. 9, Raju, (1974a).

Definition : This Zone is defined as the interval from the initial appearance of *M. globulina* to the initial occurrence of *M. (L.) droogeri*

Age : Lower Miocene (Burdigalian).

Related Stratigraphic Unit : Lowermost part of the claystone Chhasra Member of the Chhasra Formation the lowest part of Vinjhanian Stage.

***Miogypsina (Lepidosemicyclina) droogeri* Zone**

Stratotype: Khari Nadi Section, Kutch (fig.9, Raju, 1974a).

Definition : The Zone is defined by the total range of *Miogysina (L) droogeri.*

Age : Lower Miocene (Burdigalian).

Related Stratigraphic Unit : The Zone is recognised from the middle part of the claystone Member of the Chhasra Formation and the middle part of the Vinjhanian Stage.

***Miogypsina (Lepodosemicyclina) excentrica* Zone**

Stratotype: Khari Nadi Section, Kutch (Fig.9, Raju, 1974a).

Definition : The Zone is defined by the range of the zonal taxon.

Age : Lower Miocene (Burdigalian).

Related Stratigraphic Unit : The Zone is recognised from the upper part of the claystone Member of the Chhasra Formation and the upper part of the Vinjhanian Stage.

***Ammonia papillosus* Zone**

Stratotype : Not designated so far.

Parastratotype : Kankawati Nadi Section, Kutch.

Definition : The lower limit of the Zone lies at the extinction level of *M. (L) excentrica* and the upper limit is at the local disappearance of *A. papillosus.*

Age : Lower Miocene (Burdigalian).

Related Stratigraphic Unit : The Zone is recognised in the Siltstone member of the Chhasra Formation and the upper part of the Vinjhanian Stage.

CHRONOSTRATIGRAPHY

The Tertiary sequence of Kutch, between Palaeogene and Early Neogene, is characteristically rich in larger foraminifera which helped in mapping different stratigraphic units as distinct time bound segments or chronostratigraphic units. Chronostratigraphic sequence was first divided into series and stages and named according to their designated stratotypes (Biswas, 1965). The same classification was later refined further when the stage names were suffixed by IAN as per international practices and recommended changes fixing a limit of 3 to 10 million years span for a stage (Hedberg, 1976). Series nomenclatures were dropped in view of global usage of concept, the stages in the Tertiary succession of Kutch, originally described by Biswas (1965, 1971, 1973b) (and Raju (1974b) are modified here as follows:

Kankawatian Super Stage - Late Miocene and Pliocene (Langhian to Piacenzian).

Vinjhanian Stage- Early Miocene (Burdigalian)

Aidian Stage -Early Miocene (Aquitanian)

Waiorian Stage - Upper Oligocene (Chattian)

Ramanian Stage - Late Eocene (Priabonian)

Babian Stage - Middle Eocene (Lutetian-Bartonian)

Kakdian Stage - Lower Eocene (Ypresian)

Khasian/Madhian Stage- Upper Palaeocene (Thanetian).

In the later study (Biswas, 1986), it was observed that the lower part of the Kakdian Stge is referable to Palaeocene Khasian Stage described by Pandey & Ravindran (1933) from its type area in Khasi Hills, Meghalaya.

It was further established that the Tertiary stage nomenclaturre for the marine sediments is traceable all over the Indian shelf from Rajasthan to Kerala and then from Palk Bay to Upper Assam (Pandey, 1986). Accordingly, Kutch stages were extended all over the Indian shelf. This way, the overall relationship of the Kutch stages comes to be established as shown in Fig. 2.

Each of these stages is discretely and extensively mappable in the Mainland Kutch (Fig. 3) and also traceable in the subcrops of Indian Shelf. These are described here with designated stratotype sections (Figs. 6-8). Correlations of stages and rock units described earlier, could be made easily with the help of well-defined biostratigraphic marker beds as shown in Fig. 2. Synonyms have not been included in these descriptions covering essentially the marine stages. The nonmarine Palaeocene unit Madhian Stage is, however, discussed since it represents approximately the same time span as the Khasian Stage. The locations of the stage stratotypes are shown in Fig. 1 and their lithology, bed-wise, is in the Appendix.

Madhian Stage

Author : Biswas, 1965, originally defined as Madh Series.

Further Reference : Biswas and Raju, 1971.

Related Names : Sub-Nummulitic (Wynne, 1872). "Laterites and Lateritic clays (Poddar, 1959); Supra Trappean (Mathur, 1966).

Definition : Non-marine strata developed locally in Kutch area, dated as Upper Palaeocene on the basis of microflora and its position above the Deccan Trap Group, are defined as the Madhian Stage (originally defined as the Madh Series by Biswas, 1965).

Correlation : Corresponds to the Matanomadh Formation (Fig. 2) and lower part of the Naredi Formation.

Stratotype : Area around the village Matanomadh (locally called Madh), along the road sections and in the badlands surrounding this village (Fig. 6).

Boundary : Lower contact with the Deccan Trap Group and the Mesozoic rocks is disconformable and prominently marked by red laterites and basal conglomerates. The upper contact is also erosional but appears gradational when the lateritic clays are overlain by the shales and claystones of the overlying Kakdian Stage.

Lithology : Described under the Matanomadh Formation. Mainly bright colourd volcanoclastics, details shown in Appendix alongwith the lithological succession.

Fauna : See under the Matanomadh Formation. Mainly contains spores and pollens and occasionally dicot leaf impressions (Mathur, 1966).

Thickness : Highly variable. It is about 49m in the type area.

Environments : Terrestrial deposits, fluviatile and/or wind borne, locally lacustrine.

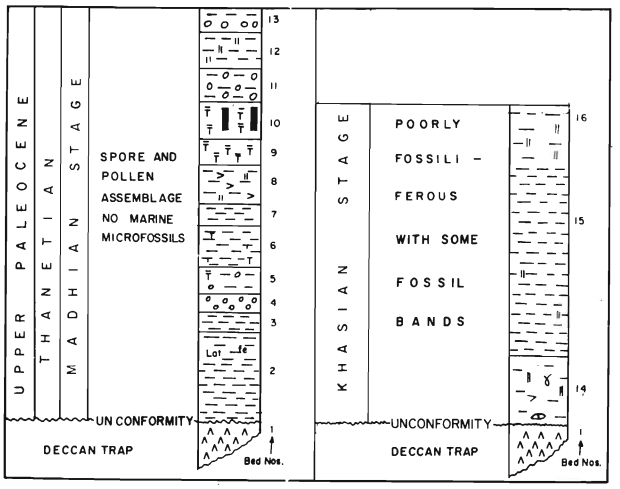

Fig.6 : Paleocene Stage Stratotypes of Kutch.

Khasian Stage

Author : Pandey, 1975.

Further Reference : Pandey and Ravindran (1988).

Related Names : Ranikot Series (Krishnan, 1968).

Definition : Defined by Pandey and Ravindran (1988) as a marine Palaeocene (Thanetian) Stage of Indian Shelf covering the zonal interval P 5 and P 6 of Blow (1979).

Correlation : In the cliff section of Kakdi Nadi, south of Naredi village, about 10m. thick marine glauconitic claystone beds containing microfaunal assemblages & correlable with Late Thanetian beds of the offshore well sections of Kutch Shelf, have been referred to the Khasian Stage. These beds represent the marine facies of the continental Matanomadh Formation which has been described in the chronostratigraphy of Kutch as the Madhian Stage.

Stratotype : Um Sohryngkew river section of Southern Meghalaya described by Pandey and Ravindran (1988).

Para-stratotypes: Cliff section of Kakdi Nadi south of Meghalaya village, close to the Naliya-Narayan Sarovar road bridge (fig.6). Also offshore well sections. KD 1 and KGH1, which are better developed.

Boundaries : It rests disconformably over the Deccan Trap flows. The upper boundary with the Kakdian Stage is conformable and marked on top of the 1 ft. *Assilina*-pelecypod limestone band. In the offshore, the upper contact is placed at the top of a regressive event which terminates the rich planktonic suite corresponding to the *Assilina* band.

Lithology : In Kutch outcrops, the stage is mainly argillaceous green glauconitic claystones with marlite and nodular coquina bands, but in offshore it is represented by Nummulitic limestones. Detailed description and lithologic succession are given in Appendix.

Fauna : A rich assemblage of larger forminifera is reported from this Stage in offshore which includes *Miscellanea miscella, Nummulites globulus indicus, N. thalicus, Discocyclina senusesi,* besides Palaeocene Globorotalids figured from Kutch outcrop (Biswas, 1986). Ostracoda and megafossils like lamellibranchs and gastropods are common.

Thickness : Only 16m in Naredi section.

Environments : Lagoonal/marginal marine.

Kakdian Stage

Author : Biswas, 1965, originally described as Kakdi Stage.

Further Reference: Raju, 1974b, Pandey and Guha, 1979 (unpublished).

Related Names : Laki Series/Beds, (Tewari, 1957, Poddar, 1959), Gypseous Shales (Wynne, 1872).

Definition : Marine fossiliferous strata corresponding to Lower Eocene (Ypresian) in Kutch constitute the Kakdian Stage. The stage is defined by Chronointerval between P6 to P9. The marine sediments of this interval in India are referred to this stage in subsequent work (Pandey and Guha, 1979; Pandey, 1986).

Correlation : In the outcrops of Kutch, this stage includes the Naredi Formation (fig. 2) and biozones Ostracoda, *Assilina spinosa* and Barren zones, from bottom to top.

Stratotype : Cliff sections along Kakdi Nadi, West of Budha (Fig. 7).

Para-stratotype: Interval between 4360 m and 4125 m in offshore Saurashtra well (Pandey and Guha, 1979).

Boundaries: In the outcrops (Naredi cliff Section), the lower boundary with the Khasian Stage is conformable. The upper boundary is disconformable as described on top of the Naredi Formation. The unconformity represents a stratigraphic lacuna between the Late Ypresian and Early Lutetian. In the western offshore area, in the parastratotype section, the erosional unconformity on the top of the stage is indicated by a zone of red colouration in the limestones.

Lithology : The stage is composed essentially of argillaceous rocks with thin limestone bands. Detailed descriptions are given under the Naredi Formation. A bed by bed description is provided in the Appendix. In offshore shelf the lithology is predominantly limestones.

Fauna: The large foraminifera are less in diversity in the outcrops but more so in the offshore where the fauna is characterised by *Nummulites globulus, Assilina spinosa, Lockhartia hunti* and *Fasciolites oblonga* and serveral other species. The stage includes three zones : Ostracoda, *A. spinosa* and poorly fossiliterous zones, from bottom to top.

Thickness : 25 m in the type section.

Environments : Shallow marine, lagoonal. Fossils indicate a maximum water depth of 0m. Represents a short transgressive phase after Late Palaeocene (post Trappean) unconformity. Sea regressed at the end of Ypresian as evident from the extensive erosional unconformity above the stage.

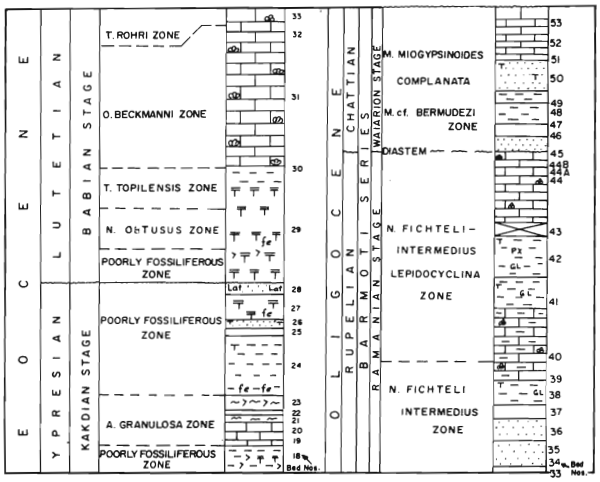

Fig. 7 : Eocene and Oligocene stage Stratotypes of Kutch.

Babian Stage

Author : Biswas, 1965, originally named as Babia Stage.

Further Reference : Mohan and Soodan, 1970; Raju, 1974b Guha, 1974; Pandey, 1982; Samanta, 1989; Khosla and Pant, 1988.

Related Names : Kirthar Beds/Series (Tewari, 1957; Poddar, 1959); Nummulitic Group (Wynne, 1872).

Definition : Indian stage of Middle Eocene (Lutetian and Bartonian age, representing the interval P 10 to P14 (part). The stage is defined by the entry of *Globigerapsis kugleri* and exit of *Orbulinoides beckmanni* in the planktonic scale. Entry of *Assilina papillata* and appearance of *Pellatispira* defines it in large foraminifera scale.

Correlation : The stage includes the Harudi and Fulra Limestone formations and biozones - *N. obtusus, T. topilensis, O. beckmanni* and *T. rohra* from bottom to top.

Stratotype : Southern flank of Babia Hils (23° 42′ 10"; 68° 46′ 20") (Fig. 7).

Para-stratotype : Berwali Nadi section described by Mohan and Soodan (1970).

Boundaries : Lower boundary is disconformable as described earlier. The upper boundary is disconformable placed on top of massive limestone bed containing characteristic saddled to undulated forms of *Discocyclina* and *Fasciolities.* In parastratotype the upper contact is marked by the disappearance of *Assilina* and appearance of *Pellatispira* about 1.5 m below the Eocene-Oligocene disconformity above *T. rohri* zone of Mohan and Soodan (1970). In the stratotype, the boundary is easily distinguishable as described in the case of the Fulra Limestone.

Lithology : Lower part is dominantly argillaceous, while the upper part is predominantly carbonate. Bed by bed description is given in the Appendix.

Fauna : The lower argillaceous part is poor in microfauna though a few thin limestone and coquina bands are full of gastropods and bivalves. Only one conspicuous band is full of *Nummulites obtusus.* Higher up the limestones are packed with varieties of foraminifera alongwith lamellibranchs, gastropods, echinoids, corals, fossil crabs, etc. *Nummulites perforatus, N. acutus, Discocyclina dispensa, D. adamsi* alongwtih other species are the common foraminifera present. Among planktonic forams, *T. rohri, T. topilensis, O. beckmanni* are characteristic (Mohan and Soodan, 1970). Guha (1974) reported eight Ostracoda species as marker of the Babian Stage including *Schizocythere, Paijenborchella, Trirulcate kutchensis* and *Uroleberis kutchensis.* Tandon and Srivastava (1980) described a new microechinoid species *Tridium keri* from this stage. Sahni and Mishra (1972, 1975) reported vertebrate fossils from this stage including a new mammal species, *Protocetus sloani* and *P. hasudiensis.*

Thickness : 37m.

Environments : The stage represents the highest stand of sea during the Eocene in India. The environment was sublittoral, clear water shallow marine shelf forming extensive carbonate bank.

Upper Eocene Hiatus

Guha and Pandey (1979, unpublished report), erected the Late Eocene Tarapurian Stage on the Western Indian Shelf corresponding to the Priabonian of Europe. It had since been recognised as a standard Indian Stage occurring on the eastern as well as western Indian Shelf (Pandey, 1986). In the offshore well KD-1, the stage has been recognised overlying the Babian Stage. It is 150m thick between well depths 810 m to 960m. In the onland areas of Kutch, the stage has been completely eroded excluding a thin interval of 3 m in the Berwali Stream, which contains *Pellatispira - Nummulites acutus* assemblage and is devoid of *Assilina* (J. Pandey, ONGC, Pers. Comm.). This stage remained unrecognised in the outcrops of Kutch in earlier studies where this was

described as a hiatus and the erosional unconformity on top of the Babian Stage was considered to be varying between *Orbulinoides beckmanni* zone and *Truncorotaloides rohri* zone. The Middle/Late Eocene boundary has been placed in the *T. rohri* zone by Blow (1979). In the Berwali Stream section also, the boundary of Babian and the Tarapurian Stages fall in the *T. rohri* zone.

Since the Tarapurian Stage is very thin and present in small discontinuous patches in the outcropping section, it is not mappable. Thus, the Babian Stage of Middle Eocene is shown to be followed by the Ramanian Stage of Lower Oligocene.

Ramanian Stage

Author : Biswas, (1971, 1973).

Further References : Raju (1974 b).

Related Names : Lakhpat Stage (Biswas, 1965); Nari Series (Nagappa, 1959; Chatterjee and Mathur, 1966).

Definition : An Early Oligocene (Rupelian) sequence corresponding to the time interval marked by the last *Pellatispira* and the last reticulate *Nummulites* on the Indian shelf, has been assigned to this stage. In the planktonic scale this time interval is marked by the P 18 and P19/20 zones.

Correlations : The stage corresponds to the lower three members of the Maniyara Fort Formation viz. Basal member, Lumpy clay member and Coral limestone member. It includes *Nephrolepidina-Lepidocyclina* zone.

Stratotype : The Oligocene rocks of Kutch are best exposed in Ramania - Walasara area. The type section is exposed in Ramania Stream section between the crossing of the Ramania-Fulae cart-track. Proceeding west along the latter cart-track, the small stream section, (tributary to the Ramania stream), exposes typically the upper part of the stage. This section is referred to as Walasara water fall section. Both sections together forms the composite stratotype (Fig. 7).

Para-stratotype: Section along the Bermoti Nadi in South-Western Kutch, between a locality 1.5 km NNE of the village Bermoti and a locality about 500 m. NE of it.

Boundaries : The lower disconformable boundary is well exposed in Jhulari-Aida stream at a locality about 2 km SW of Ramania. The unconformity is marked by a lateritised corrugated surface above the highly bioturbated white limestones of the Babian Stage, containing echinoids *(Micraster), Discocylina, and Alveolina.* The ochre yellow limestones with glauconitic pellets above the unconformity distinguish this stage. The top of the stage is marked by a nodular, calcareous sandstone bed studded with reticulate *Nummulites* occurring below a glauconitic sandstone bed with fossil bones at the base of the Waiorian Stage. At this contact a paraconformity is indicated by a small hiatus corresponding to the *Gryzvowskia tandoni* zone (Pandey, 1986). This contact is exposed typically in Walasara water fall section about 1.5 km. NE of Walasara village ($23^{0}25'40''$; $68^{0}46'30''$). In this section, only the top 3 m. section above the coralline limestone is present. In all other sections, this sequence up to the reticulate *Nummulites* band is missing.

Lithology : Detailed bed by bed description of lithology is given in the Appendix. The stage is mainly made up of limstones (also see description under the Maniyara Fort Formation).

Fauna : Among foraminifera, *Nummulites fichteli, Lepidocyclina (Eulepidina) dialata, Operculina* are characteristic. Several ostracoda are reported which include *Xestoleberis subglobosa* Bosquet, *Cytherelloidea mitra* Sohn, *Neonesidea indica, Acanthocythereis gujratensis, Actinocythereis khariensis, A.ramaniensis, Alocopocythere ennejensis, etc.* Among others, echinoids are abundant in the lower part. Mammalian and reptilian fossils are common in the upper part besides a variety of gastropods, pelecypods and corals particularly the reef builders.

Thickness : The stage is only 10m. thick in the outcropping areas and is fairly constant throughout its extent.

Environment : Infralittoral to sublittoral. A high energy condition prevailed in the upper part as indicated by the biohermal build-up of coralline limestone. This was followed by a regression with clastic flux when the sandstones of the overlying stage were deposited.

Waiorian Stage

Author : Biswas, (1965, 1971, 1973 b).

Further references : Mohan and Soodan (1970), Raju (1974 a, 1974b), Guha (1974), Raju and Drooger (1978), Drooger and Raju (1978), Raju (1978), Pandey (1982), Khosla and Pant (1988).

Related Names : Included in the Nari Series (Chatterjee and Mathur, 1966). Tewari, 1957, described it as Aquitanian Beds with *Spiroclypeus ranjanae* as an index fossil which was subsequently found to be a Chattian form (Biswas, 1973 b).

Definition : Marine strata of Chattian age constitute the Waiorian Stage developed in Kutch. The Chattian strata of Indian shelf are referable to this stage.

Correlation : This stage corresponds to the topmost Bermoti member of the Maniyara Fort Formation and includes *Miogypsina complanta-M. bermudezi* zones.

Stratotype : The type section is discontinuously exposed at three cliff sections along the right bank of Waior-Cheropadi stream from a locality about 300m NNE of Waior (23°25'05" 68°41'37') in upstream direction. A 10 m cliff NNE of Waior at the sharp band of the stream is the typical section.

Para-stratotype : The section continuously exposed along the Bermoti Nadi is designated as a reference section (Raju, 1974).

Boundaries : The lower boundary, placed at the base of the rusty brown glauconitic, ferruginous sandstone (fig.7) is exposed at the cliff section 600 m. NNE of Waior. The contact is a paraconformity as indicated by the absence of *G. tandoni* zone, which is developed in the offshore shelf area. The rusty sandstone is underlain by white limestone of the Ramanian Stage containing reticulate *Nummulites.* Locally, the sandstone which represents a regression, contains bone fragments alongwith other fossil fragments. This is very well exposed in Walasara section mentioned earlier.

The upper contact is placed on top of *Spiroclypeus* limestone bed exposed near the "Sati" stone 300 m ENE of Waior. The actual upper boundary with the overlying Aidian Stage is not exposed.

Lithology : Details are described in the Appendix. Also, descriptions of Bermoti member may be seen under the Maniyara Fort Formation. Lithology is mostly limestones in the offshore wells.

Fauna : *Spiroclypeus ranjanae* was originally described from this stage by Tewari (1956). Raju (1974a) described *Miogypsina* fauna from this stage. The larger foraminifera from this stage include : *Miogypsina (Miogypsinoides) bermudezi* in the lower part, *M. (miogypsinoides) formosensis* in the upper part, *Lepidocyclina praemarginata morgani, Planolinderina freudenthali, Escosniboyinis* and *Austrotrillina paucialveolata.* Besides microfauna, a host of mega-fauna consisting of lamellibranchs, gastropds, echinoids, corals, fossil carb and *Serpula* burrows occur in this stage. Although it is rich in larger foraminifera, hardly any planktonic forms are seen.

Thickness : 9m.

Environment : Infra-to sublittoral, bathymetry not exceeding 30m.

Aidaian Stage

Author : Biswas, (1971, 1973b).

Further Reference : Raju, (1974b).

Related Names : Lower Khari Stage (Biswas,1965), Arenaceous Group (Wynne, 1872), Gaj Beds (Poddar, 1959; Mohan and Bhatt, 1968).

Definition : The stage includes strata of Aquitanian age developed in Kutch and referable to all other Indian marine strata of the same age. The stage is delineated by post - *Spiroclypeus ranjanae* beds containing *Miogypsinoides dehaarti* and *M. indica.*

Correlation : Correlatable to the Khari Nadi Formation and post-*Spiroclypeus* poorly fossiliferous zone which is capped by *M. dehaarti–M. tani* zone (Fig.8).

Stratotype : Exposed in discontinuous cliff sections along the banks of Khari Nadi between Goyela and Laiyari (Fig.1).

Boundaries : The lower contact exposed at a locality (23°25'45"; 68°49'40") about 1.5 km south of Goyela. A persistent blue clay bed occurs at the base of the stage. The contact with the Waiorian Stage is placed at the base of this clay bed on top of the *Spiroclypeus* bed. A feeble unconformity is indicated by regional overlap.

The upper contact is seen at a locality (23°23'0"; 68°48'0"), about 2 km ESE of Laiyari, exposed at the base of a 10m. Cliff section. The boundary is conformable and marked by a prominent arenaceous limestone bed which is distinghished by the occurrence of *Turritella,* echinoid, and *Lepidocyclina,* at the base of the overlying stage.

Lithology : Described in detail alongwith the lithocolumn in the Appendix. This stage corresponds to the dominantly arenaceous Khari Nadi Formation and the lithology is also described under this in the

earlier section. In offshore area, it is mostly shales and limestones (interval P-Q of Pandey, 1982).

Fauna : Foraminifera includes mostly Miogypsinoids *M. (M.) tani, M. (M.) dehaarti* and *Nephrolepidina and Sphaerogypsina.* Locally dicot leaf impressions are seen.

Thickness : About 65m in the stratotype. The thickness increases enormously in offshore to over 300m.

Environment : Littoral to fore-shore.

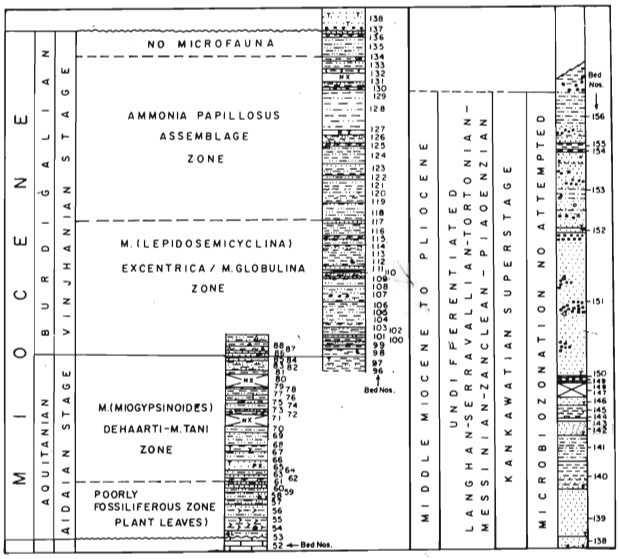

Fig. 8 Mio-Pliocene Stage Stratotypes of Kutch.

Vinjhanian Stage

Author : Biswas (1971, 1973b).

Further references : Raju, (1974b), Pandey, (1982.)

Related Names : Gaj Beds/Series (Tewari,1957, Poddar, 1959 & other earlier workers. Many workers still use this name); Argillaceous Group, (Wynne, 1872), Upper Khari Stage (Biswas, 1965).

Definition : The stage represents Burdigalian stage of Indian shelf (Pandey, 1982) marked by post-*Miogypsina dehaarti* range of *Ammonia papillosus* in Kutch.

Correlation : The stage generally corresponds to the Chhasra Formation and the *M. globulina-M.(L.) thacidaeformis* Zone to *Ammonia papillosus* Zone.

Stratotype : Exposed almost continuously along the Kankawati Nadi between a locality (23°6'07"; 69°3'40"), about 1.4m. SE of Khirasra and a locality (23°5'23"; 69°3'40"), about 1.5 km SSW of Vinjhan (fig.8).

Para-stratotype : Discontinuously exposed in the cliffs of Khari Nadi from south of Laiyari where the lower contact is exposed, to about 1.5 km S of Chhasra village.

Boundaries : The lower contact is marked by the *Turritella-Lepidocyclina* band above the Aidaian sandstones, exposed in Kankawati Nadi near Khirasra. The upper contact is marked by a prominent erosional surface with conglomerate as described earlier under the Chhasra Formation.

Lithology : Mostly shale and thin limestones packed with fossils (see under the Chhasra Formation. The litho-column with bed by bed description is given in the Appendix.

Fauna : Highly fossiliferous with varieties of mega fauna as well as microfauna as described under the Chhasra Formation.

Thickness : 116m.

Environment : Sublittoral, represents the highest stand of the sea during the Tertiary with 50 m to 100 m water depth.

Kankawatian Superstage

Author : Biswas, (1965).

Related Names : Upper Tertiary Group (Wynne, 1892); Manchhar Beds (Poddar, 1959).

Definition : Undifferentiated Middle Miocene and Pliocene strata developed in Kutch, have been grouped under this superstage. The superstage could be subdivided into stages if differentiation of Upper Miocene and Pliocene is possible in any part of the basin e.g. in offshore areas, which could not be done so far.

Correlation : This Superstage corresponds to the Sandhan Formation.

Stratotype : The type section is exposed in the cliffs along the banks of the Kankawati Nadi from 1 km. South of Vinjhan to Sandhan village.

Para-stratotype : Naera river section near Naliya. Other good reference sections are along Chok, Vengdi, Kherod and Rukmawati river sections.

Boundaries : Lower boundary with the Vinjhanian Stage is disconformable as described above. Well marked erosional unconformity with basal

conglomerate is seen very well in almost all the rivers of Southern Kutch.

The formation is overlain by Pleistocene 'Kankar' beds or nodular calcareous sandstones and alluvium. The contact is gradational.

Lithology : Dominantly sandstones (see under Sandhan Formation). Details are given in the Appendix.

Fauna : Mostly unfossiliferous excepting a few oyster banks. A yellow limestone bed in the middle contains pelecypods and gastropods. Among microfauna, *Ammonia. Pararotalia, Elphidium,* and miliolids are common. None of the fauna is diagnostic of age. The age has been assigned by inference from the order of superposition.

Thickness : The superstage is more than 294m+thick.

Environment : Transitional, estuarine or deltaic to littoral. Discussed in detail under the Sandhan Formation.

Tertiary transgression started only during the Middle Eocene and the units so far described as Early Eocene and Palaeocene are nothing but the different isochronous facies of the Middle Ecoene limestone (Fulra Limestone/ Babian Stage) is not valid. It is now conclusively evident from the offshore wells recently drilled that distinct Palaeocene planktonics occur in offshore Kutch characterizing zones P4 and P5-P6 associated with diagnostic Palaeocene larger foraminifera found in an onland section (Pandey and Ravindran, 1988). The offshore well sections are very well correlated with the lower part of the Naredi section in onland Kutch included under the Palaeocene Khasian Stage. Definite Palaeocene forms like *Turborotalia varianta, T. pseudobulloides, Chiloguembelina midwayensis* and *Lockhartia haimei* are recorded from this section. The overlying Kakdi Stage contains definite Lower Eocene larger foraminifera like *N. burdigalensis, Assilina granulosa,* as well as *N. acutus* in the upper horizon of the main *Assilina* band. The same assemblage is present even in offshore well section (Fig. 9).

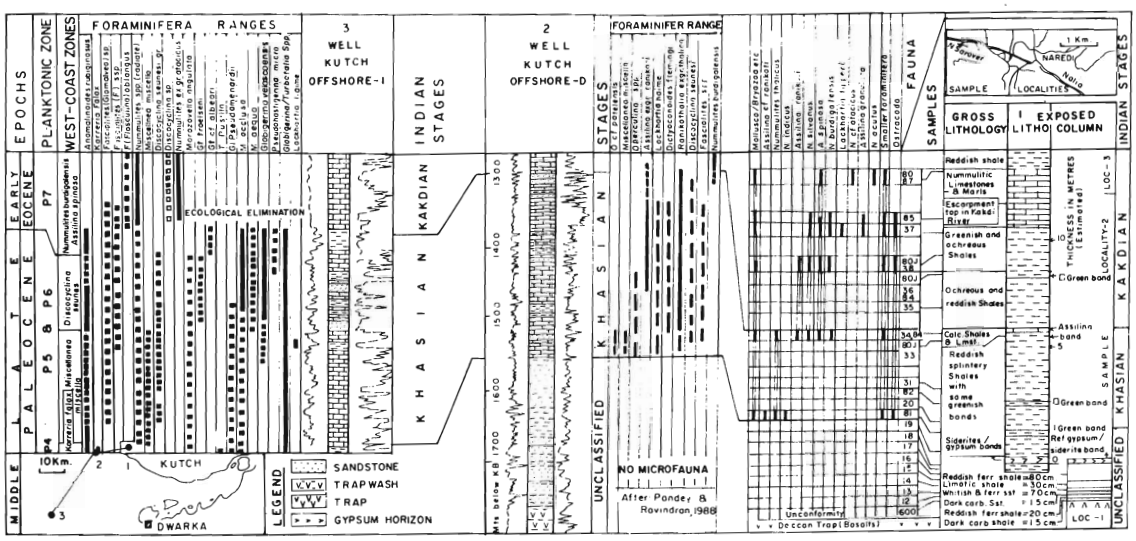

Fig. 9 : Correlation of Palaeocene of Kutch onland and offshore

CONCLUDING REMARKS

In the end I would like to take up the question of the time of initial Tertiary transgression in Kutch. In the earlier studies, I had shown that initial transgression in the basin begins with the Early Eocene Kakdian Stage and this view was confirmed in the study of Bhatt (1968) and Tandon *et al.* (1980). The latter indeed put the earliest transgression level in the Palaeocene with which I agree. The view that the Thus, not only the correlations of the Kakdi River section with the offshore well sections but also the very endemic microfaunal record substantiates that the earliest trangression over the Deccan Trap in the mainland Kutch was in the upper Palaeocene and not in the Middle Eocene.

The foraminifer zones of Kutch offshore and onland are traceable in the subcrops of Rajasthan and Western Indian Shelf from Ratnagiri offshore through

Kutch and Saurashtra offshore (Pandey and Ravindran, 1988). In all these areas, Palaeocene Khasian Stage is overlain by the Kakdian Stage and an excellent correlation of the offshore zones is seen up to the Kakdi River section in Kutch (fig.9). In the light of these correlations, the thesis propounded by Ray *et al.* (1984) that no marine bed older than Middle Eocene is present in Kutch, is not acceptable (Biswas, 1986). The detailed correlation of the offshore Palaeocene of Kutch and Naredi section, as attempted here, exhibits the typical change of assemblage from deeper to the shallower facies of the upper Palaeocene Khasian Stage. The correlation suggests the shallower facies of exposed Kakdi river section in the offshore, with low diversity of assemblage. It may be pointed out clearly that the Khasian Stage, represented by *Discocyclina senuesi* facies and planktonic elements like *Morozovella oclusa* and *M. acqua* in the well GKH-1, extends in somewhat shallower *Lockhartia haimei* assemblage zone in the offshore well KD-1. It is ultimately represented in the Kakdi River section as a foot thick *Assilina spinosa*- rare planktonics band (Biswas, 1986, fig. 1. sample position XA 64).

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REFERENCES

Bhatt, D.K. 1968. Planktonic foraminifera from Lower Eocene sediments of Kutch, India. *Bull.,ONGC.* **4**, (2) : 13-17.

Biswas, S.K. 1965. A new classification of the Tertiary rocks of Kutch, Western India. *Bull. Geol. Min. Met. Soc. India;* **35** : 1-6.

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

Biswas, S.K. 1973a. Landscape of Kutch - A morphotectonic analysis. *Proc. 60th Ind. Sci. Congr.; Abs. Adv. Note on Symp. & Discussions,* : 9.

Biswas, S.K. 1973b. Time stratigraphic classification of the Tertiary rocks of Kutch - A Revision and Amendments, *Quart. Jour. Geol. Min. Met. Soc. India,* **44** (3).

Biswas, S.K. 1986. Paleocone of Kutch - A rejoinder, *Indian Jour. Earth Sci.,* **13**, (2).

Biswas, S.K. and Deshpande, S.V.1973. A note on mode of eruption of Deccan Trap lavas with special reference to Kutch. *Jour. Geol. Soc. India.* **14**, (2): 134-141.

Biswas, S.K. and Raju, D.S.N. 1971 Note on the rock- stratigraphic classification of the Tertiary sediments of, Kutch. *Quart. Jour. Geol. Min. Met. Soc.* India.

Biswas, S.K. and Raju, D.S.N. 1973. The rock - stratigraphic classification on the Tertiary sediments of Kutch, *Bull. ONGC,* **10**, (1&2) : 37-46.

Blow, W.H. 1979 The Cainozoic Globigerinidae 3 Volumes (Leiden I.J.Brill).

Bolli, H.M.; 1957 the genera *Globigerina* and *Globorotalia* in the Palaeocene - Lower Eocene Lizard springs formation of Trinidad, B.W.I, *Bull, U.S.N.M,* **215** : 61-82.

Chatterjee, A.K. and Mathur, U.B.; 1966 Note on the Nari Series of Kutch, Gujerat, *Bull. Geol. Soc., India,* **3** (1): 9-11.

Drooger, C.W. and Raju, D.S.N.: 1978 Early *Miogypsinoides* in Kutch, Western India. *Kon. Ned. Acad. Wet.* **B81** : *186-203.*

Guha, D.K. 1961. A note on the orstracodes from lower Miocene of Chaasra, Kutch, *Bull. Geol. Min.Met.Soc. Inida,* **24** : **1-6.**

Guha, D.K. 1968. Ostracoda from Middle Eocene of Kutch, Gujarat State Western India, *Bull. ONGC,* **5**, (1) : 83-92.

Guha, D.K.1974. Observation on the Cenozoic and some Mesozoic ostracoda of India. *Publ. Centre Advance study Geology. Punjab University,* **7** : 205-212.

Hardas, M.G. and Biswas, S.K. 1973. Palaeogene sediments from South-Western Kutch, Gujarat, *Bull. ONGC,* **10** : 47-54.

Hedberg, H.D. 1976. International Stratigraphic guide. Wiley New York, 200 pp.

Jafar, S.A. 1986. Fallacious status of Palaeocene in Kutch Basin. *Proc. Symp. "Palaeocene of India: Limits and subdivision"* Lucknow, 1986, IAP. Abstract.

Khosala, S.C. and Pant, S.C. 1988. Ostracoda from the Eocene and Oligocene beds of Kutch, Gujarat, Part-I; Families Cytherellidae, Bairdiidae and Trachyleberididae, *Indian Jour. Earth Sci.,* **15** (4) : 325-46.

Khosala, S.C. and Pant, S.C. 1989. Ostracoda from the Eocene and Oligocene beds of Kachchh, Gujarat Part-II-Families Cytheridae, Hemicytheridae, Loxoconchidae, Paracytheridae, Xestoleberididae and Candonidae. *Indian Jour. Earth Sci.* **16**, (1): 1-10.

Krishnan, M.S. 1968. Geology of India and Burma. Higginbothams Madras.

Mathur, Y.K. 1966. On the microflora in the Supra Trappeans of Western Kutch, Inda. *Quart. Jour. Geol. Min. Met. Soc. India.* **38** (1) : 33-51.

Mathur, Y.K. and Mathur, K. 1969. Studies in the fossil flora of Kutch (India) (3) on the paleopalyflora in the Pliocene sediments of Naera-Bararia area. Kutch *Bull. Geol. Min. Met. Soc. India,* **42** : 1-12.

Mehrotra, K.K. and Biswas, S.K. 1989. Age of the Deccan Trap Flow in the Kutch offshore area. In Prabha Kalia-(Ed.) Micropaleontology of the shelf sequences of India, Papyrus Publishing House, New Delhi, pp.139-145.

Mohan, M. and Soodan, K.S. 1970. Middle Eocene planktonic foraminiferal zonation of Kutch, India, *Micropal.,* **16**. (1) : 37-46.

Mohan, M. and Bhatt, D.K. 1968. Burdigalian foraminifera from Kutch, India, *Proc. Natn., Inst. Sci., India.* 34. 159-190.

Nagappa, Y. 1959. Foraminiferal biostratigraphy of the Cretaceous Eocene Succession from India, Pakistan & Burma regions. *Micropalaeontology*, **5** : 145-192.

Pandey, J. 1975. Cretaceous to Middle Eocene stratigraphy of Cherra-Therria area and a study of Late Cretaceous-Early Tertiary foraminifera of Um Sohryngkew River section, Meghalaya unpublished Ph. D.Thesis, B.H.U., Varanasi.

Pandey, J. 1982. Chronostratigraphic correlation of the Neogene sedimentaries of Western Indian shelf, Himalaya and Upper Assam, *Spec. Publ. Pal. Soc. India*, **1** : 95-129.

Pandey, J. 1986. Some recent palaeontological studies and their implications on the Cenozoic stratigraphy of Indian subcontinent, *Bull. ONGC,*. **23** (2) : 1-44.

Pandey, J. and Guha, D.K., 1979 (Unpublished report) Cenozoic chronostratigraphy of the Western India shelf. Report Geo. Lab. ONGC, Baroda.

Pandey, J. and Ravindran, C.N. 1988. Foraminiferal controls in the Indian Palaeocene. Proc. Symp. "Paleocene of India, Limits & sub division", Lucknow, *Indian Assoc. of Palynologist,*: 124-184.

Poddar, M.C. 1959. Geology and oil possibilities in Kutch, Western India, *Proc. Symp. Dev. Petr. Res. ECAFE*, **10** : 146-148.

Prasad, K.N. 1964. Miocene vertebrates from Kutch District, Gujarat *India. Bull. Geol. Soc. India*, **1** : 9-12.

Prasad, K.N. 1967. Fossil mammals of Cutch District Gujarat, India *Jour. Geol. Min. Met. Soc. India*, **33** : 187-192.

Raju, D.S.N. 1971. Studies on some Miogypsinidae of Kutch, India, *Indian Sci. Congress, Proc. 58th session, Part III,*. 3117.

Raju, D.S.N. 1974 a. Study of Indian Miogypsinidae *Utrecht Micropalaeontological Bulletin*, **9** :1-148.

Raju, D.S.N. 1974 b. Observation on the Eocene, Oligocene and Miocene foraminiferal biostratigraphy of Kutch, Western India. *Publ. Centre Advanced study in Geology, Punjab Univ., Chandigarh*, **10 : 136-155.**

Raju, D.S.N. 1978. Larger foraminifera from the stratotype of the Waiorian Stage, Kutch, India (Abstract), *7th Indian Coll. Micropal. Strat., Madras,*. 11-12.

Raju, D.S.N. 1990. *Miogypsina* Scale and Indian Chrono-stratigraphy (MS).

Raju, D.S.N. and Drooger, C.W. 1978 The genus *Planolinderina* in India. Proc. IGCP. Project 1, ser B, **87** : 230-247.

Ray, A.K., Ghosh, C.C., Sen, P., Ghosh, A., Nag, S., Saha, D. and Chowdhary, A., 1984. Palaeocene of Kutch - and alternative view on the initial part of the sequence. *Indian Jour. Earth Sci.* **11**:. 207-224.

Sahni, A. and Mishra, V.P.,1972. A new species of *Protocetus* (Cetacea) from the Middle Eocene of Kutch, Western India. *Palaeontology*, **15**, (3) : 490-495.

Sahni, A. and Mishra, V.P. 1975, Lower Tertiary vertebrates from Western India. *Monograph., Pal. Soc. India,*.**3**. : 1-48.

Samanta, B.K. and Lahiri, A. 1985. The occurrence of *Discocyclina* Gumbel in the Middle Eocene Fulra Limestone of Kutch, Gujarat, Western India, with notes on species reported from the Indian region, *Bull. Geol. Min. Met. Soc. India*, **92:** 211-295.

Samanta, B.K., 1989. The study of foraminiferal biofacies and microenvironments of the Palaeogene sediments of Western Kutch, Gujarat, unpublished report submitted to KDMIPE, ONGC.

Sengupta, B.K. 1963 A restudy of two common species of *Discocyclina* from India, *Micropal,*.**9** : 39-49.

Sengupta, B.K., 1964. Tertiary biostratigraphy of a part of Northwestern Kutch. *Journal. Geol. Soc. India*, **5** :138-150.

Singh, P. And Singh, M.P. 1986. Late Middle Eocene Calcareous nannoplankton from Babia hill, Kutch, Gujarat. India, *Geoscience Journal*, **8** (2) :145-162, pl.5.

Srivastava, D.K. 1978. Microechinoids from the Oligo-Miocene rocks of Kutch, India. *Proc. 7th Ind. Colloq. Micropal. Strat., Madras,* 421-428.

Tandon, K.K., Mathur, Y.K. and Saxena, R.K. 1980. Paleocene-Early Eocene biostratigraphy in Nareda, south western Kutch, western India. *Jour. Pal. Soc. India*, **23-24** : 86-91.

Tandon, K.K. and Srivastava, D.K. 1980. A new genus and speices of the clypeasteroid echinoid from the Middle Eocene rock of Kutch, India, *Jour. Pal. Soc. India.* **23-24** :1-3.

Tewari, B.S. 1956. The genus *Spiroclypeus* from Kutch, Western India, *Curr. Sci.* **25** :319-320.

Tewari, B.S. 1957. Geology and Stratigraphy of the area between Waghopodar-Cheropadi, Kutch, Western India, *Jour. Pal. Soc. India*, **2.** : 136-147.

Wynne, A.B. 1872. Memoir on the Geology of Kutch, to accompany the map compiled by A.B.Wynne and F. Fedden during the season 1867-68, *1868-69, Mem. Geol. Surv. Ind.* **19** (2): 269.

APPENDIX
Type Sections of Tertiary Stages of Kutch

Bed No.	Description	Thickness (ft.)
	MADHIAN STAGE	
	---------- Unconformable boundary ----------	
13	Lt. bluish grey shale, bentonitic clay with conglomerate at the base	6′
12	Grey to black sh. tuff with (?) limonitic encrustations	17′
11	Clayey conglomerate	14′
10	Ash grey well-bedded carbonaceous shales	13′4″
9	Ash grey bentonitic shale with 1′-4′ thick yellow and white cl. at top	8′
8	Red to purple, white bentonitic cl. with gyp. cl.	15′10″
7	White chalky clay with slightly grey and yellow tinge and big pebbles of white chalky clay with a bed of c.gr. laterite and tuff. Sst.	7′7″
6	Ash grey shales with coarse gr.sst. band white colour and red laterite	17′6″
5	Ash grey shale with c. gr. Sst. white to yellowish	11′10″
4	White and yellow congl. with pebb. of white alt. trap, lat. cl.etc.	7′2″
3	Bentonitic red purpte and grey clay	8′5′
2	Red laterite alternating with red purple lat. cl. with band of purple clay at top	35′
	---------- Unconformable base ----------	
	Deccan trap	
	KHASIAN STAGE	
	Kakdian Stage	
	---------- Unconformable boundary ----------	
16	Yellow to greyish shale and calc. claystone with small molluscs. An 8′ hard ff. (gastropods and pelecypods) mlte. occurs at the top. At the base 4″-6″ thick and of conc., sideritic/ mud balls occur, mud balls occasionally contain small pelecyods and gastropods, seen when broken.	9′
15	Brownish claystone with brown lustrous ferruginous encrustation and occasional partings of glauconitic green sand. A few mud ball bands (up to 1′ diam.) occur at intervals towards the upper part, some balls are ff. containing molluscs and rarely *Nautilus*. upper 20′ ff. rarely.	32′
14	Dark brown to grey shale with yellow limonitic matter, gyp. Lower part highly ferr. with nodules and calc. concr.	10′
	---------- Unconformable base ----------	
	Deccan trap	
	KAKDIAN STAGE	
	Babian Stage	
	---------- Unconformable boundary ----------	
28	Red laterite	3′
27	Yellowish brown shale with thin ferruginous bands up to 1-1/2′ thick. Shale chips coated with yellow limonitic encrustation, unfossiliferous	12′
26	Brownish f. gr. sst. with 8″ hard cream col. ff. (small pelecypods) mlte. bed on top, gypsum bands at the base	3′
25	NX	4′
24	Grey to brownish unfossiliferous claystone with ferruginous laminations. Lower 10′ poorly exposed on northern bank cliff of Kakdi nala, with 4″ dark ferruginous band at the base	26
23	Light yellowish grey foraminiferal marlite studded with *Assilina*. Towards top a few gypsum layers occur	6′
22	NX (?Claystone)	3′
21	Dirty white ff. mlte. studded with *Assilina*	3′
20	Grey to dirty white Lst. studded with *Assilina*	7′6″
19	Grey foraminiferal Lst. and mlte. studded with *Assilina*	1′6″
18	Brownish claystone and shale with partings of green glauconitic sand and gyp. laminations	12′
	---------- Unconformable boundary ----------	
	Khasian Stage	
	BABIAN STAGE	
	Ramanian Stage	
	---------- Unconformable boundary ----------	
32	Dirty white to grey and yellowish on weathering; mod. hd. Lst. (biomicrite) packed with foraminifera and a few echinoids	22′
31	Dirty grey to cream coloured, fossiliferous, micrite grading to biomicrite packed with foraminifera. Lower 17′ poorly exposed.	37′
30	Grey to yellowish ff. cly. micrite and biomicrite grading to ff. calc. cl. towards the bottom packed with foraminifera and giant gastropods (*Bolis*), nod towards the upper part.	15′
29	Dark grey, greenish to brownish shale upper 33′; ff. with small molluscs. A few large *Nummulites* (*N.obtusus*) occur at about 12′ below the top. Lower 13′ unfossiliferous shales laminated with thin laminae of gypsum and iron oxide, friable, splintery with yellow limonitic coatings.	46′
	---------- Unconformable boundary ----------	
	Kakdian Stage	

RAMANIAN STAGE

Waiorian Stage

---------- Unconformable boundry ----------

45	Rusty brown friable pelletoidal glauconitic argillaceows ferr. sandstone	5′
44B	Hard calc., nod., shelly sandstone fossil shells cemented together with calc., sandy cement, packed with reticulate Numm; *Pecten, Physa* a coiled gastropod	2′
44A	Reddish brown lumpy claystone with few layers of gypsum, *Nummulitis* lower 6" greenish black fissile with large amount of glauconitic pellets full of Ret. numm.	6′6"
44	Cream to buff col. Numm. Lst. with bioherms of coral, upper part bedded lower part massive	17′
43	NX	5′
42	Dark grey glauconitic cl. st. poorly ff. poorly exposed	12′
41	Cement col. foraminiferal lamd. glauconitic cl. st.	8′
40	Greyish to white bedded bouldery weathering limestone alternating with thin layers of yellowish grey foraminiferal cl. st. occasionally gyp. thin clayey layers swirl around the bouldery limestone	12′
39	Cement col. lumpy cl. st. ff. with dark green pellets of glauconitic green sand	3′
38	Cement col. lumpy calc. cl. ft. with lenticles of glauconitic green sand ff. small pelecypods upper part highly ff. topped by 8" buff Lst. bands.	12′
37	Greenish grey lumpy calc. cl. st. with dark green glauconitic pellets rarely ff. with cream hard ff. Lst. on top	3′
36	Rusty brown bedded foraminiferal silty marlite occasionally sandy with clay containing dark green occasionally sandy with clay containing dark green glauconitic pellets	7′
35	Light brown Nummulitic calc.slt.st.	3′
34	Light brown hard foraminiferal slt. st. with thin gyp.layers	1′6"
33	Rusty ocnrous mudstone with lenticles of glauconitic green sand and thin layers of gypsum network passes into greenish black sst. with green sand; ferr burrows penetrate into the underlying limestone	1′6"

---------- Unconformable boundary ----------

Babian Stage

WAIORIAN STAGE

Aidaian Stage

53	Grey to yellowish foraminiferal hard sandy Lst. interbedded with greenish yellow silty marlite full of *Spiroclypeus.*	4′6"
52	Grey to yellowish, hard highly fossiliferous argillaceows limestone containing Echinoids, pelecypods, large forams	4′
51	Yellowish grey, sandy, limestone with calc. mic. sandstone, toward lower part ff.	5′6"
50	Greyish to yellowish interbedded calc. sandstones and sandy Lst. ff. corals, pelecypods	9′6"
49	Greyish, patchy brown ff. (small pelecypods) claystone	2′
48	Yellow to bluish grey weather lamd. silty claystone	3′6"
47	Rusty brown pelletoidal glauconitic argillaceous ferr. sandstone	1′6"
46	Grey to yellowish ff. calc. silty claystone	1′

---------- Unconformable boundary ----------

Ramanian Stage

AIDAIAN STAGE

Vinjhanian Stage

Conformable

85	Yellow ff. calc. f.gr.sst.	2′
84	Yellow ff. f. gr. sst.	2′6"
83	Variegated mic. slt. st.	10′
82	Buff, highly ff Lst. with *Turritella*	2′
81	NX (probably cl. st.)	4′
80	Yellowish mlte. with abundant *Turritella*	2′
79	NX	15′
78	Cly. F. gr. sst. variegated partly lateritised	2′
77	Grey sll. st. and el. st. alt.	8′
76	Yellow lamd gyp. slty. cl. st.	4′6"
75	Grey mic. slt. with thin ferr. bands.	4′
74	Yellowish mic. slt. st.	6′
73	Lamd. cly. slt. variegated	3′
72	Yellow gyp. slt. st. ff. with ff. mlte. band on top	3′6"
71	NX	15′
70	Grey lamd. cl. st. with lenses of c. bedded mic. f. gr. sst.	6′
69	Mic. c. bedded slt. st. and f. gr. sst.	15′
68	Grey yellowish mic. slty. sh. gyp.	8′
67	Poorly exposed mic. slt. st. and f. gr. sst.	10′
66	Hard yellow to brown mlte.	1′6"
65	Poorly exposed yellow f. gr. sst.	10′
64	Yellow to grey slt. st.	6′

63	Variegated slt. st. with cl. pockets	3′
62	Dirty yellow cl. st. ff. with highly ff. mlte. in the lower part	3′
61	Reddish, yellowish slt. st.	5′
60	Greyish, yellowish, mic. slt. st. with pockets of f. gr. sand	5′
59	Yellowish cl. st. with a few layers of gyp. Tiny pelecypods and Bryozoa impressions seen.	3′6"
58	Patchy grey to yellow and reddish slt. st. with a few tiny pelecypods, gypsiferous	9′
57	Variegated yellow reddish slt. st. with packets of unsorted sand, highly bioturbated.	7′
56	Yellow reddish slt. sl. alternating with greyish cl. st. with gyp. layers and thin fer. bed on top.	15′
55	Grey mic. cl. st. with thin c. bedded mic. f. gr., sst. gyp. abundant leaf impressions and pelecypods occur.	12′
54	Bluish cl. st. and slt. st. with mic. silty parting, upper part cly. lamellibranch impressions common.	12′

---------- Unconformable boundary ----------

Waiorian Stage

VINJHANIAN STAGE

Kankawatian Superstage

---------- Unconformable boundary ----------

136	Yellowish mic. calc. cl. st. with hard marlite band (18′at base)	3′
135	Yellow mic. slt. st. with pockets and lenses of greyish calc. cl.	23′
134	Grey to bluish grey slty. cl. st. with concr. of calc slt. st.	5′
133	Yellowish grey calc. slty. cl. st. alternating laminae of mic. slt. st.	9′
132	Lamd. to very thin bedded alternating grey cl. st. and brownish, mic. cl. st., gyp.	8′
131	NX	10′
130	Grey lamd. cl. st. alternated with thin beds of yellow mic. slt. st.	6′
129	Yellow highly ff. mlte.	2′6"
128	Grey Lamd, cl. st. with alternating thin bands of yellow cly. slt. st. and mic. slt. st.	47′
127	NX	5′
126	Yellow mic. slt. st. occasionally cross bedded and fissile cl. st. A few tiny pelecypods occur A 4" hard mlte. band at the bottom.	9′6"
125	Thinly bedded grey slt. st. and cl. st. rarely ff. with pelecypods. 4"-6′grey hard mlte.at the base.	6′
124	Grey fissle cl. st. with alternating laminae of brownish mic. slt. st. occasionally ferr. rarely ff. mostly pelecypods.	22′
123	Alternating grey fissile cl. st. and mic. slt. st. with hard f. gr. calc. sst. with micro cross-bedding	15′6"
122	Yellow ff. mic. calc. slt. with grey cl. pockets.	4′
121	Grey lamd. cl. st. alternating with brownish slt. st.	10′
120	Grey to bluish grey silty cl. st. rarely ff. with highly ff. yellow hard mlte. bed at the top.	11′
119	Yellowish grey cl. st. and mly. slt. st. highly ff.	5′6"
118	Yellow, brownish mic.cl. st. lamd ff. tiny pelecypods	22′
117	Brownish yellow mic. calc. slt. st. lower part highly ff.	4′6"
116	Well lamd, to very thin bedded alternating grey cl. st. and grey mic. slt. st.	14′
115	Grey highly ff. mlte and mic. slt. st.	2′6"
114	Brownish to greyish mic. lt. st. and cly. slt. st. with rare tiny Lamellibranchs	8′
113	Lamd. fissile grey cl. st. and brownish mic. slt. st.	15′
112	Grey welllamd. fissile cl. st. with alternating yellowish slt. st. with 1′ hard bed highly ff. *Pecten*, Echinoids, *Turritella*	14′
111	Yellowish brown ff. mly. slt. st. with thin hard ff. mlte. band on top and bottom	4′
110	Hard bed of dense mlte. yellowish highly ff. *Conus* (giant), *Pecten*, *Serpula*	3′6"
109	Yellowish highly ff. mlte. and Lst.	6′
108	Yellowish slty. mlte. and slt. st. in the lower part	9′
107	Yellowish ff. slt. st. with lenses of intraformational cglt. ff. tiney pelecypods.	19′
106	Grey mic. slty. cl. st. and fissile cl. st. rarely ff.	20′
105	Yellow calc. cly. st.	2′6"
104	Yellow to brownish ff. cl. st.	4′6"
103	Yellow hd. mlte. occasionally slty. highly ff. *Archais*, *Turritella*, *Ostrea*, Echinoids etc.	4′
102	Grey ff. calc. slt. st.	7′
101	Grey ff. calc. cl. st. with 1′ hard 1 st. on top with *Archais*, etc.	11′
100	Yellow slty. mlte. with cl. pockets highly ff. *Turritella*, *Miogypsina*, Echinoids, etc.	3′
99	Grey lamd. fissile cl. st. with tiny fossil casts	5′6"

Conformable

Aidian Stage

KANKAWATIAN SUPERSTAGE

Recent

---------- Unconformable boundary ----------

156	Pale brown to flesh pink and grey mottled, calcareous siltstone with brown and grey cl. intercalations, weathering Kankary. Upper part becoming white and brown mottled, Kankary weathering. Calc. slt. st. locally pebbly with hard bands of calc.intraform. cglt.	120′
155	Brown and grey mottled nodular weathering claystone.	12′
154	Pinkish brown nodular weathering calc. silty claysotne	5′
153	Light brown c. gr. to cgltc. calc. sst. with well rounded grains of quartz. rusty balls of iron ore etc. occasionally pebbly. Thickly bedded with parting. pockets and lenticles of grey-brown mottled slt. st. containing cl.pellets, passes into pinkish brown, hard, banded calc. slt. st. with brown grey mottled cl. partings/intercalations. Hard bands show current ripple marks.	160′
152	Grey, mottled with brown, nodular calc. sst.	9′
151	Cement grey well bedded f. gr. well sorted, well rounded sst. with calc.bands and beds and wedges of ff. cglt. containing mlte. pb. strongly current bedded with cglt.wedges and oyster-debris; overlain by thickly bedded to fissile sst. Top 20′ highly c. bedded with intraform, cglt.	300′
150	NX (scantly outcrop of bedded, cement grey, f. sst.)	6′
149	Grey calc. cglt. with assortment of well rounded pebbles, cobbles and occasional boulders of yellow mlte. and clay in a matrix of f. gr. calc. sst.	4′
148	Boulder and pebble cglt., mlte.pebble and boulders in yellow cly. sdy. and calc. matrix.	5′
147	NX	30′
146	Grey f.gr. well sorted and rounded massive, occ. c. bedded sst.	18′
145	Brown weathering grey slty. cl. st.	15′
144	Grey soft massive, f. gr. argill. sst. with well sorted rounded quartz grn. interbanded with hard yellow aren. ml. bands. Top 3′ bedded yellow marlite with sdy. partings.	12′
143	Pink sdy. marlite, lower part cglt. with pebbles of similar mlte. ff. containing *Ostrea, Aviculopecten, Pecten,* echinoids and its spines etc.	4′
142	Cement grey, med. hard, f. gr. well sorted well rounded, quartzose sst., glauconitic.	30′
141	Grey, brown weathering, lamd. clayey slt. st. with thin reddish yellow mlte. bands and pockets of pure grey sticky cl.	50
140	Brown massive, slty. cl. with thin bands of pink compact, calc. slt. st. Lr. 10′ reddish.	60
139	Cement grey, weathering into brownish yellow, f. gr. well rounded gr., high degree of sorting, mic. (muscovite and bioite) quartzose sst. with black gr. of iron ores, green epidote, pink felspars and yellowish calcite, massive with occasional simple planar cross laminations.	100′
138	Yellow to brown, bedded f. gr. well rounded, well sorted, mic. calc. sst. containing pockets of slt. st. mudstone and c. bedded aren . mlte.occasional lentiles of intraform. cglt. locally c. bedded, at the base occurs a 4"-6"band of basal cglt. - yellow calc. with well rounded pebbles of mlte. lat. cl. pellets and cl. balls in a matrix of f.gr. quartzose sst., occasionally oolitic.	25′

---------- Erosional Unconformity ----------

Vinijhanian Stage.

Abbreviations Used.

Altered	alt
Calcareous	calc.
clay	cl.
clayey	cly.
claystone	cl.st.
coarse	c.
coloured	col.
conglomerate	cglt.
concretions	concr.
ferruginous	ferr.
fine	f.
fossiliferous	ff.
grained	g.
gypsum/gypseous	gyp.
Laterrite/Lateritic	lat.
laminated	lamd.
light	Lt./lt.
Limestone	Lst./lst.
pebble	pebb.
pebbly	pebbly
marlite	mlte.
marl	mrl.
marly	mrly.
medium	med.
micaceous	mic.
Not Exposed	NX
sandstone	sst.
sandy	sdy.
siltstone	sst.
silty	slty.
Tuffaceous	tuff.

Table 1: Marine Microbiozonation in Kutch.

Chronostratigraphic Zone		Biozones	Reference	Remarks
Miocene	Lower	*Ammonia Papillosus*	Proposed	
		Miogypsina (Lepidosemicylina) excentrica Zone	Raju, 1974a,	
		Miogypsina (Lepidosemicylina) droogeri Zone	Raju, 1974a,	
		Miogypsina globulina/thecideaeformis Zone	Raju, 1974a,	
		Miogypsina (Miogypsina) tani Zone	Raju, 1974a,	
Oligocene	Upper	*M.(M.) complanata-M.(M) tani* inter-biohorizon Poorly Fossiliferous Zone	Proposed Raju, 1974a,	
		Miogypsina (Miogypsinoides) complantata-formosensis Zone	Raju, 1974a,	
		Miogypsina(Miogypsinoides) bermudezi Zone	Raju & Drogger, 1978	
		Planolinderina freudenthali Zone		
	Lower	*Nummulites fichteli-Lepidocyclina(E.) dialata* Zone	Raju, 1974b	=*N. fichteli-intermedius/Lepi-docyclina* Zone of Samanta, 1989. =*N.fichteli-intermedius Zone of Raju, 1974*
		Nummulites fichteli Zone	Raju, 1974b	
Eocene	Middle	*Truncorotaloides rohri* Zone	Mohan & Soodan, 1970 Raju, 1974b Samanta, 1989	=*C. nicava-T-rohri* Zone. of Mohan & Soodan, 1970.
		Orbulinoides beckmanni Zone	Mohan & Soodan, 1970 Raju, 1974b, Samanta, 1989	
		Truncorotaloides topilensis Zone	Raju, 1974b	=*G, lehneri* Zone of Bolli, 1957.
	Lower	*Nummulites obtusus* Zone	Samanta, 1989	
		Assilina granulosa-Nummulites obtusus Interbiohorizon poorly fossiliferous Zone	Samanta, 1989 Proposed	
		Assilina granulosa Zone	Mohan and Soodan, 1970	
Palaeocene	Upper	*Schizocythere spinosa* Zone	Khosla and Pant, 1988	