CHAPTER 7
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7-1: Biotic Consideration

7-1-1: Botanical aspect:

The palynological assemblages recorded from the formations of the Lower Tertiary age of Western Rajasthan and Kabir Kuh Anticline, Lurestan Province of Iran were analysed qualitatively and quantitatively. The Lower Tertiary sediments of Rajasthan comprise 169 species belonging to 115 form genera. Out of those, 31 species belonging to 21 genera are pteridophytes, 88 species under 55 genera belong to angiosperms, while 2 genera with 4 species have an affinity with gymnosperms. Algae are represented by 25 species of 19 genera and 8 species of 7 genera belong to fungi. Among this entire assemblage, 7 genera and 23 species were identified as new. The palynological assemblages recorded from Lurestan, Iran on the other hand comprises 33 species belonging to 28 form genera. Out of these, 21 species belong to 19 genera of algae, 5 species under 4 genera are assigned to angiosperms, while 2 genera with 3 species have an affinity with pteridophytes. Gymnosperms are represented by 1 species of 1 genus whereas 1 species under 1 genus belongs to fungi. Of this total assemblage, 2 species were also identified as new.

These assemblages are also associated with a few taxa of reworked palynomorphs of Permian and Late Mesozoic ages. Significant among these forms have been appended in a checklist as mentioned earlier.

Laboratory investigations have revealed that Lower Tertiary palynological assemblage of Rajasthan is dominated by angiosperms followed by pteridophytes, while algae, fungal elements, gymnosperms, and Microforaminiferal linings are present in subordinate quantities. Besides, a form has been recorded under ‘Incertae sedis’. The palynological assemblage of Lurestan, Iran is dominated by algae (Dinoflagellates) followed by subordinate amounts of angiosperms, pteridophytes, gymnosperms and fungal remains.

In order to interpret the probable palaeoenvironment during the sedimentation of the different lithological units, the systematic botanical affinity and its ecological considerations are discussed below:

7-1-1-1: ALGAE: The group is represented by 19 genera and 25 species in the Lower Tertiary sediments of western Rajasthan, Akli and Barsingsar Lignites whereas 19 genera and 21 species
have been recovered from Lurestan, Iran. The assemblage altogether comprises taxa like: Octaplata, Spiniferites, Cordosphaeridium, Operculodium, Homotryblium, Polysphaeridium, Impletosphaeridium, Heterosphaeridium, Paleostomocystis, Cymatosphaera, Achomosphaera, Apectodinium, Cyclonephelium, Leptodinium, Amphorosphaeridium, Surculosphaeridium, Lingulodinium, Batiacasphaera, Fibroycysta, Psilosphaera, Matanomadha, Aplanosporites, Odontochitina, Chytroeisphaeridia, Cleistosphaeridium, Hystrichosphaeridium, Hystrichokolpoma, Rhombodinium, Tuberculodinium, Microplankton type I, Evittusphaerula and Lejeunecysta. The presence of these dinoflagellates taxa suggests a brackish water to marine environment of deposition.

7-1-1-2: FUNGI: Fungal remains present in the Lower Tertiary sediments of Rajasthan occupy 8 species belonging to 7 form genera while 1 genus and 1 species was found in the Lurestan, Iran. They are spectacularly rich in Barsingsar and Akli Lignites of the Rajasthan and are represented by Inapertisporites, Phragmothyrites, Involutisporonites, Anatolinites, Pluricellaesporites, Reticellites, and Exesisporites genera. The genus Frasnacritetrus was recovered from the Lower Tertiary sediments of Lurestan, Iran. The genus Phragmothyrites is fossil ascomata referable to microthyriales. The epiphyllous ascomycetous fungi (microthyriales included) best flourish in Subtropical-Tropical areas. Heavy precipitation is the key factor in their growth. They normally grow in rain forests, rain forest margins and along creek banks. In overall the fungal assemblages point out a warm, humid (moist) climate with heavy precipitation during the deposition of these sediments.

7-1-1-3: PTERIDOPHYTA: Pterodiphytic spores are fairly dominant plant taxa both in variety and numbers present throughout the Lower Tertiary sediments of Rajasthan. These are represented by 31 species belonging to 21 form genera. The Lower Tertiary sediments of Lurestan, Iran on the other hand have 2 genera and 3 species of pteridophytes. Among them, the affinity of 5 genera could not be established. These spores are assignable to the following 9 families:

**Cyatheaceae:** These are mostly homosporous tree ferns with stout erect stems, covered with adventitious roots and palm like crown of leaves at the top. So far, 360 species belonging to 9 genera are known in nature all over the world. The species belonging to this family are: Cyathidites australis, Cyathidites minor. The present day distribution of this family is restricted to the Tropical - Subtropical regions.
Schizaeaceae: The family mostly consists of small ferns with very small stem, some are also curious leaf climbers. 5 genera consisting of 70 species are known in nature. The following species having close affinity with the family are: *Lgodiumsporites eocenicus*, *Lgodiumsporites pachyexinus*; *Schizaeoisporites eocenicus*, *Schizaeoisporites indicus* sp. nov. The family is common to both Tropical and Subtropical areas.

Osmundaceae: *Todisporites major*, *Todisporites plicatus*, are referable to this family. About 12 species belonging to 2 genera are found in nature. Members of this family are mainly found in Tropical-Temperate regions generally inhabiting damp woods and thickets favoring moist humid climate and shady environment.

Lindsayaceae: The species of this family belong to *Concavismisporites punctatus*, *Deltoisporites africana*, *Deltoisporites sp.*. They are mainly tree fern and grow in Subtropical-Tropical climate.

Glecheniaceae: This family is represented by *Gleicheniidites senonicus*, *Deltoidospora africana*, *Deltoidospora sp.*. They are mainly tree fern and grow in Subtropical climate.

Lycopodiaceae: The plants belonging to this family are leafy with well developed stems and unbranched leaf. At present, this family is classified into 2 genera having 190 species all over the world. Trilete spores related to reticulate exine belong to this family. The following taxa show a close affinity to this family: *Lycopodiumsporites palaeocenicus*, *Lycopodiumsporites speciosus*, *Sestrosorites dettmanni*, *Lycospora indica* sp. nov... The plant of this family luxuriously grow in moist and shady places in hilly areas of Tropical to Temperate regions.

Matoniaceae: The species of this family is represented by *Dandotiaspora dilata*, *D. telonata*, *D. plicata*, *D. pseudoauriculata*, *D. densicorpa*.; *Dictyophyllidites harrisi*, *Dictyophyllidites zagrosensis* sp nov. and *Biretisporites sp.*. This family of fern grows in Tropical-Subtropical regions.

Adiantaceae: The species of this family is represented by *Pteridacidites sp. cf. P. rotundus*. This family is mainly herb and possesses a cosmopolitan habitat.

Polypodiaceae: These are mostly herbaceous perennial with creeping rhizome or erect root stock and having large pinnate leaves. About 130 genera with 3000 species are prevailing in the nature of the present world. The family is represented by *Polypodiasporites tertiarus*, *Polypodiasporites nawknaensis*, *Polypodiasporites ornatus*, *Lacvigatosporites lakiensis*. The present day distribution of polypodiaceae is cosmopolitan. It is interesting to note that the...
species belonging to this family appear in the Eocene and continued throughout the Tertiary Period without any appreciable change of character. This may be due to uniformity of the environmental condition under which the plants were thriving.

7-1-1-4ANGIOSPERMAE :A large number of angiospermic genera and species are also abundant in the Lower Tertiary sediments of Rajasthan. Altogether 88 species belonging 55 form genera have been obtained in these sediments. Amongst them, 16 genera and 38 species are monocotyledons whereas dicotyledons are represented by 39 genera and 50 species. The angiosperms recorded from Lower Tertiary sediments of Lurestan, Iran are 5 species belonging to 4 genera. The presize affinity of 18 genera including 23 species could not be established due to paucity of living collection. The ecological significance of these taxa is discussed below:

7-1-1-4-1:MONOCOTYLEDONAE

Although significantly represented, as compared to dicots, the high percentage of pollen grains belonging to the family Palmae makes this class a very significant group.

Palmae : This family is characterized by a crown of leaf at the end of an unbranched stem (Hyphaene is exceptional). The family consists of 1500 species with 200 genera in the present day world. The following species: Arecipites matanomadhensis, Arecipites bellus; Palmaepollenites minor sp. nov., P. nadhamunui, P. communis, P. plicatus, P. sp.; Palmidites maximus, P. plicatus, P. naviculus; Sabalpollenites granulosus sp. nov., S. sabalpollenites indicus sp. nov.; Neoucoperipollis kutchensis, N. brevispinosus, N. excertus, N. clavatus sp. nov., N. granulatus sp. nov., N. achanatus, Couperipollis duttiae, C. robustus; Acanthotriconpites bulbospinosum are referred to this family. The present day occurrence of this family is restricted to Tropical and Subtropical regions but as a rule it is an indicator of continental element along the coastal margin. Present day Arecaceae (Palm Family) is believed to be a sister of this family.

Liliaceae : Most of the plants belonging to this family are herbs, some are shrubs and trees. The family is one of the largest of flowering plants having over 3700 species with 250 genera. The presence of this family is evidenced by Liliacidites giganticus, L. microreticulatus, Matanomadhisulcites maximus, M. kutchensis, Retimono sulcrites ellipticus. Plants of this family are cosmopolitan in distribution and exclusively aquatic.
Aracaceae: The species belonging to this family are *Proxapertites microreticulatus*, *P. assamicus*, *P. granulatus* *P. cursus*; *Spinizonocolpites echinatus*, *S. baculatus*; *Kapurdi pollenites gemmatus*. The family is chiefly of tropical origin. Nypaceae whose plants are sometimes aquatic herbs with minute flowers in the form of a dense spikes are a major component of the assemblage.

Orchidaceae: The presence of Orchidaceae in the present assemblage is doubtful as there is no fossil record of the family from the strata older than Quaternary. However, the morphological characters of *Dicotetradites reticulatus* indicate their possible relationship with the family Orchidaceae. The plants of this family usually grow as epiphytes in the rain-forest areas.

7-1-4-2: DICOTYLEDONAE

The dicots, though less frequent, show a good number of variety. They belong to 39 genera with 50 species. Among them, the botanical affinity of 15 genera and 18 species is uncertain. The following families are precisely identified.

Nymphaeceae: Perennial aquatic herbs with submerged floating or sometimes emersed and often with large leaves. The family includes 8 genera and about 50 species. It also called water lily family. The species belonging to this family are: *Nymphaeacidites indicus* sp. nov., *N. giganticus* sp. nov., *N. typicus*, *N. granulatus* sp. nov.. The family is chiefly tropical and favours an aquatic or marshy habitat i.e. grows in ponds, shallow lakes and banks of sluggish rivers.

Lamiaceae: Varghese and Verma (1968) worked out the pollen grains of some Indian Lamiaceae (Labiatae). Ocimum pollen described and illustrated by them resemble the fossil pollen *Ocimumpollenites indicus* by thick exine, pluricolumellate, broad reticulation and presence of columella in the lumina. Ocimum is a genus of aromatic herbs, undershrubs or shrubs distributed generally in the tropics.

Euphorbiaceae: *Retitribrevicolporites* (*Lakiapollis* *) matanamadhensis* belong to this family. This family is herbs, shrubs or trees often with milky juice with simple or compound leaves. It is also called Spurge family. The present day distribution of this family is cosmopolitan. Pollen grains of similar morphology are also found in the family Araliaceae.

Gentianaceae: The family is mostly herbaceous with few shrubs and contain 80 genera and 800 species. The species of this family are represented by *Retitetradites nairii*. This family is cosmopolitan in habitat.
Meliaceae: This family comprises mostly of trees and includes over 600 species with 40 genera. Fossil pollen of Meliapollis ramanujami strongly suggest the presence of this family in the Rajasthan assemblage. It has a Tropical to Subtropical distribution.

Utricaceae: Evidence for the presence of this family is doubtful. Pollen grains referred to Triporopollenites exactus appeared to be morphologically comparable to the pollen grains met within this family. But their natural relationship however, remains doubtful. Some palaeobotanist compared it with Betulaceae. It has been abundantly represented during Eocene and Oligocene times. The family is found in temperate and tropical regions.

Rhizophoraceae: The family comprises about 60 species and 12 genera. It consists of mangrooves which are found in association with the plants of the muddy swamps at the mouth of rivers and elsewhere over which tide blows daily, leaving the mud base at low water. The family is represented by Paleosantalaceaeepites minitus, P. giganticus. It is tropical in distribution.

Eucaesalpinaceae: Trisyncolpites ramanujami has undoubtful affinity with this family. The family is mostly Tropical to Subtropical in distribution and is largely associated with trees and shrubs.

Leguminosae: It is the third largest family of the flowering plants with more than 14000 species referable to 500 genera. Polyadopollenites sp.; Tricolporopilites (Retitresocolpites) robustus belong to this family. The family is chiefly Tropical to Subtropical in distribution. The present name of this family is Fabaceae (pea family).

Polygalaceae: The presence of the family is confirmed by form referred to Polygalacidites hadlaensis sp. nov. Fossil pollen of this family have been recognised from early Tertiary sediments. The family has a cosmopolitan distribution.

Onagraceae: Most of the plants of this family are herbs, a few are shrubs or tree. Pollen grain of Triangulorites (Triorites) bellus belongs to this family. Fossil pollen of Onagraceae have been recorded from Eocene strata. The family has both Tropical and Temperate distribution.

Lentibulariaceae: Polycolpites ornatus suggest the presence of this family. The family is cosmopolitan but plants generally prefer to thrive in water or moist places.

Proteaceae: The family could be represented by the pollen grains of Proteacidites protrudus, Proteacidites sp. and doubtfully by presence of Retidiporites baculatus sp. nov. R. clavatus sp. nov. In East Asia the family has a Tropical distribution.

Malvaceae: Herbs, shrubs or trees constitute this family. It is having over 700 species with 35 genera in nature. The distinctive grains of Palacomalvaceaeepollis rudis, P. paucispinosus
provide conclusive evidence for the presence of this family. It has a Tropical-Subtropical geographic distribution.

**Compositae** : The majority of of the plant of this family are herbaceous. Trees and shrubs are comparatively rare. It is the largest family of flowering plants comprising about 900 genera with over 13000 species. In the present palynological assemblage, this family is represented by single grain namely *Compositoipollenites serratus*. Living of this family is almost every conceivable situation. The family is distributed over the greater part of the Earth.

**Barringtoniaceae** : Barringtoniaceae designated by Croizat(1952) as near Mangroves plants. This plant of the hot tropical lowlands is competent to stand for long period of drought interrupted by torrential rains, and possibly also, times of active root-submersion. Barringtoniaceae is common to Asia, Africa and extending even up to Polynesia and Hawaii. *Barringtoniapollenites retipilatus* belongs to this family.

**Ctenolophonaceae** : Ctenolophon pollen for their characteristic exinal thickening can easily be recognized in the dispersed state. *Ctenolophonidites costatus* is present in the lower Eocene. Muller(1981) opines that from India Ctenolophon type of pollen disappears in post-Eocene. Kar and Jain(1981) recorded this pollen from the Miocene sediments of Kerala Coast, South India.

7.1.1.5: GYMNOSPERMAE

The gymnosperms are poorly represented in the Tertiary sediments of Rajasthan and Lurestan, Iran. They are comprise 2 genera and 4 species. But among the reworked palynomorphs 9 genera and 11 species have been identified. The reworked gymnospermous palynomorphs identified are: *Callialasporites segmentatus*, *C. sp.; Potoniesporites sp.; Cycadopites sp.; Parasaccites sp.; Callumispora tenius; Monosulcites couperi; Gingkocycadopites detersus; Gingkoretectina vastus, Granulatusporites irregularisplicatus, Cycadopites cf. C. sakagalensis*. The distribution of the gymnosperms up to family level is discussed below:

**Araucariaceae** : It was characteristic during the Mesozoic era and continued up to the Cenozoic time. It is generally absent from the living flora of the Indian subcontinent and there is no record even in the Neogene. The species belonging to this family is *Araucariacites australis*. The distribution of this family is predominantly tropical. The other families of gymnosperms have a varied habitat from plain to upland with utmost cool to arid conditions.

The following are the families identified from the Tertiary sediments of Rajasthan and Lurestan, Iran. Their climatic and ecological interpretation are as follows:
**PTERIDOPHYTA:**

<table>
<thead>
<tr>
<th>Family</th>
<th>Distribution</th>
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<tbody>
<tr>
<td>Osmundaceae</td>
<td>TROPICAL-SUBTROPICAL</td>
</tr>
<tr>
<td>Lycopodiaceae</td>
<td>TROPICAL-SUBTROPICAL-TEMPERATE</td>
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<tr>
<td>Cyatheaceae</td>
<td>TROPICAL-SUBTROPICAL</td>
</tr>
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<td>Schizaeaceae</td>
<td>TROPICAL-SUBTROPICAL</td>
</tr>
<tr>
<td>Gleicheniaceae</td>
<td>TROPICAL-SUBTROPICAL</td>
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<tr>
<td>Matoniaceae</td>
<td>TROPICAL-SUBTROPICAL</td>
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<tr>
<td>Lindsayaceae</td>
<td>TROPICAL-SUBTROPICAL</td>
</tr>
<tr>
<td>Adiantaceae</td>
<td>TROPICAL-SUBTROPICAL</td>
</tr>
<tr>
<td>Polypodiaceae</td>
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**ANGIOSPERMAE:**

*(Monocot)*

<table>
<thead>
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<th>Family</th>
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<tbody>
<tr>
<td>Aracaceae</td>
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</tr>
<tr>
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</tr>
<tr>
<td>Palmae</td>
<td>TROPICAL-SUBTROPICAL</td>
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*(Dicot)*

<table>
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<td>Nymphaceae</td>
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<tr>
<td>Meliaceae</td>
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<tr>
<td>Barringtoniaceae</td>
<td>COSMOPOLITAN</td>
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<td>Utricaceae</td>
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<td>Gentianaceae</td>
<td>COSMOPOLITAN</td>
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<tr>
<td>Rhizophoraceae</td>
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<tr>
<td>Polygalacéae</td>
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</tr>
<tr>
<td>Caesalpinaceae</td>
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<td>Compositae</td>
<td>COSMOPOLITAN</td>
</tr>
<tr>
<td>Proteaceae</td>
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<tr>
<td>Leguminosae</td>
<td>TROPICAL-SUBTROPICAL</td>
</tr>
<tr>
<td>Onagraceae</td>
<td>TROPICAL-SUBTROPICAL-TEMPERATE</td>
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### GYMNOSPERMAE:

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<th>Ecological Group</th>
<th>Family</th>
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<tr>
<td>Montane floral elements</td>
<td>Utriacaceae</td>
<td><strong>Tritoporopollenites exactus</strong></td>
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<td>Low-land elements</td>
<td>Caesalpiniaceae</td>
<td><strong>Trisyncolpites ramanujamii</strong></td>
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<tr>
<td></td>
<td>Euphorbiaceae</td>
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<tr>
<td></td>
<td>Onagracaceae</td>
<td><strong>Triangularites bellus</strong></td>
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<td><strong>Tricolporopilites robustus</strong></td>
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<td></td>
<td>Nymphaeae</td>
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<tr>
<td></td>
<td>Polygalaceae</td>
<td><strong>Polygalacidites hadlaensis sp. nov.</strong></td>
</tr>
<tr>
<td></td>
<td>Malvaceae</td>
<td><strong>Palaecomalvaceapollis rudis</strong></td>
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<tr>
<td></td>
<td>Schizaceae</td>
<td><strong>Schizaeisporite spp.</strong></td>
</tr>
<tr>
<td></td>
<td>Osmundaceae</td>
<td><strong>Todisporites major</strong>, <strong>T. plicatus</strong></td>
</tr>
<tr>
<td></td>
<td>Matoniaceae</td>
<td><strong>Dandotiaspora spp.</strong>, <strong>Dictyophyllidites spp.</strong></td>
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<tr>
<td></td>
<td>Adantiaceae</td>
<td><strong>Pteridacidites sp.</strong></td>
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<tr>
<td></td>
<td>Polypodiaceae</td>
<td><strong>Polypodiisporites spp.</strong>, <strong>Polypodiaceasporites spp.</strong></td>
</tr>
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<td>Mangrove and back</td>
<td>Rhizophoraceae</td>
<td><strong>Palaeosantalaceapites spp.</strong></td>
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<td>Mangrove elements</td>
<td>Malvaceae</td>
<td><strong>Palaecomalvaceapollis spp.</strong></td>
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<td></td>
<td>Palmae</td>
<td><strong>Arecipes spp.</strong>, <strong>Palmaepollenites spp.</strong></td>
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<td><strong>Palmidites spp.</strong>, <strong>Sabalpollenites spp.</strong></td>
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<td></td>
<td><strong>Neocoopeperipollis spp.</strong></td>
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<tr>
<td></td>
<td></td>
<td><strong>Acanthotricolpites bulbospinosum</strong></td>
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</tbody>
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7-1-2: Miofloral Comparison, Palaeoenvironment and Age

Akli Formation

The Akli Formation of Barmer Basin, Western Rajasthan contains 99 species belonging to 69 form genera. It is rich, diversified and comprises angiospermous pollen (60.72%), pteridophytic spores (17.10%), algal cysts (8.70%), foraminiferal linings (5.77%), gymnosperms (3.10%) and fungal remains (1.18%); besides, a number of Palaeozoic and Mesozoic reworked gymnosperous pollen grains. The palynological assemblage groupwise is as follows:

**Algae**

*Polysphaeridium subtile*, *Achomosphaera ramulifera*, *Heterosphaeridium difficile*, *Cordosphaeridium fibrospinosum*, *Cordosphaeridium inodes*, *Spiniferites pseudofurcatus*, *Leptodinium sp.*, *Operculodinium israelium*, *Operculodinium centrocarpum*.

**Fungi**


**Pteridophytes**


**Gymnosperms**

*Laricoidites magnus*, *L. punctatus*, *Araucariacites australis*.

**Angiosperms**

*Palmeapollenites plicatus*, *P. minor sp. nov.*, *Palmidites maximus*, *Arecipites bellus*, *A. matanomadhensis*, *Sabalpollenites indicus sp. nov.*, *S. granulatus sp. nov.*, *Matanomadhiasulcites*.

Microforaminiferal linings

Single chamber, Type I, Planispiral, Type IV, Trochospiral, Type I

Insertae sedis

Savitrinia miocenica

Reworked

Parasaccites sp., Granulatusporites irregularisplacatus, Monosulcites coupert, Gingkolycadopites deteritus, Gingkoretectina vastus.

The assemblage cited above compares well with the palynological assemblages documented from Akli lignite, Barmer (Naskar and Baksi, 1976, Tripathi, 1993, 1995 and 1997), Palana Formation, Bikaner (Sah and Kar, 1974, Sharma, 1997), Barsingsar and Hadla lignites, Bikaner (present study).

The present assemblage have also been correlated with palynoassemblages recorded from Tertiary sediments of Matanomadh Formation, Kutch, Tura Formation, Meghalaya, and Subathu Formation, Himalayan foothills, Bengal basin and Cauvery basin. At last this assemblage has also been compared with Tertiary sediments of KabirKuh Anticline, Lurestan, Iran in the present work.

Akli Lignite, Barmer basin, Rajasthan

Naskar and Baksi (1976) made the first account of the microfloral assemblage of the Akli lignite. This is characterized by the dominance of angiosperms with subdued amount of
pteridophytes, and gymnosperms being practically absent. They described 34 species belonging to 25 form genera of dispersed fossil spores and pollen grains. The overall assemblage recovered by them was dated by them as Palaeocene-Eocene in age.

Palynological study on subsurface samples from Kapurdi, Barmer was carried out by Tripathi (1993, 1995 and 1997). Recorded palynotaxa are rich and diversified being represented by dinoflagellate cysts, fungal remains, pteridophytic spores and angiospermic pollen grains. He identified two palynological zones, Assemblage zone A of Late Palaeocene age and Assemblage B indicating Early Eocene age. He compared these zones with Akli and Mataji Ka Dungar formations of the Barmer Basin respectively.

The common taxa of both the assemblages are: *Lygodiumsporites eocenicus*, *L. pachyexinus*, *Todisporites major*, *Dandotiaspora dilata*, *D. telonata*, *D. pseudoauriculata*, *Lycopodiumsporites palaeocenicus*, *Laevigatosporites laktiensis*, *Arecipites bellus*, *Spinizonocolpites echinatus*, *Matanomadhia sulcites kutchensis*, *Matanomadhia sulcites maximus*, *M. microreticulatus*, *Neoucouperipollis achinatus*, *Proxapertites assamicus*, *Proxapertites cursus*, *P. microreticulatus*, *Kapurdipollenites gemmatus*, *Retiverrumonosulcites barmerensis*.


The palynotaxa limited to the present assemblage are: *Dandotiaspora plicata*, *D. densicorpa*, *Dictyophyllidites sp.*, *Cyathidites minor*, *C. australis*, *Biretispores sp.*, *Lycopodiumsporites speciosus*, *Lycospora indica sp. nov.*, *Todisporites plicatus*, *Gleichenidites seninicus*, *Leptolepidites major*, *Cibotidites kunivaensis*, *Schizaeisporites eocenicus*, *S. indicus sp. nov.*, *Palmaepollenites plicatus*, *P. minor*, *Paludites maximus*, *Arecipites matanomadhensis*, *Sabalpollenites indicus sp. nov.*, *S. granulosus sp. nov.*, *Liliacidites giganteus*.

The present assemblage shows a close affinity with the palynological assemblage of Akli Lignite recorded by Tripathi (1993, 1995 and 1997) because of the sediments under study are from the same area. This is also reflected by the occurrence of common taxa of palynozones A and B found in the present assemblage. These are:

**Assemblage zone A**

**Assemblage zone B**
Spinizonocolpites echinatus, Matanomadhiasidcites kutchensis, Dandotiaspora telonata.

**Palana Lignite, Bikaner basin**
Sah and Kar (1974) described a palynological assemblage from the Palana Lignite, Bikaner. It consists of 67 species belonging to 44 form genera. Out of these, 11 species and 8 genera belong to pteridophytic spores, 36 species and 24 genera of angiospermic pollen grains, 16 species and 9 genera of algae and 4 species and 3 genera of fungi.

Quantitative analysis of the assemblage has revealed that angiospermous elements dominate the assemblage (70%), followed by pteridophytes (20%). Prominent monocot families are Potamogetonaceae, Palmae and Liliaceae. Dicot are comparatively better represented. The principal families include Nymphaeaceae, Leguminosae, Cruciferae, Rubiaceae, Anacardiaceae, Hippocrateaceae, Gunneraeae, Meliaceae, Proteaceae and Onagraceae. Pteridophytic spores are mainly represented by Osmundaceae, Matoniaceae, Polypodiaceae, Schizaeaceae and...
Cheilanthaceae. The algal genus Botryococcus along with microplankton are found in abundance.

The common taxa that share the both the assemblages are: *Dandotiaspora, Dictyophyllidites, Todusporites, Schizaeoisporites* and *Laevigatosporites* of pteridophytes and *Palmaepollenites, Liliacidites, Neocouperipollis* and *pseudonothofagidites* belonging to angiosperms. Among the fungal spores only *Inapertisporites* is common.

The palynomorphs restricted to Palana lignite described by Sah and Kar (1974) are: *Osmundacites, Seniasporites, Cheilanthispora, Retipilanapites, Nymphaeopollis, Tricolpites, Cupuliferoipollenites, Rhoipites, Caprifolipites, Hippocrateaeaeidites, Margocolporites, Lakiapollis, Platoniaipollenites, Verrutricolpites, Calophyllumpollenites, Kieldeyerapollenites, Meliapollis, Polybrevicolporites, Polycolpites, Diporites, Trilatiporites, Proteacidites, Priorates, Botryococcus, Tetraporina, psilosphaera, Temporina, Cephalia, Octaplata, Palanea, Cryptosphaera, Cornoplankton, Diporites, Tribrecoilpites, Callimothallus.


The great degree of inhomogeneity between the two assemblages might be due to the two different basins with unknown ecological barriers, may be the edaphic factors.

**Palana Lignite, Bithnok, Bikaner basin**

Poonam Sharma (1997) described a rich palynofloral community from the Palana Formation of Bithnok, Govinasar-Godivala, Kuchaur-Benia, Kolayat and Kolasar, Bikaner District, Western Rajasthan. The assemblage described by her comprises 65 species belonging to 50 form genera. The common taxa in both the areas are: *Dandotiaspora*

The palynotaxa restricted to the assemblage recorded by Sharma (1997) are: Lycopodium sporites parvireticulatus, Todisporites kutchensis, Dictyophyllidites granulatus, Contignisporites glebulentus, Osmundacidites cephalus, Polyphylacieaesporites major, Schizaeoisporites palanaensis, Pachymonoletesporites superbus, Perinofoveomonoletesporites excellens, Palmaepollenites kutchensis, Areicites intrapunctatus, Racemonocolpites romanus, Proxapertites operculatus, Tuberculozonisulcites retibaculatus, Verratumonoletes foveolatus, Piladiporocolpites caratini, Retidiporocolpites excellens, Tricolpites reticulatus, Bithnikiapolles striatus, B. retipilatus, Bombacacidites triangulatus, Pseudonyssapollesporites kutchenis, Chiranthodendronpollenites bikanerensis, Triangulorites bellus, Megaretrorites splendens, Proteacidites protrudus, Barringtoniapollenites retipilatus, B. retibaculatus, Platoniapollenites iratus, Retistephanocolpites kutchensis, R. granulatus, Retibaculipolycolpites bacalatus, Simplibaculatepollis aerolatus, Duplibaculatepollis septacolpites, Polybrevicolpites nadhamunii, P. cephalus, Pilapolycolpites verrucatus, Polylongicolasporites retipilatus, Polycolpites indicus, Kielmeyerapolleis indicus, Spinitetradocolpites spinosus.

Palynotaxa restricted to Akli Lignite of Barmer basin in the present study but not reported from Palana Formation by Sharma are: Dandotiaspora densicorpa, D. telonata, D. pseudoauriculata, Dictyophyllidites sp., Cyathidites australis, Biretisporites sp., Lygodium sporites speciosus, Lycospora indica sp. nov., Todisporites major, Gleichenidites senonicus, Leptolepidites major, Cibotidites kundvaensis, Schizaeoisporites eocenicus, S. indicus sp. nov., Laevigatosporites lakiensis, Palmaepollenites plicatus, P. minor, Areicites bellus, A. matanomadhensis, Sabalpollenites indicus sp. nov., S. granulosus sp. nov., Matanomadhiasulcites microreticulatus, M. giganteus, Retiverrumonoletes barmerensis, Inaperturapollenites indicus sp. nov., Inaperturapollenites sp., Neocouperipollis achingatus, N. granulatus sp. nov., N. excertus, N. dumae, Kapurdipollenites gemmatus, Bursingsarpollenites indicus gen. et sp. nov., B. spinosus sp. nov., Proxapertites microreticulatus,
Besides, the samples studied in the present work are relatively rich in phytoplankton, fungal remains, microforaminiferal linings and Palaeozoic and Mesozoic gymnospermic reworked fossils whereas these are not well represented in Palana lignite.

Sharma (1997) instituted the *Piladiporocolpites cratinii* Cenozoone which contains the following characteristic taxa: *Dandotiaspora dilata, Psiladiporocolpites pachyexinus, Padymonoletasporites superbuss, Triangulorites bellus, Polylongicolpites retipilatus, Retitetarbrevicolporites globatus* and *Polybrevicolporites cephalus*. The long ranging forms described by her are: *Pluricolumellatepollis pachyexinus, Proxapertites cursus*.

Since the localities investigated by Sharma (1997) comprise the Western extremity of the Bikaner basin very near to the Barmer basin, the two assemblages have shown comparatively a large degree of uniformity.

**Barsingsar Lignite, Bikaner basin**

The Palana Lignite of Barsingsar area has been worked out in detail during the present investigation. The palynological assemblage comprises 115 species belonging to 87 form genera. The common palynotaxa found in both Akli Lignite of Barmer and Palana lignite of Barsingsar area are: *Dandotiaspora dilata, D. plicata, D. densicorpa, D. teleonata, D. pseudoauriculata, Cyathidites minor, C. australis, Biretisporites sp., Lygodiumsporites pachyexinus, Lycopodiumsporites palaeocenicus, Lycoospora indica sp. nov., Todisporites plicatus, Laevigatosporites lakiensis, Palmaepollenites plicatus, Arecipites bellus, Sabalpollenites indicus sp. nov., S. granulosus sp. nov., Matanomadhiasulcites microreticulatus, M. giganticus, M. kutchensis, M. maximus, Retiverrunosulcites barmerensis, Inaperturapollenites indicus sp. nov., Neocouperipollis brevispinisus, N. kutchensis, N. granulatus, N. excertus, Spinizonocolpites baculatus, S. echinatus, Kapurdipollenites gemmatus, Acanthotricolpites bulhospinosus, Barsingsarpollenites indicus gen. et sp. nov., B. spinosus sp. nov., Proxapertites microreticulatus, Proxapertites assamicus, Proxapertite granulatus, Proxapertites cursus, Pluricolumellatepollis pachyexinus, Duplibaculatepollis pentacolpites, Ocimumpollenites indicus*. 


The Barsingsar area like the localities from where Sharma (1997) described her palynological assemblages constitutes the western part of Bikaner basin. The place being...
comparatively more closer to the Akli Lignite demonstrated its great homogenity in the palynological assemblages.

**Hadla Lignite, Bikaner basin**

The palynoassemblage recovered from the Hadla Lignite of Bikaner comprise 24 species belonging to 21 form genera. The common palynotaxa found in both Akli and Hadla Lignites assemblages are: *Dandotiaspora pseudoauriculata, D. plicata, Dictyophyllidites* sp., *Inaperturapollenites* sp., *Neocouperipollis* achinatus, *Proxapertites* cursus, *Matanomadhiasulcites* maximus.


Since only a single subsurface sample was available for the study of Hadla Lignite. The assemblage under consideration is a representative one and has shown a fair similarity.

**Kutch basin**

Kar and saxena (1976), Saxena (1978-1980) and Kar (1985) worked out the palynology of Matanomadh Formation of Tertiary age of Kutch. They described altogether 85 species of palynotaxa belonging to 46 form genera. The palynotaxa that share a common occurrence between the present assemblage and that of Kutch basin are: *Dandotiaspora dilata, D. plicata, Lygodiumsporites pachyexinus, Todusporites* major, *Proxapertites microreticulatus, Cyathidites australis, Inaperturapollenites kedvesii, Neocouperipollis kutchensis, N. achinatus, Retistephanocolpites flavatus.*

The palynotaxa limited to the present assemblage in Akli lignite are:


Kar (1985) instituted five palynological Cenozoens in the Matanomadh Formation. These zones in ascending order of stratigraphy are: Spong spicule Zone, Couperipollis kutchensis Cenozone, Tricolpites minutus Cenozone, Dandotiaspora dilata Cenozone and Barren Zone. The Dandotiaspora dilata Cenozone shows the following common palynotaxa with the present assemblage: Dandotiaspora dilata, D. plicata, Todisporites spachyexinus, Todisporites major, Proxapertites microreticulatus and cyathidites australis. Similarly, Tricolpites minutus Cenozone also exhibits a fair similarity with the following taxa in the present assemblage: Cyathidites australis, Dandotiaspora plicata and Inapertisporites kedvesii. The following taxa are common in Couperipollis kutchensis Cenozone of the Matanomadh Formation as well as in the present assemblage: Neocouperipollis kutchensis, N. echinatus, Retistephanocolpites flavatus.

Though there is a close similarity in the palynological assemblages of two basins at the generic level, it is surprising that the resemblance at the specific level is quite limited. Perhaps, it may be due to the geological separation of the two basins, with their different ecological conditions.

Assam-Meghalaya region

The Tura Formation of the type area in Garo Hills has been worked out by Singh (1974), Sah and Singh (1974), Singh et al. (1975) and Singh (1977). The Tura palynological assemblages described by them comprise 110 species assignable to 68 form genera.

The palynotaxa common in the type area of Tura Formation of Garo Hills and the present assemblage are: Dandotiaspora telenata, D. plicata, D. densicorpa, D. dilata, D. pseudoauriculata, Cyathidites minor, Lygodiumsporites eocenicus, Gleicheniidites, Todisporites, Biretisporites sp.,...


Singh (1977) proposed four palynological zones in the Tura Formation. These zones in ascending order are Proxapertites (Retialetes) emendatus, Dandotiaspora telonata, Palmidites 212.
plicata and Proxapertites (Nymphaeipollis) assamicus assemblage zones. The Proxapertites emendatus zone has the following common palynotaxa with the present assemblage: Dandotiaspora pseudoauriculata, D. telonata, Proxapertites assamicus, Lycopodiumsporites palaeocenicus, Cyathidites minor, Dandotiaspora plicata, Lycopodiumsporites speciosus, Neocouperipollis brevispinosus, Dandotiaspora dilata. Similarly, Dandotiaspora telonata zone shows similarity with the following taxa: Dandotiaspora telonata, D. pseudoauriculata, Proxapertites assamicus, Lycopodiumsporites palaeocenicus, Cyathidites minor, Dandotiaspora plicata, D. densicorpa, Lycopodiumsporites speciosus, Neocouperipollis brevispinosus. The undermentioned taxa are common in both Palmidites plicatus zone and the present assemblage: Palmidites maximus, Lycopodiumsporites palaeocenicus, Cyathidites minor, Dandotiaspora plicata, Lycopodiumsporites speciosus, Neocouperipollis brevispinosus, Laricoidites magnus. Likewise, Proxapertites assamicus zone possesses close relation with the present assemblage in containing common taxa: Palmidites maximus, Proxapertites assamicus, Cyathidites minor, Dandotiaspora plicata, Lycopodiumsporites speciosus, Neocouperipollis brevispinosus.

Of these four zones in the Tura Formation, only two zones viz. Proxapertites emendatus and Palmidites plicatus zones have precisely been recognized in the present assemblage. The other two zones could not be distinguished due to overwhelming percentage of common taxa.

Thus the Tertiary sediments of Meghalaya and west of Rajasthan area show a great degree of similarity in the miofloral assemblages, though they are located quite apart. This resemblance might be due to the location of two basins in isoclimatic belt during the Palaeocene-Eocene times. Similarly, the other known homotaxial assemblages of Meghalaya and Assam like those of Cherra Formation and Mikir Formation have also a close similarity with the present assemblage.

**Himalayan foothills (Himachal Pradesh)**

Palynological studies of Subathu Formation have been carried out by Mathur (1963, 1966), Saluja, Srivastava and Rawat (1969), Singh and Khanna (1980) and Sarkar and Singh (1988). Sarkar and Singh (1988) identified 58 genera and 106 species of dinoflagellate cysts, fungal remains, pteridophytic spores, gymnospermous and angiospermous pollen grains. They instituted five palynological assemblage zones in ascending order viz. Todisporites...
The common taxa found in the present assemblage and that of Subathu Formation are: *Cyathidites australis, Lygodiumsporites eocenicus, L. pachyexinus, Todisporites major, Biretisporites sp., Dictyophyllidites sp., Neocouperipollis brevispinosus, Dicotetradites sp., Inapertisporites kedvesii.*

The palynological assemblage described from the Subathu Formation are enriched with phytoplankton and Akli Formation of Barmer Basin, western Rajasthan also shows a sporadic occurrence of these elements. The common taxa in both assemblage are: *Cordosphaeridium inodes, Cordosphaeridium fibrospinsum, Operculodinium centrocarpum, Polysphaeridium subtile.*

The palynotaxa recorded in the present study shows a close affinity with *Cleistosphaeridium spp.*, *Cordosphaeridium spp.* and *Todisporites spp.* Zones of Subathu Formation proposed by Sarkar and Singh (1988). Since Subathu Formation is richly populated with dinoflagellates in comparison to the Akli Formation due to close vicinity to the sea, the two formations seems to be homotaxial due to their synchrony in deposition.

**Bengal Basin**

The palynological investigation of the subcrop sediments of Bengal basin was worked out by Baksi (1972). He instituted seven palynozones in the area. The Jalangi Formation was distinguished by him as Bengal Palynological Zone II. This zone is very rich in pollen contents which is also correspondingly reflected in the lithology by its coal lentils. The palynotaxa that show a common existence in both the areas are: *Dandotiaspora dilata, Dandotiaspora plicata, Dandotiaspora telonata, Lycopodiumsporites spp., Neocouperipollis spp., Proxapertites spp.*

The taxa restricted to Bengal Palynological Zone II are: *Assanialetes emendatus, Granulatisporites sp., Schizaosporis crassimurus, Myrtaceidites sp., Leiotiletes sp.*

Since the age marking taxa such as *Dandotiaspora* and *Proxapertites* share a common existence in both the assemblages, both the sequence seems to be synchronous in nature.

**Cauvery Basin**
Venkatachala and Rawat (1972) gave an account of the palynostratigraphy of the subsurface succession of Cauvery basin. They recognized 110 species belonging to 61 form genera. The common taxa of the both assemblage are: Lycopodiumsporites eocenicus, Spinizonocolpites echinatus, Proxapertites sp., Neocouperipollis sp.


They instituted Proxapertites hammenii and Psilodiporites hammenii zones for the Palaeocene and Early Eocene subcrop of the Cauvery basin. The sharp difference in the palaeovegetation of two area might be due to different climatic conditions during Palaeocene- Eocene time.

Pabdeh Formation, KabirKuh, Iran

The pabdeh Formation of KabirKuh Anticline, Lurestan, Iran contains 33 species belonging to 29 form genera. It is comprises of angiospermous pollen (16%), pteridophytic spores (5%), algal cysts (76.6%), gymnosperms (1.7%) and fungal remains (0.8%), besides a number of Mesozoic reworked palynomorphs.

Algae

Fungi
Frasnacritetus sp.

Pteridophyte
Dictvophyllidites harisi, D. zagrosensis sp. nov., Polypodispores ornatus.

Gymnosperms
Laricoidites himalayensis

Angiosperms

Paleosantalaceae epites giganticus, Triporopollenites exactus, Corrusporis iranica sp. nov., Proxapertites granulatus, P. assamicus.

Reworked

Cycadopites cf. C. saknagalensis, Rouseisporites sp.

The assemblage cited above is dominated by the algal cysts and subordinate amount of angiospermic pollen grains and pteridophytic spores. The common palynotaxa in this assemblage and palynoassemblage recovered from Lower Tertiary sediments of western Rajasthan are: Dicthyophyllidites, Polypodiisporites, Paleosantalaceae epites, Triporopollenites, Proxapertites, Laricoidites, Heteraspheridium, Homotrybi um, Operculodinium, Cyclonephelium, Spiniferites, Achomosphaera, Rouseisporites.

Environment of deposition

From the abovementioned data, it is logical to infer that the place of deposition for the Akli Formation was a marginal marine environment with shallow, fresh-brackish water to marine conditions probably in a coastal realm with a lagoon or delta. The coastal swamp or inlet containing swamp vegetation was existing there. Besides, there might have also been a coastal strip, supporting fairly luxuriant vegetation, which was characterized by Tropical-Subtropical plants, ferns and fungi.

Likewise, the Pabdeh Formation is abundant with dinoflagellates throughout the succession and characterize by the palm pollen having affinity with the genus Proxapertites. It also includes a number of palynomorphs belonging to upland plants that seems to have been incorporated from the surrounding area in the basin of deposition. Thus the occurrence of a rich variety of phytoplankton along with Proxapertites indicate the deposition of Pabdeh Formation in a distinct outer Shelf marine condition. This is also evident by the presence of benthic and planktonic foraminifera in the formation.

Age

On the basis of known equivalent palynological zones in western Rajasthan, Kutch basin, Meghalaya and Himalayan foot hills, it can be convincingly deduced that the Akli Formation of Barmer, Rajasthan is of Palaeocene-Lower Eocene in age.
The presence of index dinoflagellate taxa comparable with International Dinoflagellate Zones in the Pabdeh Formation indicate a Upper Palaeocene to Lower Oligocene age for this Formation. This is also corroborated by the occurrence of index planktonic foraminifera taxa.

7-1-3: Zoological aspects

The faunal assemblage of the Lower Tertiary sediments of western Rajasthan in the present study comprises 23 species belonging to 18 genera. Out of these 7 species and 6 genera are assigned to Ostracoda. The benthic foraminifera recovered from the assemblage numbering 12 species are included 9 genera. The qualitative and quantitative analyses show that the benthic foraminifera dominate over planktonic foraminifera in the assemblage.

The faunal assemblage recovered from the Tertiary sediments of Pabdeh Formation, Kabir Kuh Anticline, Iran also contains 57 species belonging to 31 genera. Out of these, 3 species belong to 2 genera are of Ostracoda. This assemblage also shows dominance of benthic foraminifera over the planktonic forms with 34 species belonging to 23 genera.

7-1-3-1: Benthic Foraminifera

The benthic taxa in foraminiferal assemblage from western Rajasthan are grouped into 9 families belonging to 4 suborder. These families include Ammodiscidae, Haplophragmoididae, Vaginulinidae, Alabamidae, Miliolidae, Nubeculariidae, Purrelloididae, Cibicididae and Rotaliidae. Quantitatively, the calcareous benthic foraminifera from western Rajasthan are more abundant than the arenaceous forms. The calcareous benthic foraminiferal assemblage is represented by suborder Rotaliina, Miliolina and Lagenina in order of specific diversity. Suborder Textulariina is of agglutinated origin.

In Rotaliina, the families are Cibicididae, Rotaliidae, Purrelloididae and Alabamidae. The family Cibicididae is represented by 2 species belonging to 2 genera. These are Cibicides aknerianus and Cibicides lobatus. The family Rotaliidae is marked by presence of Saudella cf. Saudella rugosa. The family Purrelloididae is also represented by Cibicidoides sp.1 and the family Alabamidae is represented by Valvalabamina sp. The forms belonging to suborder Miliolina is represented by the families Miliolidae and Nubeculariidae. The family Miliolidae comprises 2 genera viz. Quinqueloculina and Triloculina. The Nubeculariidae is marked by Spiroloculina cf. Spiroloculina excavata.

In the present assemblage, the suborder Lagenina is characterized by the family Vaginulinidae. This family is represented by Turkmenella sp. The arenaceous foraminifera
belonging to suborder Textulariina is represented by 2 families and 2 genera. The species of these genera are *Ammodiscoides* cf. *Ammodiscoides* sp., *Haplophragmoides* sp., *Haplophragmoides* cf. *Haplophragmoides* scitulus and *Haplophragmoides* cf. *Haplophragmoides* agrawali.

The benthic taxa from Tertiary sediments of Kabir-Kuh Anticline, Iran comprises most diverse assemblage. It is grouped into 17 families belonging to 3 suborders. These families are *Purrelloididae*, *Cibicididae*, *Discorbidae*, *Pleurostomellidae*, *Buliminidae*, *Bolivinidae*, *Anomalinidae*, *Gavelinidae*, *Vaginulinidae*, *Nodosariidae*, *Textulariidae*, *Eggerellidae*, *Spiroplectamididae*, *Tritaxidae*, *Valvulinidae*, *Prolixoplectidae* and *Lituolidae*.

Qualitatively, the calcareous benthic foraminifera are more diverse than the arenaceous ones. The calcareous benthic foraminiferal assemblage is represented by suborder Rotaliina and Lagenina. Suborder Textulariina is represented as agglutinated origin.

Suborder Rotaliina represented by 8 families, 15 species belong to 8 genera. The family *Purrelloididae* comprises of 3 species of a single genus viz. *Cibicoides eocaenus*, *Cibicoides dutemplei* and *Cibicoides* sp. II. The family *Cibicididae* is marked by 3 species belonging to 2 form genera. These are *Cibicides lobatulus*, *Cibicides ungerianus* and *Cibicidina wallii*. The family *Anomalinidae* is represented by *Anomalinoides rubiginosus*, *Anomalinoides semicribratus* and *Anomalinoides capitatus*. The family *Buliminidae* is documented by 2 species under a single genus viz. *Bidimina cf. Bidimina costata* and *Bulimina pyrula* while the other families like *Discorbidae*, *Pleurostomellidae*, *Bolivinidae* and *Gavelinidae* are represented by *Discorhis cf. Discorhis mira*, *Ellipsolingulina sp.*, *Brizalina variabilis* and *Gyroidina soldani*. The suborder *Lagenina* is made up of 2 families and 11 species belonging to 7 genera. Similarly, the family *Vaginulinidae* is represented by *Margimdnopsis sp.*, *Percultazonaria sp.*, *Vaginulinopsis hauerina*, *Lenticulina inornata*, *Lenticulina costata* and *Neoflabellina jarvisii*. The forms belong to family *Nodosariidae* are *Nodosaria simplex*, *Nodosaria radiata*, *Nodosaria affinis*, *Nodosaria pyrula* and *Dentalina inornata*. The arenaceous foraminifera belonging to Textulariina represented by 7 families and 7 genera. The species of these genera are *Textularia gramen*, *Textularia laevigata*, *Dorothia oxycona*, *Spiroplectinella cf. Spiroplectinella carinata*, *Tritaxia trilatera*, *Clarulinia pacifica*, *Karrendina sp.* and *Ammobaculites sp.*

7-1-3-2: Planktonic Foraminifera

The planktonic foraminifera belonging to suborder Globigerinina are represented by the families viz. *Globigerinidae* and *Globorotaliidae* in Lower Tertiary sediments of western
Rajasthan while the families such as Truncorotaloididae, Globigerinidae, Hantkeninidae and Globorotaliidae are present according to their abundance in Pabdeh Formation, Kabir Kuh Anticline, Iran.

The planktonic foraminiferal assemblage recovered from western Rajasthan comprises 4 species belonging to 3 genera while the assemblage from Pabdeh Formation, Kabir Kuh, Iran contains 18 species belonging to 6 genera. The families represented in western Rajasthan quantitatively in descending order are: Globorotaliidae (75%) and Globigerinidae (25%). Globorotaliidae family represented by *Turborotalia pseudobulloides*, *Turborotalia fringa* and *Planorotalites compressa*. Globigerina collactea is assigned to Globigerinidae family in this assemblage.

The families represented in Pabdeh Formation, Kabir Kuh, Iran quantitatively in descending order are: Truncorotaloididae (50%), Globigerinidae (33%), Hantkeninidae (11%) and Globorotaliidae (6%). The family Truncorotaloididae is represented by 9 species belonging to 2 genera. These are *Morozovella lehneri*, *Morozovella subbotinae*, *Morozovella aequa*, *Morozovella spinulosa*, *Morozovella aragonensis*, *Morozovella marginodentata*, *Morozovella formosa gracilis*, *Acarinina bullbrooki* and *Acarinina soldadoensis angulosa*. The family Globigerinidae comprises 6 species under the single genus. These are *Globigerina patagonica*, *Globigerina yeguaensis*, *Globigerina cf. Globigerina praebulloides*, *Globigerina officinalis*, *Globigerina linaperta* and *Globigerina ouachitaensis*. Hantkeninidae family is represented by *Hantkenina alabamensis* and *Hantkenina brevispina* and Globorotaliidae family is occupied by *Globorotalia wilcoxensis*.

**7-1-3-3: Ostracoda**

In addition to the prolific and varied assemblage of foraminifera, few species of Ostracoda were also recovered. These are represented by 7 species belonging to 6 genera from the Lower Tertiary sediments of western Rajasthan and 3 species of 2 genera from Pabdeh Formation, Kabir Kuh Anticline, Iran. The genera from western Rajasthan assemblage belong to 5 families with 2 suborder. Suborder Platycopina represented by family Cytherellidae is witnessed by the species *Cytherella cf. Cytherella sp.*. Suborder Podocopina is marked by Krithidae family, which included *Kritha oryza*. Trachyleberididae is marked by *Alocopocythere rajasthanensis* and *Archicythereis sp.*. Xestoleberididae is represented by *Xestoleberis cf. Xestoleberis sp.* and Candonidae through the *Paracypris ghotarufortensis* and *Paracypris sahui*. 

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Besides, the assemblage belonging to Pabdeh Formation, Kabir Kuh, Iran is occupied by Podocopina Suborder with two families viz. Trachyleberididae and Hemicytheridae. The genera belonging to these families are *Alocopocythere gopinathkillaensis*, *Alocopocythere indica* and *Hornibrookella chandrai*.

The overall preservation of the specimens recovered in this study is very good but due to lack of sufficient literature, specific identification of some specimens could not been attempted up to proper specific level. Also some specimens are left for further investigation.

In order to interpret the probable palaeoenvironment during sedimentation of different lithological units, the ecological considerations are discussed below:

Norton (1930) examined four bathymetric temperature zones such as:

Zone A: Lithoral down to 5 fathoms (0-9 m) with a temperature of 21.5–31.4 °C i.e. Tropical-Subtropical Zone. In this zone Miliolidae and Peneroplididae are dominant and Valvulinidae, Calcarinidae, Homotrematidae and Nonionidae are frequent.

Zone B: 5 to 60 fathoms (9-110 m) and with a temperature of 18.9-24.8 °C i.e. Subtropical Zone. Decrease of Miliolidae and Peneroplididae but frequent occurrence of Nodosariidae, Textulariidae, Buliminidae and Asterigerinidae.

Zone C: 500-825 fathoms (1097-1508 m) and temperature within 4-7.61 °C i.e. Subpolar Zone.

Zone D: 200-2850 fathoms (3656-5210 m) has a water temperature between 1.83-2 °C i.e. Polar Zone.

Zone C and D show the dominance of planktonic foraminifera belonging to families Globigerinidae and Globorotalidae. The families Buliminidae and Nodosariidae continue to great depths but only in small number. Rotaliidae and Anomalinaidae families are distributed in all zones.

7-1-4: Microfaunal Comparison, Palaeoenvironment and age

The development of Paleogene in the Indian Subcontinent is mostly in pericratonic basins, which extend from upper Assam to Kutch. From here, the deposits extend into Pakistan, where they are exposed vividly in Potwar Plateau and traditionally classified as Ranikot, Laki and Kirthar. These rock sequences extend well up to Rajasthan and are exposed extensively in the westem part of Bikaner and Jaisalmer. The development of the Paleogene succession on the Indian Shelf is related to gradually accelerating trangression of sea, which
seems to have reached its acme during Middle Eocene time when extensive carbonate facies developed all around the Indian Shield. The carbonate succession of Middle Eocene is an extensive larger foraminiferal facies, with very little to negligible benthic foraminifera and a few thin bands of planktonics. This development extends all along the Western Indian Shelf as also on the Eastern Indian Shelf.

The microfaunal comparison of Lower Tertiary foraminifera and Ostracoda of western Rajasthan with that of other area in Indian Subcontinent are, therefore, as follows:

7-1-4-1: Jaisalmer basin

The taxa recovered from the three sections of Lower Tertiary sediments of western Rajasthan comprising Khuaila and Bandah Formations inclose both benthic, planktonic foraminifera and Ostracoda.

Benthic foraminifera:


Planktonic foraminifera:

- Turborotalia pseudobulloides, Turborotalia fringa, Globigerina collactea, Planorotalites compressa.

Ostracoda:


The assemblage cited above compares well with the faunal assemblages documented from Rajasthan, Kutch, Meghalaya, Simla Hills and Pondicherry of south India.

Rajasthan, Northwest India

Habibnia and Mannikeri (1990) recorded 24 taxa of benthic and planktonic foraminifera belonging 12 families from the surface sequence of Khuaila (Ypresian) and Bandah (Lutetian) Formations of Jaisalmer District, Western Rajasthan.
The assemblage is also found associated with the larger benthic foraminifera and Ostracoda. The common genera in both assemblages are *Cibicides*, *Spiroloculina*, *Quinqueloculina*, *Triloculina* and planktonic foraminifera.

Singh (1971) studied the planktonic foraminifera in the Eocene sediments of Rajasthan. On the basis of the faunal assemblage besides the lithological characteristic, he recognised four local zones for Kolayat Stage and two zones for Bikaner Stage. These in ascending order are: Ostracod Zone, Nummulites Zone, Pelecypoda Zone, Assilina Zone, Discocyclina and Flusculina Zones. In Ostracod Zone besides the genera and the species of the Ostracoda, the important planktonic species identified are: *Globigerina collactea*, *Globigerina prolata*, *Globorotalia formosa gracilis*, *Globorotalia formosa formosa*, *Globorotalia aragonensis*, and *Globorotalia broedermanni*.

This assemblage zone also contain *Eoassilina elliptica*, *Assilina granulosa*, *Assilina leymerie*, *Operculina spp.*, *Operculinoides spp.*, *Rotalina crookshankina*, *Cibicides praecursorius*, *Cibicides aff. beaumontina*, *Nonion scapha var. indica*, *Discorbis globularis*, *Discorbis spp.*, *Dentalina sp.*, *Pseudoglandulina sp.*, *Bulimina sp.* and *Quinqueloculina sp.*


The common genera in this assemblage and present assemblage are: *Cibicides*, *Quinqueloculina spp.*, *Triloculina spp.*, *Globigerina spp*. And *Globorotalia spp*. No microfauna could be found associated with Pelecypoda in the Pelecypoda Zone.

The stratigraphical important species *Assilina exponens* identified in Assilina Zone and the other foraminiferal genera have not been reported. The Discocyclina Zone contains planktonic foraminifera viz. *Globorotalia lehneri*, *Globorotalia spinulosa* and the Flusculina Zone comprises *Truncorotaloides rohri*, *Globigerapsis tropicalis*, *Globigerina officinalis*, *Globigerina frontosa* and *Globigerina pseudocorputenta*. 

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The similarity between planktonic foraminifera in abovementioned Zones and in the present assemblage has been only observed at the generic level. This may be an endemic factor related to different types of population in the two basins.


A precise comparison can only be attempted after a detailed investigation on this aspect.

**Kutch, Western India**

Singh (1967) studied the Lower Tertiary sequence of Kanoj, Kutch and recovered fauna assemblage comprising 32 species belonging to 17 genera. This assemblage is represented by 10 families namely *Miliolidae*, *Discorbidae*, *Globigerinidae*, *Rotaliidae*, *Globorotaliidae*, *Nonionidae*, *Orbulinidae*, *Ataxophragmoida*, *Textulariidae* and *Nodosariidae* according to their abundance.

The common taxa in both assemblages are *Quinquiloculina*, *Trilocuina*, *Cibicides spp.*, *Globigerina*, *Turborotalia*. The taxa confined to the assemblage recorded by Singh (1967) are: *Textularia*, *Clavulinoides*, *Pyrgo*, *Nodosaria*, *Nonionella*, *Discorbis*, *Rectoepomides*, *Rotalia*, *Ammonia*, *Cycloloculina*, *Globigerapsis* and *Globigerinatheka*.

Thus the resemblance in the planktonic forms of the two basins point out their synchoronity in age and the identical environment of deposition. The difference in benthic community may be related to the local factors.

Jauhri (1991) recorded 29 species of smaller benthic foraminifera from the Middle Eocene rocks of the Vinjhan-Miani area of Kutch. The common taxa in both assemblages are *Trilocuina*, *Cibicides*. The taxa limited to assemblage of Kutch are:
Textularia, Bigerina, Pseudobolivina, Clavulina, Fissurina, Buliminella, Bolivina, Discorbis, Vavulineria, Glaratella, Rotalia, Pararotalia, Lockhartia, Nonion, Heterolepa and Anomalinoi de

The assemblage of benthic foraminifera described by Jauhri (1991) seems also different from the present assemblage due to the reason cited above.

Tewari et al. (1964) reported 27 species of foraminifera from Waghopadar, southwestern Kutch. This assemblage comprises of both benthic and planktonic foraminifera. The common genera in both assemblages are: Quinqueloculina, Spiroloculina, Cibicides and Globigerina. The taxa restricted to the assemblage from Kutch are Textularia, Stainforthia, Tubulogenerina, Anomalina, Discorbis, Schlumbergerina, Linderina, Nonionella, Nonio, Reussella, Operculinella, Rotalia, Pyrgo, Glandulina, Nodosaria, Clavulina, and Cibicidella.

Meghalaya, Northeast India

Pandey (1978) studied the Palaeocene smaller foraminifera of Um Sohryngkew River area, Meghalaya. He recorded 121 species of benthic and planktonic foraminifera belonging to the Mahadeo and Langpar Formations, exposed in Theria area. Out of these 72 species belong to Palaeocene. The common taxa in both assemblages are: Planorotalites compressa, Turborotalia fringa and Turborotalia pseudobulloides.


The taxa confined to foraminiferal assemblage of Um Sohryngkew River area are: Bathysiphon, Reophax, Ammobaculites, Spiroplectamnia, Textularia, Spiroplectinata, Tritaxia, Dorothia, Nodosaria, Astacolus, Dentalina, Frondicularia, Lagenia, Lenticulina, Marginulina, Marginulinosis, Saracenaria, Guttulina, Bullopora, Fissurina, Bulimina, Guembelitria, Chiloguembelina, Neoguembelina, Acarinina, Morozovella, Globorotalia, Nodosarella, Cassidinella, Quadimorphina, Pullenia, Gyroidina, Osangularia, Anomalinoi de, Coelites, Heterolepa, Karrera and Pulsiphonina.

At this instance also the equivalency is displayed through the planktonic forms. Both the basins were having different benthic forms due to their vast geographical separation.
Bhandari (1992) recovered a rich assemblage of Ostracoda containing 59 taxa from the Palaeogene (Jaintia Group) subsurface sequence of Garro Hills, Meghalaya and Assam. On the basis of Ostracodes, he instituted five zones in ascending order: *Alocopocythere gopinathkillaensis-Paijenborchella bhatiai-Cytherella siddiquii* Assemblage Zone, Poorly Fossiliferous Zone, *Alocopocythere garoensis-Hermanites basanti* Assemblage Zone, Poorly Fossiliferous/Barren Zone, and *Alocopocythere meghalayaensis-Paijenborchella swaraswatae* Assemblage Zone. The common Ostracodes taxa in both assemblages are *Cytherella, Krithe, Alocopocythere, Xestoleberis* and *Paracypris*.

The present assemblage belonging to Lower Tertiary sediments of western Rajasthan is comparable with Zone I (*Alocopocythere gopinathkillaensis-Paijenborchella bhatiai-Cytherella siddiquii* Assemblage Zone) of Meghalaya by having common taxa like *Cytherella, Alocopocythere spp.* and *Paracypris spp.*

**Simla Hills, North India**

Datta and Banerji (1972) recorded 48 species of calcareous smaller foraminifera from five biostratigraphic zones, worked out on the basis of the distribution of larger foraminifera, in the Subathu Subgroup (Upper Palaeocene to Middle-Upper Eocene) in Simla Hills. The common taxa in both assemblages are *Cibicides, Triloculina* and *Quinqueloculina*. The taxa confined to assemblage recorded by Datta and Banerji (1972) are *Pyrgo, Lenticulina, Discorbis, Vaiulineria, Globorotalia, Planulina, Loxastomum, Nonionella, Alabamina* and *Anomalina*. The taxa encountered in the present assemblage are *Cibicidoides, Saudella, Spiroloculina, Ammodiscoides, Valvulabamina, Turkmenella, Haplophragmoides, Turborotalia, Globigerina, Planorotalites* and a few number of Ostracodes taxa.

The least similarity between the two assemblages may be related to the different palaeogeographic position during the Palaeocene-Eocene time.

**Pondicherry, South India**

Samanta (1968) re-examined the Discocyclina-bearing Limestone reported by Furon and Lemoine (1938) and Furon (1941) from a bore-hole in the Pondicherry area, south India. He found that the Discocyclina-bearing Limestone is abundant with smaller microfossils including several index planktonic foraminiferal species. On the basis of the presence of these forms, he assigned an Upper Palaeocene-Early Lower Eocene age to this horizon.
The common taxa in both assemblages are *Cibicides and Quiqueloculina*. The restricted taxa in assemblage presented by Samanta (1968) are: *Anomalina, Darbyella, Discocyclina, Globorotalia, Lenticulina* and *Parrella*.

The limited taxa in present assemblage recovered from Rajasthan are: *Cibicidoides, Saudella, Spiriloculina, Ammodiscoides, Triloculina, Valvalabamina, Turkmenella, Haplophragmoides, Turborotalia, Globigerina, Planorotalites* and a few number of Ostracodes taxa.

This major difference between two assemblages perhaps may be related to their broad distance in their location.

7-1-4-2: Pabdeh Formation, KabirKuh Anticline, Iran

The faunal assemblage recovered from three sections of Pabdeh Formation comprises benthic, planktonic foraminifera and Ostracoda.

**Benthic Foraminifera:**


**Planktonic Foraminifera:**

*Morozovella lehneri, Morozovella subboiniae, Morozovella aequa, Morozovella aragonensis, Morozovella marginodentata, Morozovella Formosa gracilis, Morozovella spinolosa, Globigerina patagonica, Globigerina cf. Globigerina praebulloides, Globigerina yeguaensis, Globigerina officinalis, Globigerina linaperta, Globigerina ouachitaensis, Acarinina soldadoensis angulosa, Acarinina bullbrooki, Globorotalia wilcoxensis, Hantkenina alabamensis* and *Hantkenina brevispina.*
Ostracoda:

Alocopocythere gopinathkillaensis, Alocopocythere indica and Hornibrookella chandrai.

The assemblage from Lower Tertiary sediments of KabirKuh Anticline, Iran has been compared with those of Rajasthan, Kutch, Meghalaya, Simla Hills and Pondicherry in south India.

Rajasthan

Habibnia and Mannikeri (1990) studied 24 smaller benthic and planktonic taxa from the surface sequence of Khuaila and Bandah Formations of Jaisalmer District, Western Rajasthan.

The common taxa in the assemblage recorded by them from Jaisalmer and the present assemblage from Pabdeh Formation, KabirKuh, Iran are: Cibicides, Discorbis, Textularia, Clavulina, Gyroidina, Ammobaculites and Globorotalia. The taxa confined to Jaisalmer assemblage recorded by aforesaid authors are: Bathysiphon, Spiroloculina, Quinqueloculina, Pyrgo, Sigmoilina, Triloculina, Globulina, Halkyardia, Florilus. The assemblage recovered from Jaisalmer District, Western Rajasthan in the present study shows the following similarity of the generic level with the assemblage from Lower Tertiary sediments of KabirKuh, Iran: Cibicidoides, Cibicides, Turborotalia, Globigerina and Alocopocythere.

The restricted taxa belonging to Lower Tertiary sediments of Jaisalmer area in the present study are: Saudella, Spiroloculina, Ammodiscoides, Tricuina, Quinqueloculina, Valvalabamina, Turkmenella, Haplophragmoides, Planorotalites and Hornibrookella.

Singh (1971) instituted four zones on the basis of faunal assemblage besides the lithological characteristic for Lower Eocene succession of Jaisalmer, Western Rajasthan. The assemblage recovered from Lower Tertiary sediments of KabirKuh, Iran is comparable with that recorded by Singh (1971) on the basis of following taxa: Morozovella (Globorotalia) formosa gracilis, Morozovella (Globorotalia) aragonensis, Globorotalia spp., Globigerina spp., Globigerina officinalis, Cibicides, Discorbis, Dentalina and Bulimina.

The taxa limited to assemblage recorded by Singh (1971) are: Praeindicula, Nonion, Pseudoglandulina, Quinqueloculina, Rotalia, Cutulinia, Nonionella, Asterigerina. Besides, the larger foraminifera present like Eoassilina, Assilina, Operculina, Nummulites, Discocyclina and Lockhartia.

This degree of similarity/dissimilarity may be due to the difference in palaeogeographic placement of the two basins.
Kutch

Singh (1967) studied the Lower Tertiary sequence of Kanoj, Kutch and recovered faunal assemblage comprising 32 species belonging to 17 genera. The following common taxa in both assemblages are: *Textularia, Nodosaria, Discorbis, Cibicides, Globigerina spp., Globorotalia spp.*

The taxa limited to the assemblage from Kutch area are: *Clavulinoides, Quinqueloculina, Triloculina, Pyrgo, Rectoepionides, Rotalia, Ammonia, Globigerapsis and Globigeratheka.*

Restricted taxa of the assemblage in present study are: *Cibicidoides, Marginulinopsis, Ellipsolingulina, Percultazonaria, Dentalina, Bulimina, Dorothia, Spiroplectinella, Tritaxia, Clavulina, Karrerulina, Vaginulinopsis, Lenticulina, Brizalina, Anomalinoideae, Neoflabellina, Gyroidina, Ammobaculites* and *Hantkenina.* Besides a few number of Ostracodes are also present. The reason of similarity may be the same as cited above.

Jauhri (1991) on the other hand, recorded 29 species of smaller benthic foraminifera from the Middle Eocene rocks of the Vinjan-Miani area of Kutch. The accompanying planktic and larger foraminifera and calcareous nanofossils suggest Late Middle Eocene age to this assemblage. The common taxa in both assemblages are: *Textularia, Clavulinida, Discorbis, Cibicides* and *Anomalinoideae.* The following taxa are restricted in the assemblage belong to Kutch area: *Bigenerina, Pseudobolivina, Triloculina, Miliola, Fissurina, Buliminella, Bolivina, Valvulineria, Glabratella, Rotalia, Pararotalia, Lockhartia, Nonion* and *Heterolepa.*

The limited taxa in the assemblage of present study are as follow: *Cibicidoides, Marginulinopsis, Ellipsolingulina, Nodosaria, Dentalina, Percultazonaria, Bulimina, Dorothia, Spiroplectinella, Tritaxia, Karrerulina, Vaginulinopsis, Lenticulina, Brizalina, Neoflabellina, Gyroidina, Ammobaculites* and a outnumbered of planktonic foraminifera belonging to family *Globigerinidae* and *Globorotaliidae.* Besides, a few number of Ostracodes are present.

The degree of similarity in the two assemblages may be related to their palaeoposition during the Palaeocene-Eocene time.

Meghalaya

Pandey (1978) recorded 121 species of foraminifera of the Mahadeo and Langpar Formations, exposed in Therria area, Meghalaya. Seventy two of them occur in the Palaeocene sediments of the Sohryngkew River section.
The common taxa in the assemblage recorded by him and the present assemblage belonging to KabirKuh Anticline, Iran are: *Ammobaculites*, *Textularia*, *Trintaxis*, *Dorothia*, *Nodosaria*, *Dentalina*, *Lenticulina*, *Marginulopsis*, *Bulimina*, *Acarinina*, *Morozovella*, *Turborotalia*, *Globorotalia*, *Gyroidina* and *Anomalinoides*.

The taxa confined to the assemblage from Meghalaya are: *Bathysiphon*, *Reophax*, *Spiroplectammina*, *Spiroplectinata*, *Astacolus*, *Frondicularia*, *Lagenia*, *Marginulina*, *Saracenaria*, *Guttulina*, *Bullopora*, *Fissurina*, *Guembeltria*, *Chilouguembelina*, *Neoguembelina*, *Planorotalites*, *Globoconusa*, *Nodosarella*, *Cassidella*, *Quadririmphina*, *Pilania*, *Osanguaria*, *Coles*, *Heterolipa*, *Karreria* and *Palsiphonina*.

**Simla Hills (Subathu Subgroup)**

Datta and Banerji (1972) recorded 48 species of calcareous smaller foraminifera from five biostratigraphic zones, worked out on the basis of the distribution of larger foraminifera, in the Subathu Subgroup of Simla Hills.

The common taxa in both assemblage are: *Lenticulina*, *Discorbs*, *Globorotalia* and *Cibicides*. The restricted taxa in the assemblage belong to Simla Hills are: *Quinqueloculina*, *Pyrgo*, *Triloculina*, *Bolivina*, *Valvulineria*, *Planulina*, *Loxostomum*, *Nonion*, *Alabamina* and *Anomalina*.

**Pondicherry, south India**

Samanta (1968) studied the Discocyclina-bearing Limestone of the Pondicherry area. He found that horizon contains abundant microfossils including several index planktonic foraminiferan species and a few Ostracodes.

The common taxa in the assemblage from Pondicherry (Gowda, 1964 and Samanta, 1968) and the present assemblage are: *Cibicides*, *Lenticulina*, *Globigerina*, *Globorotalia*. The taxa restricted to the assemblage from Pondicherry are: *Anomalina*, *Darbyella*, *Eponides*, *Parrella* and *Quinqueloculina*.

The difference of Indian assemblages with that of Pabdeh Formation of KabirKuh Anticline, Lurestan, Iran may be owing to the vast geographical separation of the two basins.
7-2: Biostratigraphic Zonation

As mentioned earlier, the Lower Tertiary sediments of western Rajasthan particularly in the Barmer basin are made up of Fatehgarh Formation followed by Barmer, Akli, Mataji Ka Dungar and Kapurdi Formations. In the Jaisalmer basin the equivalent sediments are comparatively deep water facies and represented by Sanu, Khuaila and Bandah Formations. All these sediments have been deposited in a very shallow marine conditions allowing the profound growth of animal and plant population. Hence, the succession can successfully be divided into the finer lithological intervals based on the relative preponderance of plant and animal fossils.

On the basis of spores and pollen assemblages and dinoflagellate taxa the Akli lignite of Barmer, Rajasthan has been differentiated into seven Spore-Pollen Zones, while the restricted ranges of certain dinoflagellates have permitted the subdivision of the lignite into four Dinoflagellate Zones.

The Sanu, Khuaila and Bandah formations are though poor in plant fossils but are abundant with foraminifera and ostracoda thereby indicating their accumulation under distinct marine conditions. Detail investigations carried out on the planktonic and benthic foraminifera as well as Ostracoda reveal that this exclusively marine succession of Jaisalmer basin can be distinguished into four Foraminiferal Zones. The Ostracods taxa found in these horizons indicate the differentiation of this sequence into two Ostracodes Zones.

Finally, the different types of biostratigraphic zones instituted on the basis of spores-pollen, dinoflagellates, foraminifera and Ostracoda have been compared with Indian as well as International Zones of these taxa established by the various workers.

Similarly, the Pabdeh Formation of Iran on the basis of a composite assemblage of spores-pollen grains and dinoflagellates has been differentiated into five Palynostratigraphic Zones and six Foraminiferal Zones including benthic and planktonic foraminifera. In this connection an attempt has been made to work out the biostratigraphic framework of planktonic foraminifera for their global correlation whereas the benthic forms have been utilized to find out the finer composition of each planktonic zone (Text Figure 28).

Unfortunately, the Ostracod taxa recovered here are only a few which have been illustrated in the range chart (Text Figure 27). As such their stratigraphic significance can be known after a detailed investigation.
7-2-1: Palynological Zonation of Akli lignite, Barmer, Rajasthan

The palynological zonation scheme proposed here for the Lower Tertiary sediments in western Rajasthan with reference to Akli lignite is based on the concept of “Assemblage Zone” outlined by Hedberg (1976). It is defined by the two palynomorph species which are restricted and dominant to abundant in the respective zones. The lower and upper boundaries of these zones are marked by the First Appearance Datum (FAD) and Last Appearance Datum (LAD). The palynozones are based on both spore/pollen and dinoflagellate cysts data (Text Figure 24).

7-2-1-1: Spore-Pollen Zones

Aklipollis indica-Matanomadhiasulcites maximus Assemblage Zone
Place of Occurrence: Girla Mine, Barmer, Rajasthan.
Lithology: Grey coloured carbonaceous shale and sandy shale
Lower contact: Not exposed
Upper contact: Basal Lignite
Restricted species: Aklipollis indica gen. et sp. nov., Matanomadhiasulcites maximus, Granulopunctatites indicus gen. et sp. nov., Involuitisporonites kutchensis and Leptolepidites major.
Remark: Matanomadhiasulcites giganticus, Spinizonocolpites baculatus, Cordosphaeridium inodes and Dandotiaspora plicata are the abundant elements of the assemblage.

Palaeomalvaceaeapollis rudis-Retitetradites nairii Assemblage Zone
Place of Occurrence: Girla Mine, Barmer, Rajasthan.
Lithology: Lignite
Lower contact: Grey coloured carbonaceous sandy shale underlying the basal lignite.
Upper contact: Carbonaceous shale overlying the basal lignite.

**Restricted species:** *Palaeomalvaceaepollis rudis, Retitetradites nairi, Spiniferites pseudofurcatus* and *Heterasphaeridium difficile*.

**Common species:** *Barsingsarpollenites spinosus gen. et sp. nov., Polysphaeridium subtile, Todisporites plicatus, Neocouperipollis brevispinosus, Nympheacidites indicus sp. nov., Kapurdi pollenites gemmatus, Spinotetrasyncolpites barmerensis gen. et sp. nov., Dandotiaspora pseudoauriculata, Matanomadhasulcites giganticus, Cyathidites australis, Duplibaculatepollis pentacolpites, Lycopodiumsporites speciosus and Pluricolumellatepollis pachyexinus.*

**Remark:** The common species found in significant percentage are *Dandotiaspora pseudoauriculata, Neocouperipollis brevispinosus* and *Kapurdi pollenites gemmatus*.

Schizaeoisporites eocenicus-Laricoidites magnus Assemblage Zone

**Place of Occurrence:** Girla Mine, Barmer, Rajasthan.

**Lithology:** Grey coloured carbonaceous; silty-sandy shale in lower part and lignite in upper part.

**Lower contact:** Basal Lignite

**Upper contact:** Carbonaceous shale overlying Lower Lignite band.

**Restricted species:** *Laricoidites magnus, Schizaeoisporites eocenicus, Schizaeoisporites indicus sp. nov., Tribrevicolporites eocenicus, Inaperturapollenites indicus sp. nov., Laevigatosporites lakienis, Ocimumpollenites indicus and Lycopodiumsporites palaecenicus.*

**Common species:** *Dandotiaspora plicata, Todisporites plicata, Araucariacites australis, Palmaepollenites plicatus, Neocouperipollis brevispinosus, Pluricolumellatepollis pachyexinus, Duplibaculatepollis pentacolpites, Spinizonocolpites baculatus, Sabalpollenites granulosus sp. nov., Dandotiaspora pseudoauriculata, Dandotiaspora dilata, Neocouperipollis duttae, Proxapertites assamicus, Cyathidites australis* and *Microforaminiferal linings.*

**Remark:** *Araucariacites australis, Pluricolumellatepollis pachyexinus, Duplibaculatepollis pentacolpites, Dandotiaspora dilata* and *Microforaminiferal linings* are found in significant numbers.

Barsingsarpollenites indicus-Acanthotricolpites bulbospinosus Assemblage Zone

**Place of Occurrence:** Girla Mine, Barmer, Rajasthan.

**Lithology:** Grey coloured carbonaceous sandy shale

**Lower contact:** Lower Lignite
Upper contact: Middle Lignite

Restricted species: Barsingsarpollenites indicus gen. et sp. nov., Acanthotricolpites bulbospinosus, Retiverrumonosulcites barmerensis, Trisyncolpites ramanujamii, Neocouperipollis granulatus, Neocouperipollis exsertus, Cibotidites kundvaensis and Leptodinium sp.

Common species: Dandotiaspora plicata, Neocouperipollis brevispinosus, Kapurdipollenites gemnatus, Retitetrabrevicolporites globatus, Lygodiumsporites pachyexinus, Cythidites australis, Matanomadhiasulcites kutchensis, Lycospora indica sp. nov., Sabalpollenites granulosus sp. nov., Spinizonocolpites echinatus, Simplibaculatepolpis bithnokensis and Microforaminiferal linings.

Remark: The common species found in significant number are: Kapurdipollenites gemnatus, Lygodiumsporites pachyexinus and Simplibaculatepolpis bithnokensis.

Jafarianpollis indica Assemblage Zone

Place of Occurrence: Girla Mine, Barmer, Rajasthan.

Lithology: Lignite

Lower contact: Grey-dark grey coloured carbonaceous sandy shale underlying the Middle Lignite.

Upper contact: Carbonaceous shale overlying the Middle Lignite.

Restricted species: Jafarianpollis indica gen. et sp. nov., Dandotiaspora telonata, Neocouperipollis kutchensis, Laricoidites punctatus, Dicotetradites reticulatus, Proxapertites microreticulatus and Retistephanocolpites flavatus.

Common species: Dandotiaspora plicata, Nymphaeacidites indicus sp. nov., Pluricolumellatepolpis pachyexinus, Simplibaculatepolpis bithnokensis, Duplibaculatepolpis pentacolpites, Spinizonocolpites baculatus, Dandotiaspora pseudoauriculata, Dandotiaspora dilata, Matanomadhiasulcites giganticus and Tribrevicolporites eocenicus.

Remark: Duplibaculatepolpis pentacolpites, Simplibaculatepolpis bithnokensis, Pluricolumellatepolpis pachyexinus, Nymphaeacidites indicus sp. nov. are found in significant numbers.

Palmaepollenites minor-Clavadiaporopollenites raneriensis Assemblage Zone

Place of Occurrence: Girla Mine, Barmer, Rajasthan.

Lithology: Grey-dark grey coloured carbonaceous silty shale


Lower contact: Middle Lignite
Upper contact: Upper Lignite

Restricted species: *Palmaepollenites minor* sp. nov. and *Clavadoripollenites raneriensis*.

Common species: *Spinizonocolpites echinatus*, *Spinizonocolpites baculatus*, *Arecipites matanomadhiansis*, *Kapurdipollenites gemmatus*, *Spinotetrasyncolpites barmnerensis* gen. et sp. nov., *Lycospora indica* sp. nov., *Operculodinium centrocarpum*, *Dandotiaspora pseudoauriculata*, *Neocouperipollis brevispinosus* and Microforaminiferal linings.

Remark: *Spinotetrasyncolpites barmnerensis* gen. et sp. nov., *Kapurdipollenites gemmatus* and Microforaminiferal linings are found in sufficient number.

**Gleichenioidites senonicus-Inapertosporites kedvesii Assemblage Zone**

Place of Occurrence: Girla Mine, Barmer, Rajasthan.

Lithology: Lignite

Lower contact: Carbonaceous shale underlying the Upper Lignite band.
Upper contact: Carbonaceous shale overlying the Upper Lignite layer.

Restricted species: *Gleichenioidites senonicus*, *Inapertosporites kedvesii*, *Savitrinia miocenica*, *Neocouperipollis achinatus* and *Inaperturapollenites* sp.

Common species: *Dandotiaspora dilata*, *Palmaepollenites plicatus*, *Cyathidites minor*, *Neocouperipollis duttae*, *Proxaperites microreticulatus*, *Dandotiaspora telonata*, *Dandotiaspora pseudoauriculata*, *Neocouperipollis brevispinosus*, *Matanomadhiasulcites kutchensis*, *Pseudonothofagidites cerebrus*, *Paleosantalaceaeptites minutus*, *Sabalpollenits indicus* sp. nov., *Proxaperites granulosus*, *Palmidites maximus*, *Dandotiaspora densicorpa*, *Duplicibaculatepollis pentacolpites*, *Arecipites matanomadhiansis*, *Sabalpollenites granulosus* sp. nov., *Lycozodiumsporites specious*, *Matanomadhiasulcites giganticus* and *Cordosphaeridium inodes*.

Remark: *Sabalpollenites granulosus*, *Dandotiaspora pseudoauriculata*, and *Dandotiaspora dilata* are found in significant percentage.

**7-2-1-2: Dinoflagellate Zones**

**Cordosphaeridium-Operculodinium Assemblage Zone**

Place of Occurrence: Girla Mine, Barmer, Rajasthan.

Lithology: Grey coloured carbonaceous sandy shale
Lower contact : Not exposed.
Upper contact : Basal Lignite layer.
Restricted species : *Cordosphaeridium fibrospinosum*, *Operculodinium israelium* and *Achomosphaera ramulifera*.
Common species : *Polysphaeridium subtile*, *Operculodinium centrocarpum* and *Cordosphaeridium inodes*.

**Remark** : This assemblage zone comparable with *Xenicodinium rugulatuin* Zone established by Hansen(1977) of Danian age and *Apectodinium hyperacanthum* Zone instituted by Caro(1973) for Late Palaeocene sediments of Northern Spain. The present assemblage compares closely with *Aklipollis indica-Matanomadhiasulcites maximus* Assemblage Zone proposed in the present work.

*Spiniferites pseudofurcatus-Heterasphaeridium difficile* Assemblage Zone

**Place of Occurrence** : Girla Mine, Barmer, Rajasthan.

**Lithology** : Lignite

Lower contact : Grey coloured carbonaceous sandy shale underlying the Basal Lignite layer.
Upper contact : Carbonaceous shale roofing the Basal Lignite.

Restricted species : *Spiniferites pseudofurcatus* and *Heterasphaeridium difficile*

Common species : *Polysphaeridium subtile*

**Remark** : The present assemblage is comparable with *Kisselovia reticulata* Zone (LC-3) established by Bujak(1980) of Early Eocene age in the London clay, England. This Assemblage Zone is also concomitant to *Palaeomalvaceae pollenis rudis- Retitetradites nairii* Assemblage Zone recognized in present work based on spores and pollen taxa.

*Leptodinium sp.* Assemblage Zone

**Place of Occurrence** : Girla Mine, Barmer, Rajasthan.

**Lithology** : Grey coloured carbonaceous silty-sandy shale in lower part and lignite in the upper part.

Lower contact : Basal Lignite
Upper contact : Carbonaceous shale overlying the Lower Lignite.

Restricted species : *Leptodinium sp.*
Remark: The present assemblage is comparable with Subzone VIIa instituted by Manum (1976) for Norwegian-Greenland Sea sediments of Early Eocene in age. Besides, this assemblage is also comparable with Schizaeoisporites eocenicus-Laricoidites magnus and Barsingsarpollenites indicus-Acanthotricolpites bulbospinosus Assemblage Zones proposed in the present work.

Cordosphaeridium inodes-Operculodinium centrocarpum Assemblage Zone

Place of Occurrence: Girla Mine, Barmer, Rajasthan

Lithology: Grey coloured carbonaceous shale and Middle and Upper Lignites.

Lower contact: Carbonaceous shale underlying the Middle Lignite.

Upper contact: Fuller’s earth overlying the Upper Lignite.

Abundant species: Cordosphaeridium inodes and Operculodinium centrocarpum

Remark: This assemblage zone is comparable with Jafarianpollis indica, Palmaepollenites minor-Clavadioporopollenites raneriensts and Gleicheniidites senonicus-Inapertisporites kedvesii Assemblage Zones proposed in the present study.

7-2-2: Foraminiferal Zonation of Lower Tertiary sediments, Jaisalmer, Rajasthan

(Tex Figure 25)

Turborotalia pseudobulloides-Planorotalites compressa Assemblage Zone

Place of Occurrence: Jaisalmer, Rajasthan

Lithology: Fine grained sandy limestone and calcareous sandstone

Lower contact: Fine grained sandstone underlying the succession.

Upper contact: Lower Pelecypoda Limestone Member overlying the sandy limestone.


Common species: Saudella cf. S. rugosa, Cibicides aknerianus, Cibicidoides sp. and Valvalabamina sp.
Remark: The present Assemblage Zone recovered from Lower Tertiary sediments of Jaisalmer basin is equivalent to Pla-P1d of Planktonic Standard Zones instituted by Berggren and Van Couvering (1974) of Palaeocene age.

Spiroloculina cf. Spiroloculina excavata Zone
Place of Occurrence: Jaisalmer, Rajasthan
Lithology: Argillaceous limestone and marl
Lower contact: Lower Pelecypoda Limestone underlying the argillaceous limestone and marl.
Upper contact: Limestone horizon capping the argillaceous limestone.
Restricted species: Spiroloculina cf. S. excavata
Common species: Saudella cf. S. rugosa, Assilina spp., Cibicides aknerianus, Cibicidoides sp. and Valvalabamina sp.
Remark: In the absence of a proper index taxon, the zone cannot be compared precisely with any standard zone.

Assilina spp. Zone
Place of Occurrence: Jaisalmer, Rajasthan
Lithology: Limestone and marl
Lower contact: Argillaceous limestone underlying limestone and marl.
Upper contact: Upper Pelecypoda Limestone following limestone and marl.
Restricted species: Assilina spp.
Remark: Precise affinity cannot be established in the absence of marker taxa.

Discocyclina spp.-Flusculina spp. Assemblage Zone
Place of Occurrence: Jaisalmer, Rajasthan
Lithology: Limestone and sandy limestone
Lower contact: Upper Pelecypoda Limestone underlying the limestone and sandy limestone.
Upper contact: Not developed
Restricted species: Discocyclina spp. And Flusculina sp.
EARLY-MIDDLE PALAEOCENE
LATE PALAEOCENE
EARLY EOCENE
MIDDLE EOCENE
LATE EOCENE
EARLY OLIGOCENE AGE

Outer Shelf-Upper Bathyal Environment

PABDEH FORMATION, KABIRKUH ANTICLINE, IRAN

Foraminiferal zones:
- Globigerina eugubina-Morozovella pseudobulloides-Morozovella trinidadensis Zone (P1a-P1d)
- Morozovella iehneri-Hantkenina spp. Zone
- Morozovella subbotinae-Acarinina soldadoensis angulosa Zone
- Morozovella Formosa gracilis-Anomaiinoides spp. Zone
- Anomalinoides sp.-Bulimina sp. Zone
- Proxapertites granulatus Zone
- Nodosaria spp.-Cibicides lobatulus Zone

Palynological standard zones:
- Spiniferites sp.-Laricoidites himalayensis Zone
- Dictyophyllidites zagrosensis-Tuberculma sp. Zone
- Rhombodinium draco Zone
- Homotryblium spp.-Operculodinium centrocarpum Zone

Text Figure 2: Biostratigraphic correlation of Lower Tertiary sediments of Lower Tertiary sediments of the Pabdeh Formation, Kabirkuh Anticline, Iran.
7-2-3: Ostracoda Zones

Krithe oryza-Paracypris spp. Assemblage Zone
Place of Occurrence: Jaisalmer, Rajasthan
Lithology: Sandy limestone, fine grained calcareous sandstone
Lower contact: Fine grained sandstone underlying the above horizon.
Upper contact: Lower Pelecypoda Limestone capping the succession.
Restricted species: *Krithe oryza*, *Paracypris ghoturfortensis* and *Paracypris sahui*.

Alocopocythere dattai-Cytherella sp. Assemblage Zone
Place of Occurrence: Jaisalmer, Rajasthan.
Lithology: Argillaceous limestone and marl.
Lower contact: Lower Pelecypoda Limestone underlying the argillaceous limestone and marl.
Upper contact: Limestone overlying the argillaceous limestone and marl.
Restricted species: *Cytherella cf. Cytherella sp.*, *Alocopocythere dattai*, *Alocopocythere rajasthanensis*, *Xestoleberis* *Xestoleberis* sp. and *Archicythereis* sp.
Remark: These two Ostracode Assemblage Zones are comparable with Zone I (*Alocopocythere gopinathkillaensis*-Paijenborchella bhatiae-Cytherella sindiquii Assemblage Zone) of Eocene age of Meghalaya instituted by Bhandari (1992).

Text Figure 23 depict the lithological and Palaeontological correlation of Lower Tertiary sediments of Barmer and Jaisalmer basins based on index microfossils taxa.

7-2-4: Palynological Zonation of Pabdeh Formation, Lurestan, Iran

The palynological zonation proposed here for the Pabdeh Formation from KabirKuh Anticline, Lurestan, Iran is based on the same concept that was followed for the biostratigraphic zonation of the Lower Tertiary sediments of western Rajasthan, India (Text Figure 26).

7-2-4-1: Palynological Zones
Proxapertites granulatus Assemblage Zone
Place of Occurrence: Darreh Shahr Section, Kabir Kuh Anticline, Lurestan, Iran
Lithology: Alternation of limestone and thin bedded argillaceous limestone
Lower contact: Lopha Limestone of Gurpi Formation
Upper contact: Purple shale
Restricted species: Proxapertites granulatus and Lejenuecysta hyaline.
Common species: Psilosphaera plicata and Aplanosporites robustus.

Homotryblium spp.-Operculodinium centrocarpum Assemblgae Zone
Place of Occurrence: Qaleh Darreh Section, Kabir Kuh Anticline, Lurestan, Iran.
Lithology: Purple shale with intercalation of argillaceous limestone
Lower contact: Alternation of limestone and thin bedded argillaceous limestone forming the Proxapertites granulatus Assemblage Zone
Upper contact: Lower Limestone of Pabdeh Formation
Restricted species: Triporopollenites exactus, Operculodinium centrocarpum, Hystrichokolpoma sp., Homotryblium pallidum, Cleistosphaeridium sp., Cleistosphaeridium brevispinosum and Hystrichosphaeridium heteracanthum.
Common species: Homotryblium tenuispinosum and Psilosphaera plicata.
Remark: The present Assemblage Zone is comparable with Homotryblium tenuispinosum-Hafniasphaera septata Zone instituted by Williams (1977), Eatonicysta ursulae Zone (LC-2) and Deflandre phosphoritica by Bujak (1980) of London clay Formation. These are of Early Eocene in age.

Rhombodinium draco Zone
Place of Occurrence: Sikan Section, Kabir Kuh Anticline, Lurestan, Iran.
Lithology: Lower Limestone, purple shale and argillaceous limestone
Lower contact: Purple shale with intercalations of argillaceous limestone
Upper contact: Alternation of shale and argillaceous limestone underlying the Upper Limestone
Restricted species: Rhombodinium draco, Odontochitina operculata and Matanomadhia indica.
Common species: Psilosphaera plicata, Aplanosporites robustus and Proxapertites assamicus.
Remark: The present Assemblage Zone is comparable with Rhombodinium draco Zone of Europe (England, Germany and Belgium) established by Costa and Downie (1976) emended by Bujak (1979) and Heteraulacacysta parosa Zone by Bujak (1980). This Assemblage Zone is of Middle Eocene in age.
Text Figure 27: Stratigraphic distribution and Foraminiferal Zonation of Pabdeh Formation, Kabir Kuh Anticline, Lurestan, Iran

**Palaeogene**
- **Early Eocene**
  - *P.11*: ?
  - *P.12*: ?
  - *P.13*: ?
  - *P.16*: ?
- **Middle Eocene**
  - *P.1*: ?
  - *P.2*: ?
  - *P.3*: ?
  - *P.4*: ?
- **Late Eocene**
  - *P.5*: ?
  - *P.6*: ?
  - *P.7*: ?
  - *P.8*: ?

**Recent**
- *P.9*: ?
- *P.10*: ?

**Foraminiferal Zone**
- *Upper Cretaceous-P3*
- *P.5*: ?
- *P.6*: ?
- *P.12*: ?
- *P.16*: ?

**Lithology**

**Foraminiferal Standard Zones**
Dictyophyllidites zagrosensis-Tuberculodinium sp. Assemblage Zone

Place of Occurrence: Sikan Section, KabirKuh Anticline, Lurestan, Iran.

Lithology: Upper Limestone and alternations of shale and argillaceous limestone

Lower contact: Lower Limestone

Upper contact: Alternation of shale and argillaceous limestone

Restricted species: Heterosphaeridium sp., Tuberculodinium sp., Polypodiisporites ornatus, Corrusporis iranica sp. nov., Chyrtosphaerdiathebaetica, Dictyophyllidites zagrosensis sp. nov. and Microplankton type.

Common species: Aplanosporites robustus, Psilosphaera plicata and Proxaperites assamicus

Spiniferites sp.-Laricoidites himalayensis Assemblage Zone

Place of Occurrence: Qaleh Darreh Section, KabirKuh Anticline, Lurestan, Iran.

Lithology: Alternation of shale and thin beds of argillaceous limestone

Lower contact: Upper Limestone

Upper contact: Thick bedded-Massive limestone of Asmari Formation

Restricted species: Spiniferites sp., Laricoidites himalayensis and Cyclonephelium compactum.

Common species: Corrusporis iranica sp. nov. and Homothyblium tenuispinosum.

Remark: The assemblage cited above can be correlated with the Zone V (Spiniferites mirabilis) instituted by Costa and Downie (1979) of Europe of Late Eocene age.

7-2-4-2: Foraminiferal Zonation of Pabdeh Formation, Lurestan, Iran (Text Fig 27)

Nodosaria spp.-Cibicides lobatulus Assemblage Zone

Place of Occurrence: KabirKuh Anticline, Lurestan, Iran.

Lithology: Alternation of limestone and thin bedded argillaceous limestone

Lower contact: Lopha Limestone of Gurpi Formation

Upper contact: Purple shale

Restricted species: Nodosaria affinis, Dentalina inornata, Neoflabellina jarvisi, Textularia gramen, Ellipsolinguina sp. and Cibicides lobatulus.

Common species: Tritaxia trilateral, Clavulina pacifica, Dorothia oxycona, Nodosario pyrula, Textularia laevigata and Cibicidina walli.
Remark: The common taxa found in significant numbers are *Tritaxia trilateral*, *Clavulina pacifica* and *Textularia laevigata*.

**Anomalinoides sp.-Bulimina sp. Assemblage Zone**

**Place of Occurrence**: Kabir Kuh Anticline, Lurestan, Iran.

**Lithology**: Purple shales with thin argillaceous limestone band.

**Lower contact**: Argillaceous limestone overlying the *Nodosaria* spp.-*Cibicides lobatulus Assemblage Zone*

**Upper contact**: Purple shale

**Restricted species**: *Bulimina pyrula*, *Discorbis cf. D. mira* and *Gyroidina soldanii*.

**Common species**: *Ammodiscoides cf. Ammodiscoides sp.*, *Tritaxia trilateral*, *Dorothia oxycona*, *Textularia laevigata*, *Anomalinoides rubiginosus* and *Brizalina variables*.

Remark: The benthic taxa recorded as *Nodosaria* spp.-*Cibicides lobatulus* and *Anomalinoides sp.-Bulimina sp. Assemblage Zones* are comparable with those reported by Pandey (1978) from Palaeocene sediments of Meghalaya, India. These are commonly reported from the upper part of *Globotruncanina stuartiformis Zone-Planorotalites pusilla pusilla Zone* (P1-P3) on the basis of Planktonic Foraminifera established by Berggren and Van Couvering (1974). These assemblages belong to Early to Middle Palaeocene in age.

**Morozovella formosa gracilis-Anomalinoides spp. Assemblage Zone**

**Place of Occurrence**: Kabir Kuh Anticline, Lurestan, Iran.

**Lithology**: Purple shale

**Lower contact**: Approximately lower part of the purple shale horizon

**Upper contact**: Upper part of the purple shale

**Restricted species**: *Lenticulina costata*, *Marginulinopsis sp.*, *Anomalinoides semicribatus*, *Morozovella marginidentata* and *Morozovella formosa gracilis*.

**Common species**: *Ammodiscoides cf. Ammodiscoides sp.*, *Tritaxia trilateral*, *Dorothia oxycona*, *Percultazonaria sp.*, *Spiroplectinella cf. S. carinata*, *Textularia laevigata*, *Anomalinoides rubiginosus*, *Anomalinoides capitatus*, *Cibicidoides dutemplei*, *Morozovella aragonensis* and *Globigerina ouachitaensis*.

Remark: The common taxa found in significant number are *Spiroplectinella cf. S. carinata*, *Globigerina ouachitaensis* and *Morozovella formosa gracilis*.
The Marker taxa recorded in the assemblage of present study show a close similarity with 
*Morozovella velascoensis* Zone (P5) instituted by Berggren and Van Couvering (1974). It is 
considered to be Late Palaeocene in age.

**Morozovella subbotinae-Acarinina soldadoensis granulose Assemblage Zone**

**Place of Occurrence**: KabirKuh Anticline, Lurestan, Iran.

**Lithology**: Alternation of grey calcareous shale argillaceous limestone.

**Lower contact**: Upper part of purple shale

**Upper contact**: Grey calcareous shale resting over the abovementioned purple shale

**Restricted species**: *Nodosaria simplex*, *Nodosaria radiata*, *Cibicidoides sp.*, *Globorotalia wilcoxensis*, *Morozovella spinulosa*, *Morozovella subbotinae*, *Morozovella aequa*, *Glohigerina patagonica* and *Acarinina soldadoensis angulosa*.


**Remark**: The planktonic foraminifera outnumber the other elements of the assemblage. The marker taxa recorded in the abovementioned assemblage is comparable with *Morozovella edgari-Morozovella subbotinae-Morozovella aragonensis* (P6-P8) Standard Planktonic Foraminifera Zones of Berggren and Van Couvering (1974). These are also equivalent to *Globorotalia rex* Zone instituted by Bolli (1957a). All of these Zones are of Early Eocene in age.

**Morozovella lehneri-Hantkenina spp. Assemblage Zone**

**Place of Occurrence**: KabirKuh Anticline, Lurestan, Iran.

**Lithology**: Alternation of argillaceous limestone and grey coloured shale.

**Lower contact**: Grey coloured calcareous shale.

**Upper contact**: Lower Limestone.

**Restricted species**: *Karrerulina sp.*, *Vaginulinopsis sp.*, *Bulimina cf. B. costata*, *Cibicides ungerianus*, *Morozovella lehneri*, *Acarinina bullbrooki*, *Hantkenina brevispina* and *Hantkenina alabamensis*.

**Common species**: *Tritaxia trilateral*, *Dorothia oxycona*, *Lenticulina inornata*, *Cibicidoides dutemplei* and *Glohigerina linaperta*.
Text Figure 26: Stratigraphic distribution and Palynological Zonation of Kahir Kuh Anticline, Lurestan, Iran

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Palaeocene</th>
<th>Early Eocene</th>
<th>Middle Eocene</th>
<th>Late Eocene</th>
<th>Early Oligocene</th>
</tr>
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<tbody>
<tr>
<td><strong>Palaeeocoe</strong></td>
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</tr>
<tr>
<td><strong>Early Eocene</strong></td>
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<tr>
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<tr>
<td><strong>Early Oligocene</strong></td>
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</tr>
</tbody>
</table>

**Early Eocene**
- *Dictyophyllidites zagrosensis* - Tuberculina Zone
- *Heterophragium mirabilis* - Pusillides Zone

**Middle Eocene**
- *Dictyophyllidites zagrosensis* - Tuberculina Zone
- *Heterophragium mirabilis* - Pusillides Zone

**Late Eocene**
- *Dictyophyllidites zagrosensis* - Tuberculina Zone
- *Heterophragium mirabilis* - Pusillides Zone

**Early Oligocene**
- *Dictyophyllidites zagrosensis* - Tuberculina Zone
- *Heterophragium mirabilis* - Pusillides Zone

**Palynological Zones**
- *Cyclonephelium compagnum*
- *Ixiricoidites himalayensis*
- *Spiniferites sp.*
- *Triporopollenites exactus*
Remark: The planktic foraminiferal assemblage recorded here can be compared with Morozovella lehneri (P12) and Orbulinoides beckmanni (P13) Zones of standard scheme proposed by Blow (1979) and Berggren and Van Couvering (1974). On the basis of marker taxa, a Middle Eocene age is proposed here for this assemblage.

Globigerina yeguaensis-Cibicidoides eocaenus Assemblage Zone

Place of Occurrence: Kabir Kuh Anticline, Lurestan, Iran.

Lithology: Upper Limestone and alternation of shale and argillaceous limestone

Lower contact: Lower Limestone.

Upper contact: Asmari Limestone.

Restricted species: Ammobaculites sp., Cibicidoides eocaenus, Globigerina yeguaensis and Globigerina cf. G. praebulloides.

Common species: Lenticulina inornata, Cibicidoides dutemplei, Globigerina officinalis and Brizalina variabilis.

Remark: The marker taxa in this assemblage show a close similarity with Turborotalia cerroazulensis (P16-P17) Zone of Berggren and Van Couvering (1974). The Late Eocene-Early Oligocene age is considered for this Zone.

Text Figure 15 shows the lithological and palaeontological correlation of Pabdeh Formation of Kabir Kuh Anticline, Lurestan, Iran based on microfossils data.

Text Figure 28 depicts the biostratigraphic zonation of Pabdeh Formation of Iran and their equivalent Lower Tertiary sediments of western Rajasthan based on different fossil assemblages.
Text Figure 25: Stratigraphic distribution and biozonation of foraminifera and Ostracoda taxa of Lower Tertiary sediments, Jaisalmer, Rajasthan

<table>
<thead>
<tr>
<th>SANU FORMATION</th>
<th>KHUAILA FORMATION</th>
<th>BANDAH FORMATION</th>
</tr>
</thead>
<tbody>
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</table>

**LITHOLOGY**

<table>
<thead>
<tr>
<th>Saudella cf. S. rugosa</th>
<th>Cibicides okarianus</th>
<th>Cibicides indahus</th>
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<td>Spiroloculina cf. S. excavata</td>
<td>Ammodiscus cf. A. sp.</td>
<td>Triloculina sp.</td>
</tr>
<tr>
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<td>Haplophragmoides cf. H. scitulus</td>
<td>Haplophragmoides cf. H. agrawali</td>
</tr>
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<td>Turborotalia sp.</td>
<td>Turborotalia frigus</td>
<td>Globigerina collecta</td>
</tr>
<tr>
<td>Planorotalites compressus</td>
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**FORAMINIFERAL ZONE**

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**OSTRACODA ZONE**

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**INDIAN OSTRACODA ZONE**

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<th>age</th>
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**OSTRACODEN**

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**BIOSTRATIGRAPHIC ZONES**

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<th>P. bhatia</th>
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Text Figure 24: Stratigraphic distribution and Palynological Zonation of Akli Lignite, Banner, Rajasthan.
Text Figure 23: Lithological and Palaeontological correlation of sediments in Western Rajasthan

BIOSTRATIGRAPHICAL ZONES

Eocene

MIOCENE

LATE TERTIARY

CECONE

COMPOSITE SECTION

STRATIGRAPHIC ZONES

COMPOSITE SECTION (Jaisalmer Basin)

SPOROPollen ZONE
(Damar Basin)

DINOCYTHET FILTER

AGE

SOUTH OF KHAULA VILLAGE

KHAYILLA-HABUR ROAD

BANDAH VILLAGE

AKLI,BARMER

LIMESTONE

SHEIL BED

LIGNITE

ARGILL LIMESTONE

SANDY LIME

SANDSTONE

FULLER S EARTH

Text Figure 23: Lithological and Palaeontological correlation of stratigraphic sections of Lower Tertiary sediments in Western Rajasthan
Text Figure 15: Lithological and Palaeontological correlation of stratigraphic
Text Figure 9: Simplified table of Rock Units in South-West Iran