CHAPTER I

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A. Scope of the present work:

The association of natural oil with Tertiary rocks (characterised by foraminifera as the dominant type of fossil) is a unique feature of many oil fields of the world. For example, in Caucasus, the chief oil field of Russia, the main oil occurrence is connected with foraminifera bearing Oligo-Miocene Maikop beds. In Iraq and Iran limestones of Eocene-Oligocene to Lower Miocene age are the main oil bearing formations. In India and Burma the oil bearing sequence extends from Middle Eocene to Pliocene. Therefore, the Tertiary rocks have received particular attention from palaeontologists and stratigraphers. In the Far East the Tertiary rocks are biostratigraphically zonated on the basis of larger foraminifera into 7 major faunal zones (Tan, 1932; Vlerk, 1955). In the Middle East, systematic
biostratigraphic study on the Tertiary rocks have also been attempted by more than one worker (Hension, 1950; Thomas, 1950). The Indian subcontinent occupies geographically more or less an intermediate position between the Middle East and Far East and hence it requires a detailed biostratigraphic investigation on foraminifera-rich marine Tertiary rocks which will not only help a wide intercontinental correlation but may also throw some light on the new oil deposits of our country.

In peninsular India, considerable work on the Lower Tertiary rocks (Palaeocene–Eocene) has been done so far (Sengupta, 1964; Samanta, 1968). But systematic biostratigraphic work on the Mid-Tertiary rocks in the Peninsula has been undertaken by very few workers.

Moreover, the Mid-Tertiary biostratigraphy is particularly worthy of investigation as it involves the boundary problem between the Oligocene and Miocene. The problem of demarcation of this boundary was already discussed by Glaessner (1953), Eames et al. (1962) and Drooger (1964).

Any biostratigraphic investigation of Tertiary rocks essentially involves the foraminifera. If we look into the phylogenic history of different groups of organisms, it is found that the evolution of each group follows a definite line; its first appearance is followed by gradual development, increase of number, a period of climax and ultimate racial
extinction. Foraminifera, a group of marine protozoa, although they appeared in Cambrian Period, attained their climax and a great diversity during the Tertiary Period and hence their fossils are abundant in many marine Tertiary sediments, including those of India.

Larger foraminifera are more important for stratigraphic purpose since many of their genera and species are index fossils, and they also show evolutionary change of morphological characters with time. Thus if the succession of an area be more or less complete, one can trace out the nature of modification of these characters by observing a large number of specimens of a population. This study helps in the identification of the different species of a genus forming a morphogenetic sequence marked by stages in the progressive structural development of morphological characters (bioseries). Stratigraphic implications of the morphogeny of larger foraminifera have been already examined by Tan (1939). Similar approach was made by Drooger (1952, 1956b, 1963, on mioapsinids), Grimsdale (1959, on lepidocyclinids) and Vlerk (1959, on lepidocyclinids). As these methods are still not in a final stage as pointed out by these authors, more data from different regions are necessary and they might throw new light on the strength of these established bioserial stages and their reliability of the application in worldwide correlation. In India, since Mohan (1958), little work has been done on this line. Hence it is necessary to investigate
the evolutionary trends of certain groups of larger foraminifera (specially the miogypsinids and lepidocyclinids, having world-wide distribution throughout the Mid-Tertiary period). Such a study would reveal how far the sequence of *Miogypsinoides* and *Miogypsina* species, known from the Indo-Pacific region (Drooger, 1963; figure 25) could be traced out in our country and whether it would be necessary to modify the previous idea. A similar approach could also be made from the investigation with lepidocyclinid group. Moreover, study of these two groups of larger foraminifera might help in finding out any possible correlation if present, between them so far as their rate of evolution be concerned.

There is another reason too for the emphasis on foraminifera as an aid to the study of the marine Tertiary rocks. It is easy to collect adequately these microfossils which are more abundant and are generally better preserved than the megafossils.

The above considerations have led the writer to undertake the investigation of the larger-foraminiferal biostratigraphy of a selected Mid-Tertiary succession.

Sind-Beluchistan, the type area for marine Tertiary rocks in Indian region is now in Pakistan. From the published report, it is found that in the Peninsula, no other marine Tertiary succession (Kathiawar, Surat-Broach or Quilon) is so complete as that of Cutch. In Assam, northeast India, the Oligo-Miocene rocks are chiefly estuarine to fresh water.
deposits. So the region of Cutch may be regarded as the type area of the Tertiaries in India proper. Although a broad regional stratigraphic work was done by Biswas (1971), detailed biostratigraphic work in the different parts of Cutch is required for precise correlation and age-determination. Sengupta (1964) already investigated biostratigraphically the Tertiary rocks of Lakpat in northwestern Cutch. But similar significant work in other parts of this region is lacking.

A preliminary biostratigraphic observation was made by the author (1966) in Waior-Cheropodi, western Cutch. The investigation showed that this could be an ideal area for biostratigraphic investigation of the Mid-Tertiary rocks because of the following reasons:

(a) Marine Oligo-Miocene rocks are well represented here.

(b) Larger foraminifera fossils are abundant and mostly well-preserved and in many cases the fossil-tests are easily separable from the soft marly rocks.

(c) Structurally the area is simple consisting of horizontal to gently dipping beds.

(d) Rocks are traceable continuously along few nalas: sections which are more or less running in the direction of dip of the beds.
The main objects of the present scheme are as follows:

1. Preparation of a biostratigraphic succession and a biostratigraphic map of the Mid-Tertiary rocks of this selected area.

2. To recognise the major types of rocks and to show their distribution by a lithostratigraphic map.

3. To correlate the fossil zones of this area with other known Tertiary successions.

4. Systematic study of the important larger foraminifera which are used in the zonation and correlation.

5. To show the trends of evolutionary modification of certain morphological characters of some commonly distributed forms like Nummulites, Miogypsina, Miogypsinoides and Lepidocyclina.

Microfossils other than foraminifera and megafossils have been kept out of the scope of this present work and these are reported only in an elementary way.

B. Previous work:

Grant (1837) for the first time published a geological map of the northwestern part of Cutch and separated the
Nummulitic rocks from the Tertiaries; the fossils, collected by Grant, were examined by Sowerby.

Carter (1856) investigated some Tertiary belts of the Western India, including Cutch and gave a simple three fold classification; a lower group of Eocene, a middle group of Miocene and an upper group of Pliocene age. Later Carter (1857) revised his view and recognised only a lower and an upper division corresponding to the Eocene and Miocene age respectively.

Systematic mapping of the Jurassic-Tertiary rocks of Cutch and Kathiawar was undertaken by Wynne (1872). Wynne classified the Tertiary column on the basis of lithological characters into six divisions beginning with 'Sub Nummulitic group' and 'Gypseous shales', followed successively by 'Nummulitic group', 'Arenaceous group', 'Argillaceous group' and 'Upper Tertiary group'. The lower four divisions were placed within Eocene, while the 'Argillaceous' and 'Upper Tertiary group' were assigned to Miocene and Mio-Pliocene age respectively. The total thickness of the succession was estimated as 1600 to 2800 feet.

In Sind-Beluchistan, the rocks were investigated and classified by Medlicott and Blandford (1879) and Blandford (1880). They also attempted a correlation between Tertiary rocks of Cutch and those of the type area. 'Sub Nummulitic and Gypseous shales' were correlated with
'Ranikot series' (Palaeocene age); 'Nummulitic group' with 'Laki' and 'Kirthar series'; Arenaceous group' with 'Nari series', 'Argillaceous group' with 'Gaj series' and 'Upper Tertiary group' with 'Morchhar series' of the type area.

Duncan and Sladen (1883) carried out a systematic work on the Tertiary corals and echinoids of western India and confirmed the correlation established by Medlicott and Blandford between the type area and Cutch.

Vredenburg (1906) studied the fossil foraminifera collected by Wynne and gave zonal distribution of Indian Nummulites.

Nuttall (1925-26) investigated the Tertiary rocks in some parts of western India, including those of the type area and Cutch. He reported the occurrence of reticulate Nummulites represented by the typical Oligocene form Nummulites fichteli, associated with Nummulites obiteus, a new species of Nuttall. These beds with reticulate Nummulites probably constitute the lower part of Wynne's 'Arenaceous group' and were thus referred to as Oligocene.

Vredenburg (1925-28) concluded that the molluscan fossils of Cutch are of lower Nari ( = Lattorrian and/or Stampian) Lower Gaj (Aquitianian) and upper Gaj. (Burdigalian) in age. He pointed out that equivalents of Upper Nari series in north west India are probably devoid of mollusca but contain Lepidocyclina dilatata associated with an echinoid Breymia.
multituberculata, a new species of Vredenburg. This might constitute the upper part of Oligocene.

Tertiary rocks near Surat-Broach, western India, were rich investigated by Rao (1939, 1941). The occurrence of foraminifera/Upper Eocene and Lower Miocene rocks were established.

Eames (1952) introduced the name 'Tapti series' (Upper Eocene age) in the stratigraphy of western India which is characterised by Nummulites, Discocyclina and Pellatispira.

Tewari (1952) worked on the Tertiary rocks of Vinjhan-Miani, south western Cutch, and recognised 5 beds equivalent to 'Laki', 'Kirthar', 'Nari', 'Gaj' and 'Manchhar series' respectively. Tewari (1956) reported for the first time the occurrence of Spiroclupeus, represented by a new species Spiroclupeus ranjanae from Lower Miocene beds near Waior, western Cutch. Mohan and Chatterjee (1956) investigated the Miocene rocks of Kathiawar, western India. Rao et al. (1957) gave a review of the Miocene rocks of India. Tewari (1957) investigated the Tertiary rocks near Waior and Waghopadar, Cutch and gave two separate successions for these two areas respectively. Mohan (1958) presented an excellent work on the Miogypsinidae of Kathiawar. The Cretaceous-Tertiary rocks of India, Pakistan, and Burma were critically reviewed by Nagappa (1959). Sengupta (1959, 1964) made some detailed biostratigraphic work on the Tertiary rocks of Lakpat, north western Cutch, based on larger foraminifera. He classified
the sequence into seven faunal zones (three of Eocene, three of Oligocene and one of Miocene age). According to him, most of the foraminifera of this region have importance in Indo-Pacific correlation.

Sastri, Mohan and Guha (1964) gave a comparative account of the Tertiary microfauna (foraminifera and ostracoda) occurring in some outcrop and subcrop samples of western India, including Cutch, Cambay and Ankleswar. They have also indicated the presence of Upper Eocene fauna (represented by Nummulites, Discocyclina and Hantkenina alabamensis) in all these areas although Pellatispira is present in subcrop samples of Ankleswar only. A brief account of Oligo-Miocene foraminifera of Cutch was given by Datta, Banerjee and Bedi (1965) and they also reported the occurrence of Cassigerinella, an important Oligo-Miocene planktonic foraminifera of Indo-Pacific region. Mohan (1965) studied the reticulate Nummulites of Cutch and concluded that Nummulites clipeus of Nuttall is merely a variant of Nummulites fichteli.

Biswas (1965) gave a new classification for the Tertiary rocks of Cutch. According to him a complete succession from Palaeocene to Pleistocene is present here.

Chatterjee and Mathur (1968) reported the 'Stampian' equivalent in western Cutch, evident from the occurrence of beds containing an association of Nummulites fichteli and Lepidocyclina (Eulepidina) dilatata. They also reported doubtful occurrence of Upper Oligocene beds characterised by Spiroclypeus only.
The writer (1966) made a preliminary work on the larger foraminiferal biostratigraphy of Oligo-Miocene rocks of Waior-Cheropodi, western Cutch, and recognised 6 faunal zones (three within Oligocene and three within Lower Miocene). He also reported definite occurrence of Middle Oligocene beds with Eulepidina and reticulate Nummulites, overlain by the doubtful Upper Oligocene beds containing Miogypsinoides of complanate, Nephrolepidina sp. and Spiroclypeus ranjeneae.

Tewari and Singh (1967) gave a short account of geology of Tertiary rocks of Kanoj-Sehe area and indicated the presence of lower part of Upper Eocene from the occurrence of planktonic foraminifera. Pant and Mathur (1968) published a brief report on the Tertiary of Lakpat. Mohan and Bhatt (1968) presented a general account of Burdigalian microforaminifera of Cutch. The details of geology of Cambay subcrop was available after Chandra and Chouhary (1969). The present writer (1969) reported the occurrence of Discocyclina (Discocyclina) omphalus from the topmost Eocene beds near Waior and Waghopadar. The writer (1970) restudied the reticulate Nummulites of western Cutch and tried to show evolutionary changes of some morphological characters found in them. He also suggested that Nummulites clipeus is a distinct and valid species.

A geological and a tectonic map of Cutch were presented by Biswas and Deshpande (1970). Raju (1970) gave a note on the nature of Oligo-Miocene boundary in Ramania
area, western Cutch. He suggested that in this area the hiatus between Eocene and Oligocene is of greater magnitude than that of Lakpat (Sengupta, 1964). Raju (1971a) published a report on the occurrence of Miogypsina (Miogypsinoidea) *complanata* from western Cutch. Biswas and Raju (1971), and Biswas (1971) gave a detailed account of Jurassic-Tertiary rocks of Cutch including the regional Tertiary biostratigraphy. The present author (1973) gave an account of the Miogypsinidae and the biostratigraphy of Oligo-Miocene rocks of Wiior-Cheropodi based on them. He also reported the occurrence of Miogypsinoidea bantamensis, Miogypsina (Miogypsina) gunteri and Miogypsina (Miogypsina) tani from the Indian subcontinent. The author gave the detailed systematic palaeontology of the seven different species of the Miogypsinidae occurring in this area of western Cutch. He also showed evolutionary changes of a few morphological characters found in them.

In northeast India, systematic biostratigraphic work was done on the Lower Tertiary rocks of Assam by Sarmanta (1964, 1965, 1968). Biswas (1959) also reported the occurrence of Tertiary rocks below the Indo-Gangetic alluvium of Bengal basin.

Data on the fauna and age of some Mid-Tertiary beds occurring in south India have been also available from a number of workers. Eames (1950) critically reviewed the fauna of Quilon beds, Karikal and Ceylon and suggested that all these beds are nearly equivalents and are of Lower Miocene
age. Jacob and Sastri (1951a) suggested the age of Quilon beds as Lower Miocene (= Burdigalian) from the occurrence of *Taberina* and *Austrotrillina*. Guha et al. (1965) studied the Karikal subcrops and proved the presence of Eocene–Lower Miocene beds. Raju (1968) zonated the Tertiary rocks (Eocene–Oligocene) of the Cauvery basin on the basis of planktonic foraminifera.

The Miocene fauna of Ceylon was investigated by Wayland and Davies (1923) who suggested the age of the corresponding beds as Middle Miocene (= Vindobonian). Later Eames (1950) modified it and suggested a Lower Miocene (= Burdigalian) age for these beds.

The Tertiary rocks of Andaman were investigated by Jacob and Sastri (1951b) and Chatterjee (1964) and the latter classified the Tertiary column (Palaeocene to Lower Miocene) and mentioned the characteristic foraminifera of each division.

In Burma, the marine Tertiary rocks are ranging in age from Palaeocene to Middle Miocene and these were investigated by a number of workers including Stamp (1922), Leeper (1933), Cotter (1933) and Evans and Samson (1941). Here Mid-Tertiary rocks (Pegu series) are rather poor in foraminifera but contain abundant mollusca.
C. Summary of the results of the present investigation:

The contribution made by the writer on the Mid-Tertiary biostratigraphy of the Waior-Cheropodi area may be briefly summarised as follows:

1. A lithostratigraphic and a biostratigraphic map have been prepared of an area of approximate 100 Sq. mile around Waior-Cheropodi.

2. Oligocene - Lower Miocene rocks are classified biostratigraphically into 8 faunal zones (three within Oligocene and five within Lower Miocene). Zones D, F and G are, however, new additions in Cutch stratigraphy.

3. Correlation of the faunal zones of this area with other important Mid-Tertiary successions of India and other countries is discussed.

4. Oligocene is shown to be fully represented here and definite occurrence of equivalents of Lattorfiian, Rupelian and Chattian has been established.

5. A shallow marine sedimentation is suggested throughout the Mid-Tertiary, although the basin got more and more shallow towards the end of Lower Miocene.
(6) Systematic palaeontological studies of the following groups of larger foraminifera have been made:

(a) **Nummulites** : Validity of *Nummulites clipeus* and *Nummulites fichteli* has been established from the study of their morphological variations with time.

(b) **Spiroclypeus** : *Spiroclypeus ranjanae* is recorded from both Oligocene and Lower Miocene beds in this region. This poorly described species has been investigated in details and is compared with other important species of the Indo-Pacific.

(c) **Miogypsinidae** : Seven species of *Miogypsinidae* have been identified (3 of *Miogypsinoides* and 4 of *Miogypsina*) of which *Miogypsinoides bantamensis*, *Miogypsina gunteri* and *Miogypsina bhogatensis* are new reports from Cutch. Evolutionary trends of certain characters of these forms are shown graphically. The sequence of the different species is compared with that of the Indo-Pacific region (Drooger, 1963, Figure 25) and it is shown that the same series may be more or less followed here with slight modifications.
(d) **Lepidocyclina**: Four species of *Lepidocyclina* (1 of *Eulepidina* and 3 of *Nephrolepidina*) are recognised of which *Lepidocyclina (Nephrolepidina) parva* and *Lepidocyclina (Nephrolepidina) morganii* are reported for the first time from Cutch. Values of 'evolution gradus' of different species of *Nephrolepidina* of this area have been calculated and their gradual change with time is shown graphically. It appears that the value of 'evolution gradus' may be used for stratigraphic correlation as assumed by Vlerk (1959).

(e) Among *Soritidae*, *Taberina malabarica*, *Archaias angulatus* and *Sorites marginalis* are described.

(f) **Austrotrillina**: Occurrence of *Austrotrillina striata* which is slightly more primitive than typical Lower Miocene *Austrotrillina howchini*, is reported from a lower level of Miocene.
CHAPTER II

GEOLOGICAL SETTING OF THE AREA