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CENOZOIC LITHOSTRATIGRAPHY OF THE JAISALMER BASIN, RAJASTHAN

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ABSTRACT

The Jaisalmer Basin represents the eastern shelf part of the Indus Basin and belongs to a major tectonic province known as "West Rajasthan Shelf" which hosts a number of sedimentary basins viz. Barmer, Jaisalmer and Bikaner-Nagaur. The present study is confined to the detailed Cenozoic lithostratigrphy of the Jaisalmer Basin. Availability of voluminous subsurface data generated in ONGC's exploratory wells has facilitated the above study.

The Cenozoic lithounits are well exposed in southeastern part of the basin. Based on the study of surface and subsurface sections, the entire Cenozoic sequence is divisible into four formations which are Sanu, Khuiala, Bandah and Shumar. The maximum development of these formations of the order of more than 2100m is recorded in deeper part of the basin in the Shahgarh area. One major unconformity between Tertiary and Quaternary sequences along with disconformities/paraconformities has been mapped. Similarly, non-extension of marine Palaeocene in the outcropping area, thinning and erosion of Tertiary-Quaternary formations in shoreward areas and facies changes in basinward area have been observed.

The surface and subsurface lithofacies could be tied up precisely based on adequate biostratigraphic control, and lithostratigraphy has been standardized. Stratotypes of all formations have been established and their depositional characters along with faunal and floral elements and their stratigraphic relationship with succeeding formations have been discussed.

Keywords: Jaisalmer Basin, Rajasthan, Cenozoic, Lithostratigraphy, larger feraminifera

INTRODUCTION

The Tertiary sequence of the Jaisalmer Basin is of a great importance in view of the discovery of encouraging hydrocarbon prospects in the equivalent sequence in the adjoining Indus Basin. The Jaisalmer Basin is the eastern extension of the shelf part of the Indus basin and represents a more or less central part of the tectonic province known as "West Rajasthan Shelf" which is located to the west of Aravalli ranges and hosts a number of sedimentary Basins which are Barmer, Jaisalmer and Bikaner-Nagaur. The Jaisalmer basin occupies an area of 42000 sq.km. and most of its western part is covered by desert sands and sand-dunes. Tectonically, it is divisible into four geotectonic blocks which from north to south area are Kishangarh sub-basin, Jaisalmer-Mari high, Shahgarh sub-basin and Miajlar sub-basin (Fig.1).

Cenozoic rocks are mainly exposed along the Eocene Escarpment which forms a persistent and prominent feature in the vast expanse of Thar or great Indian desert. These exposed rocks represent the north western extremity of the outcropping area and go beneath the sand mantle in further north western direction. The arenaceous to calcareous facies, cyclic sedimentation of limestone and shale with frequent foraminifera-bearing beds are some of the important features of Tertiary sediments.

In the west of the outcropping area, ONGC is carrying out the exploration programme since last four and half decades and has drilled so far 74 wells in almost all geotectonic blocks except Kishangarh sub-basin which falls under the jurisdiction of Oil India Ltd. Cenozoic litho-column has been encountered in almost all wells. In general, the wells have been drilled up to Mesozoic (Jurassic) but a few have encompassed the full sequence comprising basement, Palaeozoic, Mesozoic and Cenozoic rocks. The maximum thickness of the Cenozoic sequence is of the order of more than 2100 m in the basinward Shahgarh area.

The present paper incorporates the evaluated and standardised Cenozoic lithostratigraphy of the Jaisalmer Basin. The surface and subsurface sedimentary sequence of this basin could be tied up precisely on the basis of lithological correlation with adequate biostratigraphic control. Unconformities and disconformities/paraconformities have been recognised. Stratotypes of all formations have been established and described, indicating lithology, depositional character, faunal and floral elements, stratigraphic relationship of their lower and upper boundaries and intrabasinal correlation along with lateral lithofacies variations. Moreover, the index species of larger foraminifera from the Tertiary formations having biozonal importance and mappable in the entire basin, have been illustrated. This has also been considered relevant as these have not been published so far.

TECTONIC SETTING

Tectonic setting of the Jaisalmer Basin has adequately been discussed by the author in his previous paper, while dealing with Mesozoic lithostratigraphy of the basin (Singh, 2006). The basin has extensively been covered by various geoscientific surveys. ONGC and GSI have jointly carried out geological surveys in 1957. Bose (1956) of GSI conducted gravity magnetic survey in the Jaisalmer and Barmer areas. Aeromagnetic surveys were conducted in 1956 under the aegis of Colombo plan to cover the Western Rajasthan Shelf (Agocs, 1957). The aeromagnetic and ground gravity magnetic data provided important leads to have better understanding of the basin architecture. It has been possible to trace surface structural features including faults and lineaments to the subcrop area. The Bouguer anomaly data clearly define the highs and lows distributed over the western Rajasthan. Devikot-Pokrán-Nachna high delimits the Jaisalmer Basin in the east. Fatehgarh fault isolates it from the Barmer Basin in the southern part and basement ridges bound the basin in the southwest. However, the basin opens up towards north west and merges with the Indus Shelf.

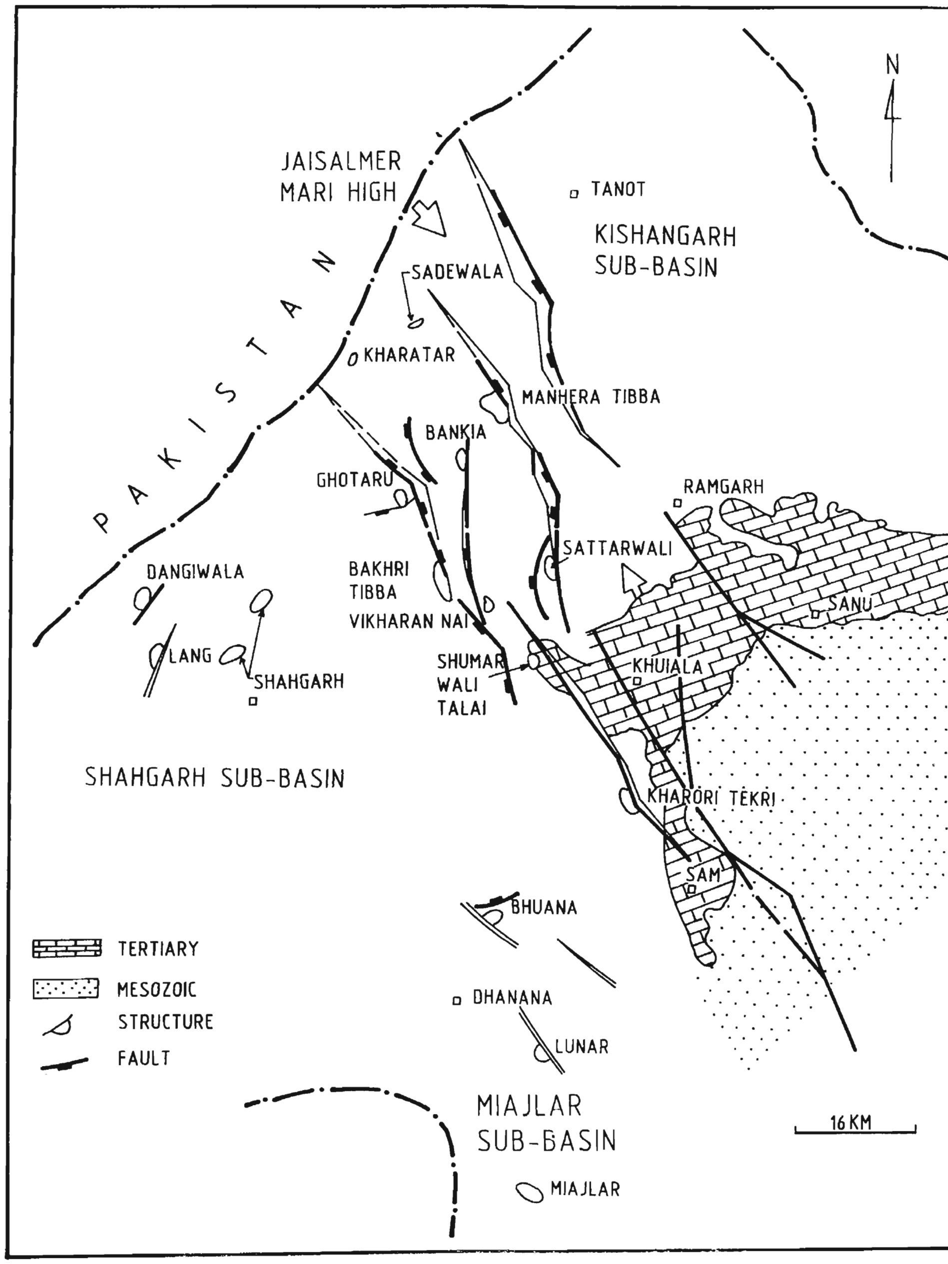


Fig. 1. Location map of the Jaisalmer Basin.

The Jaisalmer Basin is a pericratonic basin and is located on the north western slope of the Indian platform. Moreover, it represents the westerly dipping eastern flank of the Indus Shelf. Dasgupta and Mahesh Chandra (1978) presented the first account of tectonic setting of the Jaisalmer Basin. Subsequently, Datta (1983) also presented the structural analysis of the basin. Structural style of the basin bas been controlled by master faults (Mishra and Sharma, 1986). Its maximum effect is limited between Ramgarh and Kanoi master faults which are very extensive and can be traced from outcrop to subsurface. The structural trends in the Jaisalmer Basin are mainly NNW-SSE or NW-SE corresponding to the Dharwarian trend. Besides, a subsidiary NE-SW trend corresponding to the Aravalli ranges also exists.

As already indicated, the Jaisalmer Basin is differentiated from north to south into four geotectonic blocks. The Kishangarh sub-basin is a part of north westerly homoclinally gentle dipping shelf with NE-SW depositional strike, the Jaisalmer-Mari High is not a simple upwarp in the basement affecting overlying sediments. This high is a present-day gravity high feature located along the shoulder zone of Kanoi fault and is attributed to upthrusting and wrench faulting. It is rather a zone of lifted blocks. The Shahgarh sub-basin is deepest depression and is less disturbed having NNW-SSE trending faults while structurally simpler Miajlar sub-basin is located in southern extremity of the basin.

A major uplift of the axial belt gave rise to a prominent hiatus ranging in age from Maastrichtian to Danian (Upper Cretaceous to Lower Palaeocene). This hiatus not only indicates non-deposition but also considerable erosion of the Cretaceous sequence along the basin margin and even on the basinal highs (Rahman, 1963). The relief of the structures was accentuated in the post-Cretaceous, i.e. after the deposition of the Parh Formation. It is inferred that strike-slip movement dominated in the basin at the end of Mesozoic syntaxial to the formation of Cambay rift which has structural manifestation towards NW through the Sanchor-Barmer basins up to the Ramgarh-Kanoi graben.

LITHOSTRATIGRAPHY

As mentioned earlier, a major uplift of the axial belt gave rise to a prominent hiatus ranging in age from Upper Cretaceous to Lower Palaeocene and brought an end to Mesozoic marine cycle. In the outcropping area of the Jaisalmer Basin, the Early Cretaceous (Aptian) sediments of the Habur Formation are overlain by the Palaeocene sediments (Sanu Formation) with a pronounced unconformity involving an appreciable hiatus of approximately 47 million years. This, however, decreases basinward where the Parh Formation of Coniacian age is overlain by the Sanu Formation of Thanetian age as a result of which Santonian, Campanian, Maastrichtian and Danian stages seem to be missing. This indicates a hiatus of about 15 million years (Singh, 2003). The Tertiary formations, namely the Sanu, Khuiala and Bandah got deposited after this major break. The first major marine transgression engulfed the Jaisalmer Basin during Thanetian (upper Palaeocene). A phase of igneous activity started in the early Palaeocene in the Barmer Basin and instability caused thereby brought about the most widespread lower marine transgression that swept the Kutch, Sanchor, Barmer, Jaisalmer and Bikaner-Nagaur basins and even up to the Potwar Basin (Dasgupta, 1974).

The earlier studies on the systematic geological mapping of the Jaisalmer area, are those by Blanford (1876), Oldham (1886), Latouche (1902) and Allison (1938 in Arkell, 1956). This was followed by the studies of Swaminath *et al.* (1959), Narayanan *et al.* (1961), Narayanan (1964), Willm (1964), Dasgupta (1974) and Singh (1984). Besides, the basin has also been adequately covered by geophysical surveys by ONGC in order to understand the subsurface stratigraphic set up and structural features.

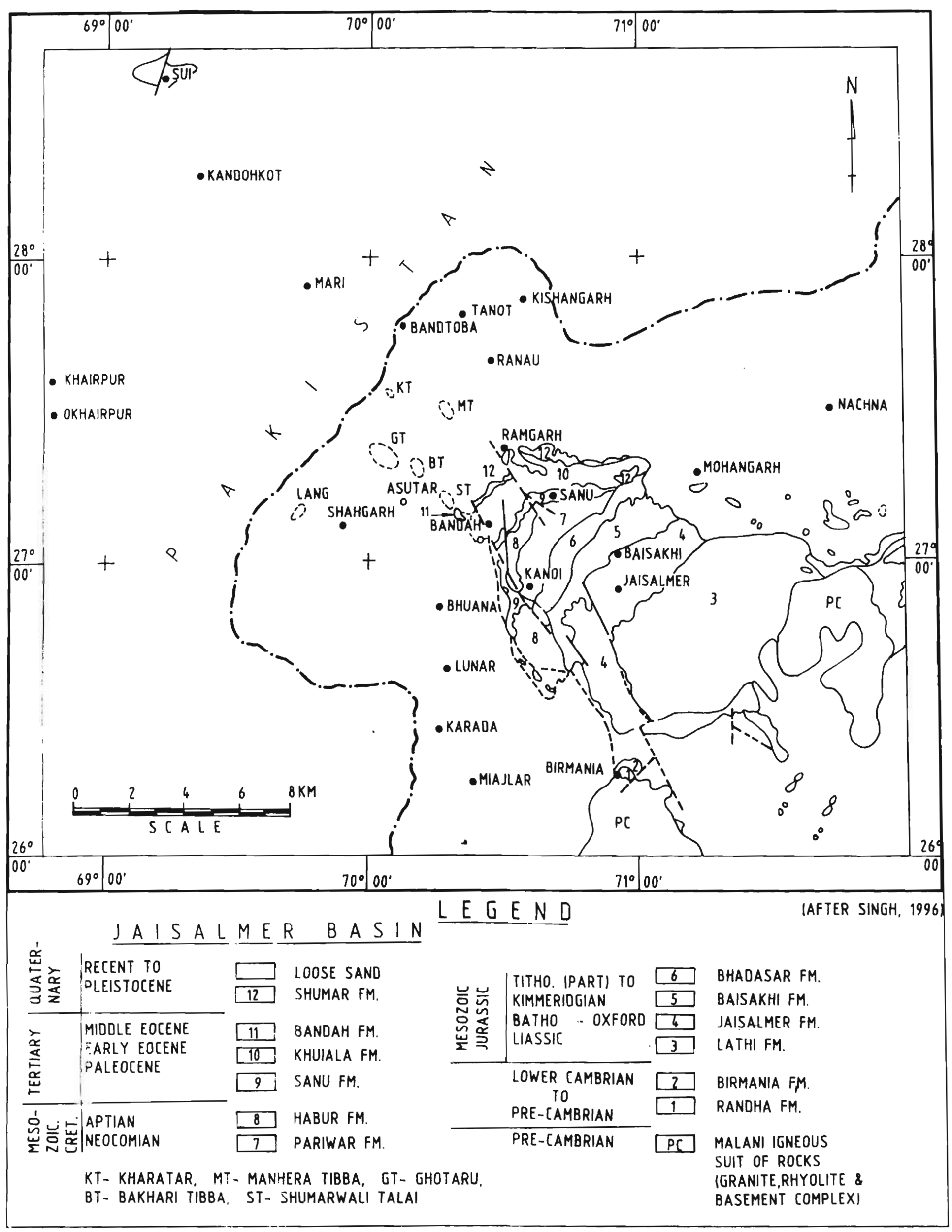


Fig. 2. Geological map of the Jaisalmer Basin, Rajasthan.

The Tertiary-Quaternary outcrops are well exposed in the northern and western extremity of the Jaisalmer district around Khuiala Bandah, Sanu and Ramgarh villages (Fig. 2). The maximum development of lithofacies is observed in deeper parts of the basin in subsurface sections but some of these do not extend to the surface. The author presented the updated Mesozoic-Tertiary stratigraphy of the basin, while discussing its biostratigraphy in detail (Singh, 1996). The stratigraphic column of the exposed sequence of Cenozoic formations along with their thicknesses, age and brief lithology is given in Fig. 3.

The Jaisalmer Basin is under active exploration and 74 wells have so far been drilled by ONGC covering all the geotectonic blocks barring Kishangarh Sub-basin which has been explored by Oil India Ltd. A voluminous data on the Tertiary sequences has been generated. The subsurface stratigraphy of the basin has been worked out by a number of geoscientists of ONGC. The contributions made by Sigal (1965, 1967a, 1967b), Sigal *et al.* (1970, 1971), Sigal and Singh (1980), Mehrotra and Singh (1968), Mathur and Mathur (1968), Dasgupta (1975), Lukose (1974, 1977) and Singh (1969, 1976, 1982, 1984, 1996, 2003) are noteworthy and have helped in evaluation of the straigraphy of the basin substantially. Compilation of Mishra *et al.* (1993) presented a composite picture for the first time and same description of the formations was included in a compilation entitled 'Stratigraphy of Indian Petroliferous Basins' by Pandey and Dave (1998) without adequate diagrams, fossil illustrations and sequential presentation. The updated generalised subsurface stratigraphy is given in figure 4. Moreover, the lithologic correlation of the subsurface formations along EEN-WWS is also given to show the lateral behavior of different formations and unconformities (Fig. 5).

Cenozoic lithostratigraphy has been worked out in accordance with the guidelines given by the International Subcommission on Stratigraphic Classification (1976). Adequate biostratigraphic control has helped in evaluation of the lithostratigraphy. Popular nomenclature has been retained, and formalisation of stratotypes of each formation attempted. Due to non-availability of definite type localities in respect of the formations in the existing literature, the selection of lectostratotype was considered. In the low dipping (3° to 5°) and poorly exposed Jaisalmer area, it is not possible to encounter the entire section of a particular formation at one place and hence two to three type localities have been taken into account to reconstruct the entire section. Besides, such type localities were essentially considered which included lower and upper limits of the formation (boundary stratotype). Under this broad frame work, description of the Cenozoic formations is given as below :

SANU FORMATION

Nomenclature : Authors; Dasgupta, Dhar, Mehta (1973). The formation was first designated by Dasgupta *et al.* (1973) after village Sanu. Narayanan *et al.* (1961) described this lithounit as "Upper Habur bed" which was later refuted by Willm (1964) and Dasgupta *et al.* (1974). Willm (1964) included this lithounit under the Pariwar Formation. Dasgupta *et al.* (1974) mapped this unit as Sanu Formation of Paleocene age. Singh (1984) subdivided this formation into two members based on his studies of subsurface sections and finalised their nomenclature as Mohammad Dhani Member and Kharatar Members in correlation with the surface exposures. He observed that only lower Mohammad Dhani Member is exposed.

Type area and other reference sections: Typical section of the formation is exposed in Pariwar hill located in the west of Pariwar village. The entire exposed section of the formation could be brought to record by integrating two localities, namely Mohammad-Ki-Dhani and Sam Nala Section (Singh, 1984). Kharatar and Lang wells are taken as reference wells for describing the formation in subsurface. A maximum thickness of 20 m has been reported by Dasgupta *et al.* (1973) around Pariwar village. In the subsurface, it is 670 m in Shahgarh sub-basin.

Lower boundary: Lower boundary is a major unconformity involving considerable hiatus between Mesozoic and Tertiary. In outcrops, it overlies the Pariwar Formation in the north-eastern areas whereas in south western part it overlies the Habur Formation. In the subsurface, it overlies the Parh Formation in basinward areas and the Goru Formation in the shoreward areas.

Upper boundary: The upper contact with the overlying Khuiala Formation is conformable in the subsurface, whereas in outcrops it is unconformable due to absence of overlying Kharatar Member as a consequence of strong overlap.

Lithology: The formation is composed of reddish brown to unconsolidated, current-bedded sandstone (Fig.6). At Mohammad Dhani area, its good section is exposed. The lower part comprises ocherous yellow to dark brown and reddish black-coloured, coarse-to-fine grained moderately hard to friable, cross-bedded sandstone. This grades upwards into light pink, argillaceous, silty sandstone having fine to silt-sized, occasionally, medium-grained quartz grains. In the subsurface, particularly in the Kharatar well section which has been considered as a reference well, the formation comprises medium-to-coarse grained, friable sandstone, argillaceous and glauconitic in uppermost part. This is overlain by argillaceous limestone with intercalations of shale and thin streaks of lignite. It is divisible into two members.

Mohammad Dhani Member: It is a thick sequence of sandstone which is dominantly medium-to coarse-grained, friable, clean and moderately sorted. At the base, the sandstone is argillaceous, medium grained with layers of chocolate brown clay. The sandstone in the upper part is argillaceous, fine grained with streaks of lignite intercalations and grey fissile shale.

Kharatar Member: It comprises greenish grey, fine- to coarse-grained argillaceous, slightly calcareous sandstone with coquinoidal layer in the lower part. This is followed by argillaceous, light greenish grey, glauconitic limestone intercalated with marl. The upper part is represented by dark grey to black fissile shale and interbeds of sandstone. Sandstone is light grey, medium- to coarse-grained with streaks of lignite. The top of the member is marked by chocolate brown slightly silty shale/clay. Singh (1984) analyzed in detail the lithological succession of the Sanu Formation in the subsurface and indicated a persistent sandy/silty, glauconitic clay at the base of the formation.

Age and depositional environment: In outcrops, the formation is devoid of microfauna but in the subsurface the upper member, i.e. Kharatar Member has yielded a fairly rich microfauna. Both planktic and benthnic foraminifera occur in this sequence. The lower Mohammad Dhani Member shows marine influence at its top in the basinward areas. Sigal *et al.* (1971), Singh (1976, 1984) and Singh and Sharma (1991) have reported rich foraminiferal assemblage from the Kharatar

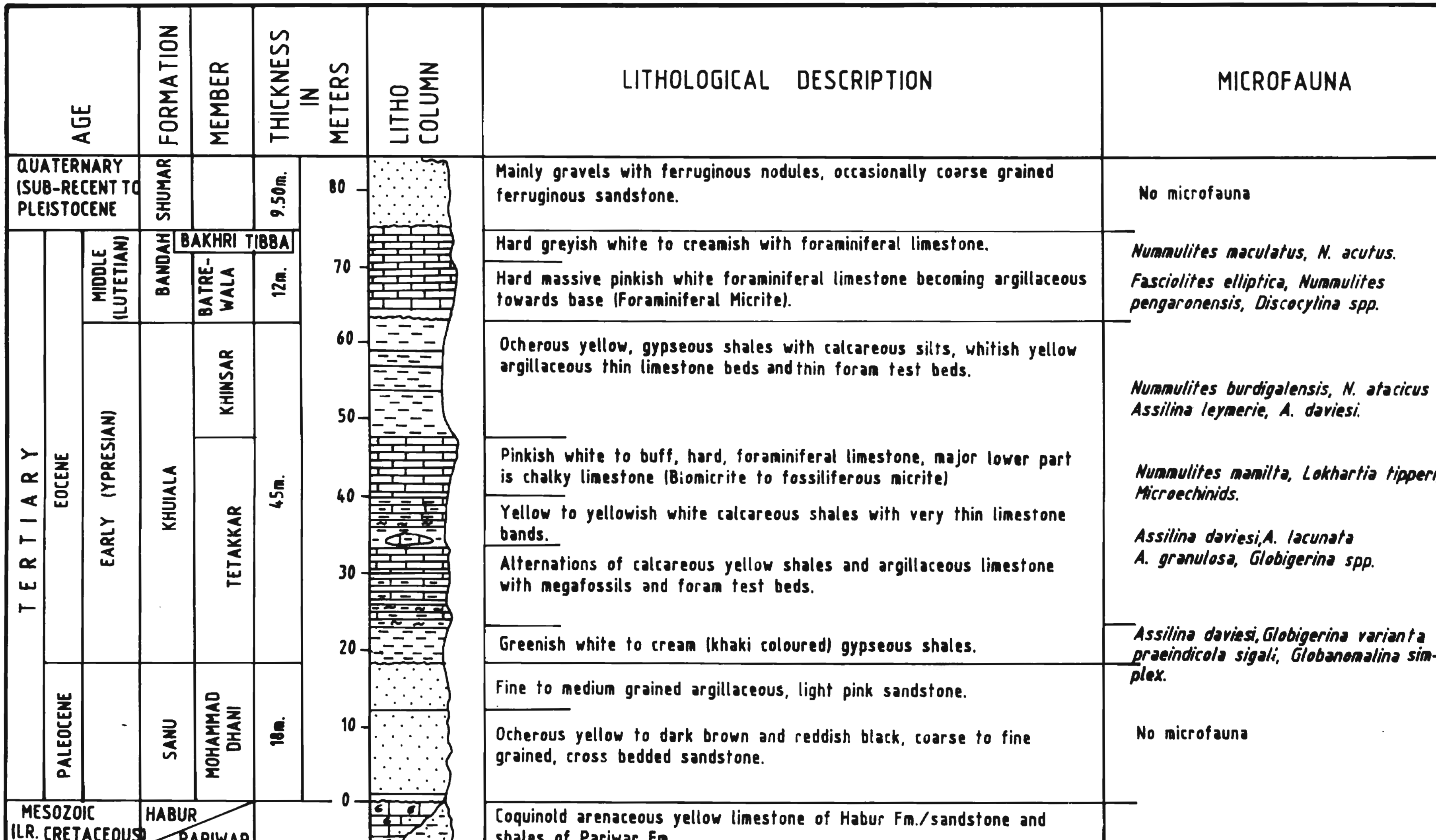


Fig.3. Generalised Cenozoic stratigraphy of the Jaisalmer Basin (Surface).

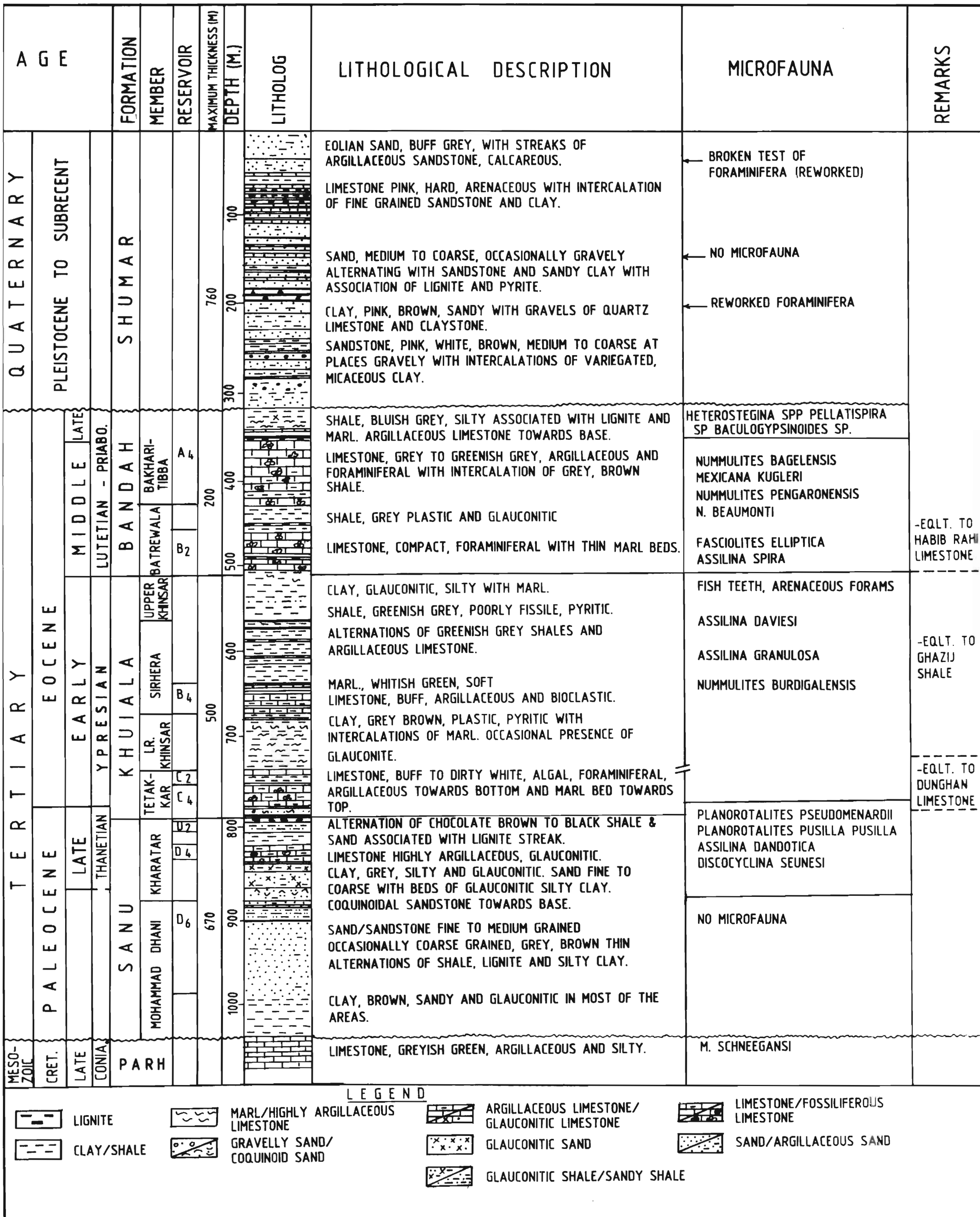


Fig.4. Generalised Cenozoic stratigraphy of the Jaisalmer Basin (Subsurface).

Member. However, Singh (2003) has critically analyzed the biostratigraphy of the Jaisalmer Basin and has indicated that three biostratigraphic zones of global status such as *Planorotalites pusilla pusilla, P. Pseudomenardii* and *Morozovella velascoensis/Assilina dandotica* have been recognized and have been dated as P 3 to P 6A on planktic scale, i.e. upper Palaeocene (Thanetian). The age of lower member is therefore inconclusive, however, it is also inferred

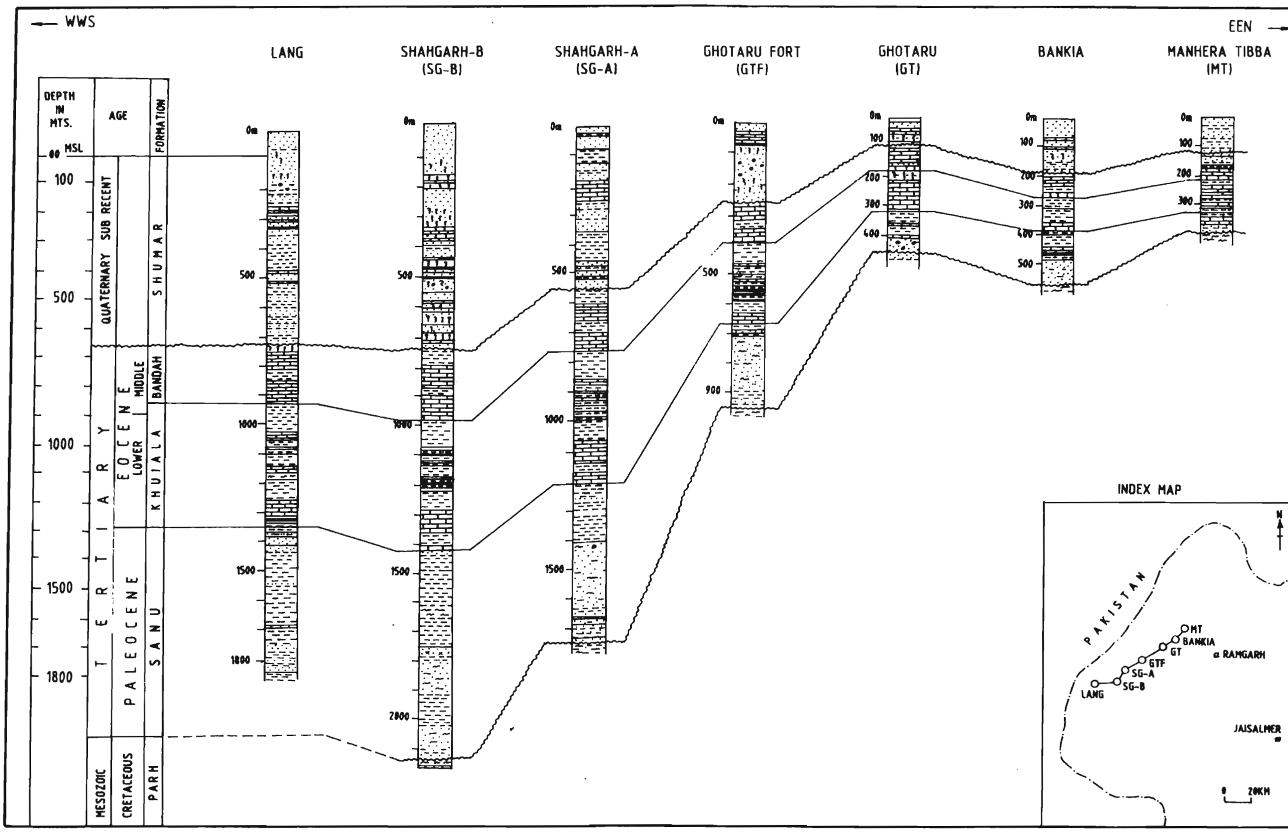


Fig.5. Subsurface lithologic correlation of the Tertiary sequence in the Jaisalmer Basin.

to be Palaeocene on its stratigraphic position. *Assilina dandotica* is generally taken to mark the top of Palaeocene in the subsurface sequence. This larger benthic forminifera along with overlying early Eocene benthic foraminifera and sporocarps of the algae Dasycladaceae is illustrated in Fig. 6.

The presence of highly argillaceous, friable calcareous sandstone or bluish grey, pyritic, silty clays at the base of the Sanu Formation in the subsurface indicates a continental environment with little marine influence. The upper part of formation represented by argillaceous limestone, glauconitic sandstone with intercalated shale and marl consisting of keeled planktic foraminifera with intervening benthic foraminifera rich layers indicate a marine environment ranging from inner to outer shelf regimes.

Correlation and regional lithological variation: The sediments of the Sanu Formation are quite persistent throughout the basin which is evident with earlier referred profile (Fig. 5). In outcrops, the formation is represented only by sandstone facies whereas in the subsurface a marine sequence of limestone and marl develops over this clastic sequence. The lower sandstone (Mohammad Dhani Member) shows abrupt variations in thickness as noticed in the wells of Manhera Tibba structure. This suggests an uneven topography at the end of Mesozoic with highs and lows. Laterally, the Mohammad Dhani Member shows an increase in argillaceous content from the basin margin to the basinal part. The basal sandy clays of the member which does not exceed 15 m in wells located on Jaisalmer-Mari High, has appreciable thickness in the Lang well. The Kharatar Member representing marine facies of alternating limestone and marl becomes quite argillaceous in the Lang area and mainly shows marly facies. Laterally, it is restricted only to the subsurface and does not crop out anywhere. The formation is exposed around Pariwar village and extends further in to southwest around Sanu, Serawa and Habur villages and to the northeast of Ramgarh-Biprasar fault. Beyond this fault the formation tapers to a narrow strip in the south where it is overlain by the Khuiala Formation. In the subsurface, it is extensive throughout the Jaisalmer basin with gradual reduction in thickness towards the east.

KHUIALA FORMATION

Nomenclature : Author; Narayanan, (1959). The Eocene limestone beds were first mapped by Oldham (1886), who named them as "Nummulitic limestone beds". Ghosh (1952) and Swaminath *et al.* (1959) followed the same. Dasgupta *et al.* (1958) differentiated these beds into two lithounits; lower and upper based on their litho association. Narayanan (1959) formally introduced the Khuiala Formation for the lower litho unit of Dasgupta (1974) after the village Khuiala. He further classified this formation into six units which are 1) Gypseous clay/ shale 2) *Assilina* bed 3) Shell limestone 4) Fragmental limestone 5) White to yellow chalk and 6) Te-Takkar limestone. Willm (1964) followed Narayanan's (1959) classification. Again Dasgupta (1975) divided Khuiala Formation in four members, which from base to top are; Khuiala Scarp or Basal Member, Sirhera Member, Te-Takkar Member and Hingola Member. Singh (1984) redefined the exposed Khuiala Formation while correlating with subsurface sequence. He placed upper limit of the formation at the top of alternations of bentonitic clays, silts and thin beds of fragmental limestone which Narayanan (1964) included in the lower part of Bandah Formation. Singh

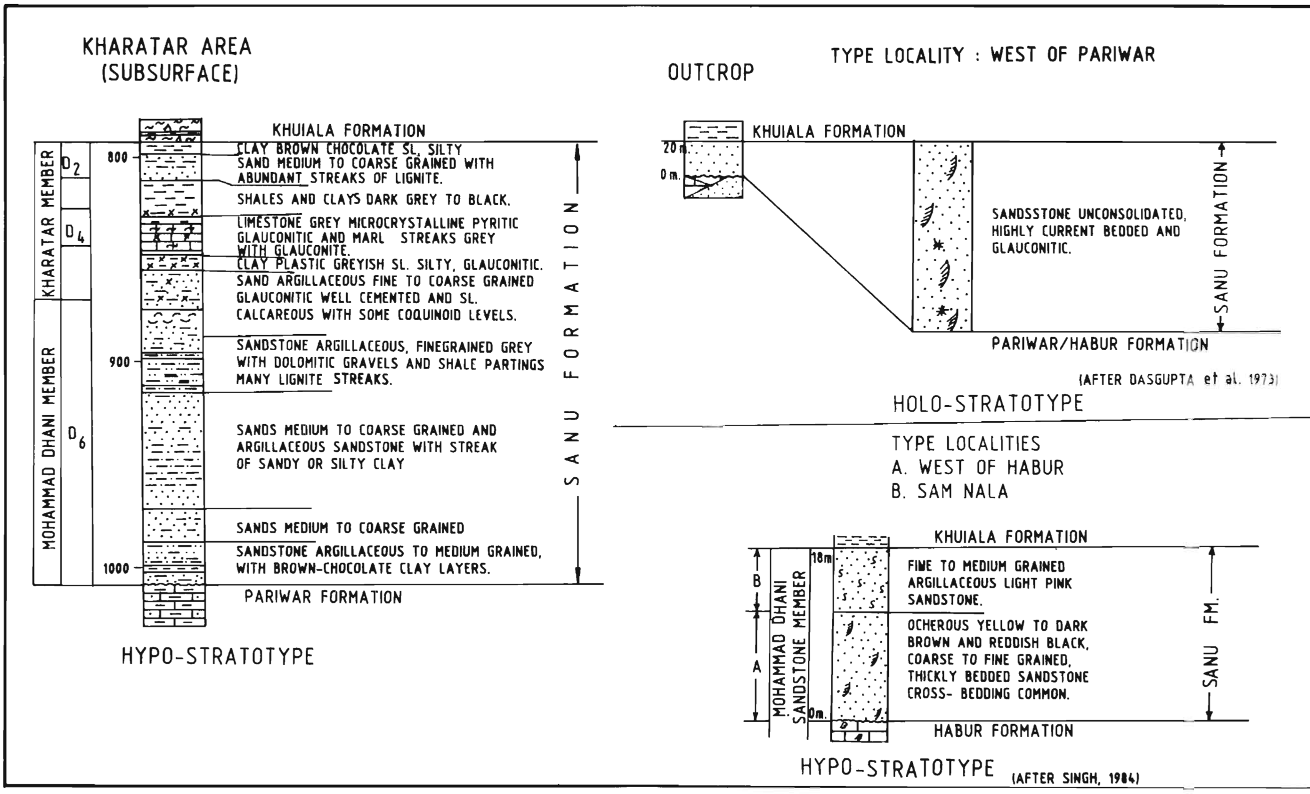


Fig. 6. Stratotype of Sanu Formation.

(1984) also subdivided the exposed Khuiala Formation into two members, namely, Te-Takkar Limestone and Khinsar Shale. In the subsurface, the Tertiary Formations were described as the Ranikot, Laki and Kirthar formations. Dasgupta (1974) extended the Sanu, Khuiala and Bandah formations in place of above mentioned names. Misra *et al.* (1993) followed Singh's (1984) classification but observed that an argilloaceous limestone sequence intervening the Khinsar shales had additionally developed in the basinward areas of the Jaisalmer Basin and hence they indicated four members; Te-Takkar, Lower Khinsar, Sirhera and Upper Khinsar for the subsurface sections.

Type area and other reference sections: Te-Takkar scarp located near west of Mohammad-Ki-Dhani. The complete section of the Khuiala Formation is not exposed at one place. It has therefore been erected after considering two type localities Te-Takkar and Khinsar. In the subsurface, the Kharatar and Lang well sections have been taken as reference sections. Narayanan *et al.* (1961) estimated its thickness around 30 m in the type area. Dasgupta (1975) indicated 100 m sequence which seems to be conjectural. Singh (1984) has indicated 45 m. In the subsurface, the minimum and maximum thicknesses have been recorded as 78 m and 505 m in Lunar and Dangiwala wells respectively.

Lower Boundary: The formation disconformably overlies the Sanu Formation in the exposed area. However, in the subsurface the contact is conformable.

Upper Boundary: In the surface section the upper contact with the Bandah Formation is disconformable. In the subsurface, no disconformity is noticed, although a short break at its upper contact with the Bandah Formation is observed in shallower part which dies down in basinward areas.

Lithology: Narayanan *et al.* (1961) has classified the Khuiala Formation into six beds as already mentioned. In outcrops, the formation comprises dominantly lower carbonate unit exposed at Te-Takkar scarp and upper shale unit exposed near Khinsar (Fig.7). Based on two distinct lithological variation the formation has been divided into the following two members (Singh, 1984) which are ;

Te-Takkar Member: The lower part comprises alternations of highly argillaceous yellow limestone, foraminiferal bed and thin shale/clay beds, while its upper part is composed of pinkish white to buff, soft chalky as well as hard compact limestone studded with larger forminifera. Petrographically, it is described as biomicrite.

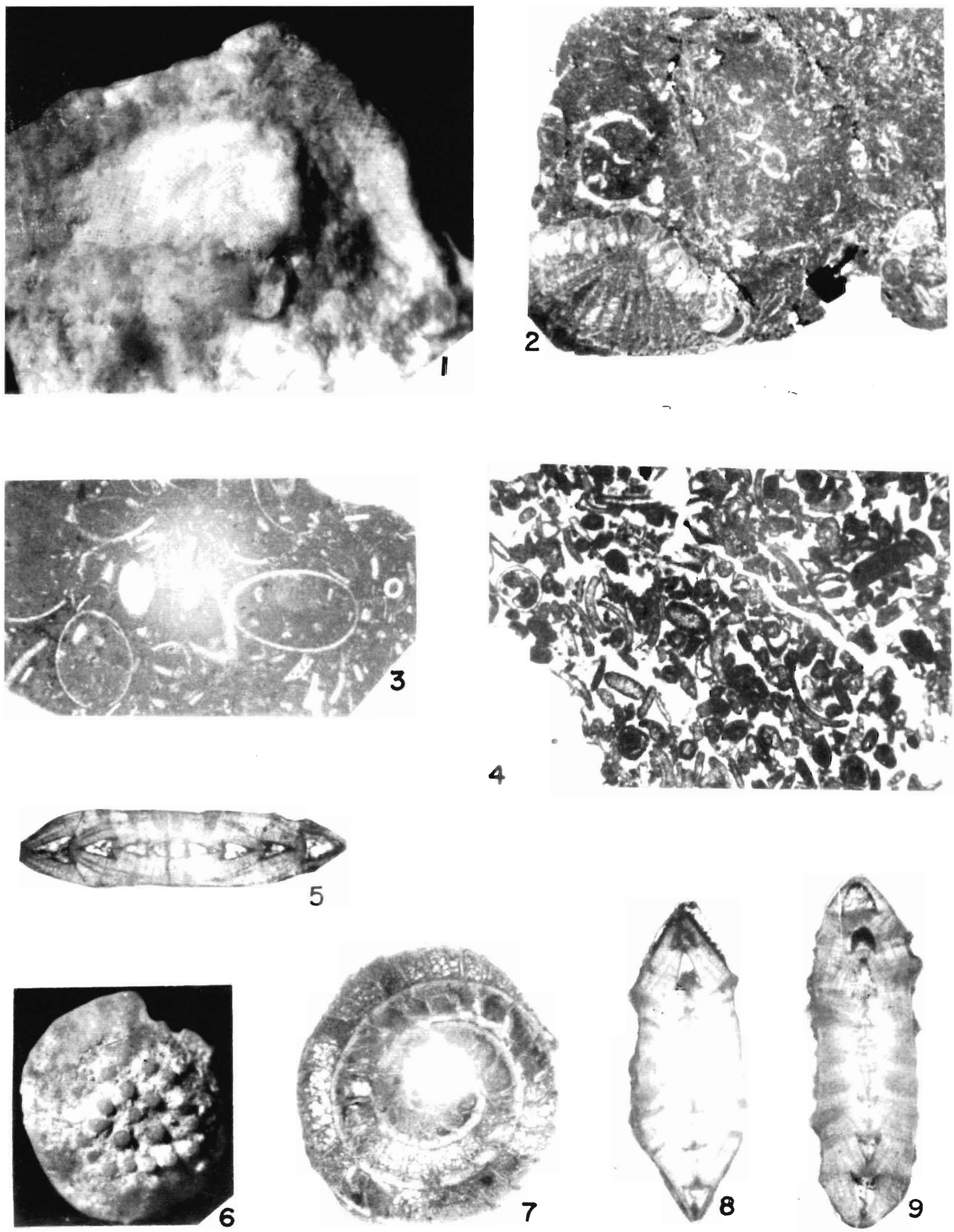
Khinsar Member: It is mainly represented by ocherous

EXPLANATION OF PLATE I

1. ***Orbitolites complanatus*** Lamarck, lower to middle Eocene. The broken pieces of the species are embedded in Tetakkar rock fragement of Bakhri Tibba Well section, X 14.5
2. Tetakkar rock section from Bakhri Tibba well section having ***Dictyoconoides flemengi*** X 16; early Lower Eocene (Ypresian).
3. Tetakkar rock section from Bakhri Tibba well section including ovoidal bodies (sporocarps of algae Dasycladaceae), X 19, lower Eocene.
4. Tetakkar rock section from Bakhri Tibba well section with algal filaments and pieces of ***Orbitolites complanatus*** X 14.

5-9. ***Assilna dandotica*** Davies, late Palaeocene, Loc. Bakhri Tibba well section. 5, 8-9 : Axial sections, 5, X 22.5, 8, X 18 and 9, X 23. 6 : External view X 14; 7: Equatorial section X 16 Specimens 5 to 9 belong to megalosphaeric generation.

Plate I



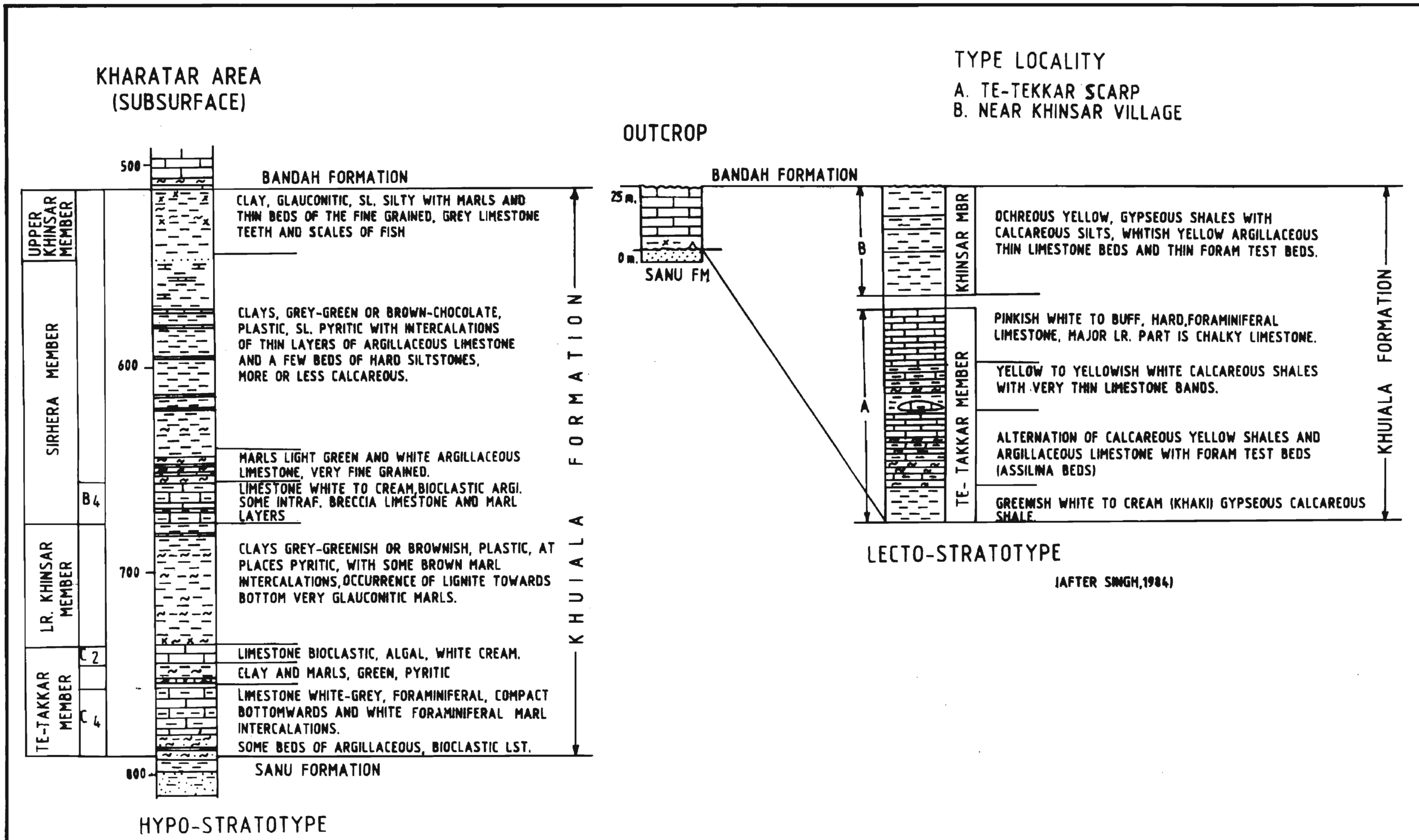


Fig. 7. Stratotype of the Khuiala Formation

yellow, gypseous shale with calcareous silt, rare argillaceous thin limestone bed and foram test bed.

In the subsurface particularly in the Kharatar well section which has been taken as a reference well, the formation is divisible into four members, namely, Te-Takkar, Lower Khinsar, Sirhera and Upper Khinsar. An additional development of a sequence having alternations of argillaceous limestone and shale interbedded with the Khinsar Member in the basinward areas is responsible for such differentiation, otherwise no major difference exists in lithological associations between surface and subsurface sections. Similar situation has been observed in the further basinward area in Lang well.

Age and depositional environment: The formation is richly fossiliferous both in the surface and subsurface sections. The foraminiferal assemblage recorded from the exposed formation is dominated by larger benthic foraminifera whereas subsurface sediments have sheltered planktic foraminifera also. Sigal *et al.* (1971) and Singh (1976, 1984, 1996) recorded the classic foraminiferal assemblage of lower Eocene. *Assilina* dominate the assemblage in outcrops. Two biostratigraphic zones, namely *Assilina granulosa-Fasciolites globosa* and *Assilina daviesi* have been recognized. In the subsurface secions, an increase in foraminiferal frequency and diversity is noticed. In addition to the above, *Morozovella formosa* planktic zone has developed within *Assilina daviesi* zone in the lower the Khinsar Member. Not only that, in the basinward areas *Planorotalites pseudomenardii* zone also falls in the basal part of the Khuiala Formation. Considering the above faunal assemblages a late Palaeocene to lower Eocene age in the basinward areas and lower Eocene (Ypresian) age in the shoreward areas including the outcropping areas has been assigned to this formation. *Assilina granulosa, Assilina daviesi, Assilina lacunata, Nummulites mamilla, Nummulites burdigalensis; Nummulites irregularis* are the classic fossils of lower Eocene (Ypresian). Besides, the biostratigraphic zones mappable in the subsurface (shoreward areas) and outcropping areas have also been established based on above larger foraminifera. These have been illustrated in plates II to VI.

The litho-association of limestone, shale and marl and dominance of larger foraminifera in the exposed area suggest that the sediments were deposited in an inner-neritic environment. In the subsurface, the rise in bathymetry is noticed in the lower part of the shale sequence with the presence of *Assilina* spp and sporadic occurrence of planktics such as *Globigerina* spp. and *Planorotalites* spp. An inner to middle shelf environment is envisaged.

Correlation and regional lithological variation: The formation is quite persistent and very well correlatable throughout the basin (Fig. 5). The lower and upper boundaries are marked by sharp changes in lithology. It is exposed along a 16 km wide belt extending from southeast of Khuiala to north-north-east up to Jiyadesar (Narayanan *et al.*, 1961) and beyond. However, Dasgupta (1975) mentioned that this formation is exposed along the scarp sections, more or less continuously over a distance of 100 km from southwest to northeastern part of the basin. In the subsurface, this formation has been encountered in all the wells drilled so far in the Jaisalmer Basin and gradually becomes more argillaceous in the basinward areas particularly in Shahgarh where the limestone sequences have become shaly.

BANDAH FORMATION

Nomenclature: Author; Narayanan, (1959). The formation was first proposed by Narayanan (1959) as "Bandah Formation" after village Bandah with its type section south of Bandah. He informally subdivided it into four beds including shale sequence of Lower Eocene at its base which was equated with the Ghajiz shales (Pakistan). Willm (1964) followed Narayanan (1959) but subdivided the formation into two, i.e. lower part and upper part and recognised the upper part as the Bakhri Tibba Limestone Member. Verdier *et al.* (1967) described "Kirthar Formation" in the subsurface and followed the nomenclature of Willm (1964) for the Upper Member and designated the lower limestone sequence as "Habib Rahi Limestone Member". Dasgupta (1975) did not accept the name "Kirthar Formation" in sub-surface and extended the nomenclature of Narayanan (1964) on the basis of its correlation and lithological similarities but agreed for the subdivisions proposed in subsurface by Verdier *et al.* (1967). Subsequently, Singh (1984) mapped a limestone sequence at Batrewala Tibba and renamed the lower Habib Rahi Limestone Member as the Batrewala Limestone Member. He also redefined the lower limit of the formation and placed it at the top of shale sequence (Khinsar Shale Member) rather than at its base (Narayanan, 1959).

Type area and other reference sections: Exposure south of Bandah Village. The complete section of the exposed Bandah Formation is not available at one place. This has therefore been erected on two type localities which are: Batrewala Tibba and Shumarwali Talai. In the subsurface, the Kharatar well has been taken as a reference well. In the exposures, a maximum thickness of 25 m has been recorded by Narayanan *et al.* (1961). In the subsurface, the thickness of 208 m is recorded from Dangiwala well and 8 m in Sattarwali well. In the Shahgarh sub-basin, it shows maximum development.

Lower Boundary: In outcrops, the formation has a disconformable contact with the underlying Khuiala Formation. The boundary is marked between the massive bioclastic limestone of the Bandah Formation and the sandy shales of underlying Khuiala Formation. In the subsurface, it is placed between the limestone of the Bandah Formation and the calcareous, sandy shales of the Khuiala Formation. The latter has yielded fish teeth, ossicles and arenaceous foraminifera in wells located on Jaisalmer-Mari High.

Upper Boundary: The upper boundary is marked by a pronounced unconformity throughout the basin. It is overlain by the Sub-Recent Shumar Formation.

Lithology: The formation generally comprises bentonitic clays argillaceous limestone and chalky to crystalline limestone sequence as per Narayanan *et al.* (1961) but it was revised by Singh (1984). The formation comprises in general a foraminiferal limestone sequence which has been subdivided into two members, namely the Batrewala Limestone and the Bakhri Tibba Limestone (Fig. 8).

Batrewala Limestone Member: It is represented by hard, massive, pinkish white foraminiferal limestone which becomes argillaceous towards base. The rock is studded with mega invertebrates, e.g., echinoids (Srivastava and Mathur, 1996) and large-sized *Nummulites* sp. *Assilina* sp, *Discocyclina* sp and *Fasciolites* sp which can be seen and identified even with the naked eyes.

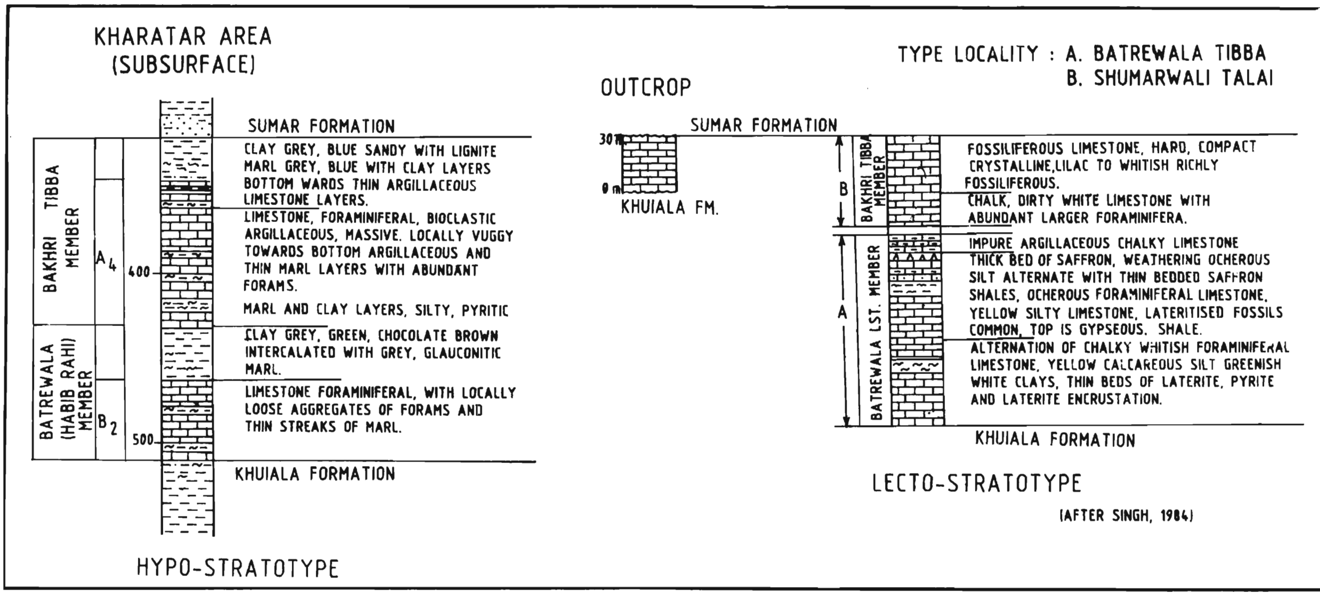


Fig. 8. Stratotype of the Bandah Formation.

Bakhri Tibba Limestone Member: This member comprises hard greyish white to creamish white foraminiferal limestone and contains large-sized, saddle-shaped *Discocyclina* sp. The limestone is more dense compared to the underlying member.

In the subsurface, the above members are separated from each other by grey to bluish grey, soft and sandy clay. In the basinward areas, an additional layer of bluish grey plastic clays intercalated with marl has developed on the topmost part of the Bakhri Tibba Limestone Member.

Age and depositional environment: The formation representing mainly a carbonate sequence has yielded a very rich foraminiferal assemblage both in the surface and subsurface sections. Larger benthics particularly *Nummulites* and *Discocyclina* flourished in this carbonate sequence. Three biostratigraphic zones, namely *Assilina spira-Fasciolites elliptica, Nummulites bagelensis* and *N. fabianii-Baculogypsinoides* sp. of middle–late Eocene have been recognized (Singh, 1984). At the sites of deeper bathymetry, a good diversity of characteristic middle Eocene planktic foraminifera is observed and the *Orbulinoides beckmanni* zone equivalent to P 13 on planktic scale is established. Based on above zonal assemblages, the Lutetian to Priabonian (middle to upper Eocene) age has been assigned to the Bandah Formation. *Assilina* dominates the scene during early Eocene, whereas *Nummulites* chiefly flourished in great number during middle Eocene. *Nummulities bagelensis, Nummulites pengaronensis, Nummulites beaumonti, Nummulites maculatus* are common index fossils of the middle Eocene, whereas *Fasciolites (Fasciolites) elliptica, Fasciolites (Flosculina) elliptica, Assilina spira, Assilina papillata* and *Assilina subpapillata* define the lower part of middle Eocene sequence. Besides, *Dictyoconoides cooki* and number of the species of *Discocyclina* are the diagnostic foraminifera of this sequence. In view of this, the above foraminifera have been illustrated in Plates VII to XII.

Presence of foraminiferal limestone, greenish grey clays and glauconitic marl in association with the planktic assemblage is suggestive of a marine shelf environment ranging from inner to middle shelf regime.

Correlation and regional lithological variation: The formation shows excellent correlation and persistency in EES-WWS profile (Fig. 5). Though it is finely correlatable, it is totally absent towards east and south eastern part particularly in the Lunar well. There is a gradual thickening towards the west and northwest (Kharatar area) of the basin. The formation is exposed south of Bandah and extends towards north and northeast up to Biprasar where it abutts against the older Khuiala rocks separated by the Jiyadesar-Biprasar fault. Only the lower part of the formation is exposed towards the Biprasar area. In the subsurface, it is extensive throughout the basin except in the eastern and south-eastern part where it shows effect of erosion. Laterally, there is no major lithological variation except, the thickening of the marl and clay beds towards the basinal parts which intervene as well as overlie the limestone sequence.

SHUMAR FORMATION

Nomenclature : Authors; Narayanan, *et al*. (1961). The Quaternary sequence was mapped originally by Dasgupta *et al.* (1958) as "Sub-recent Formation". Narayanan *et al*. (1961) were first to propose this sequence as "Shumar Formation" by grouping together the conglomerate and lateritic sequences

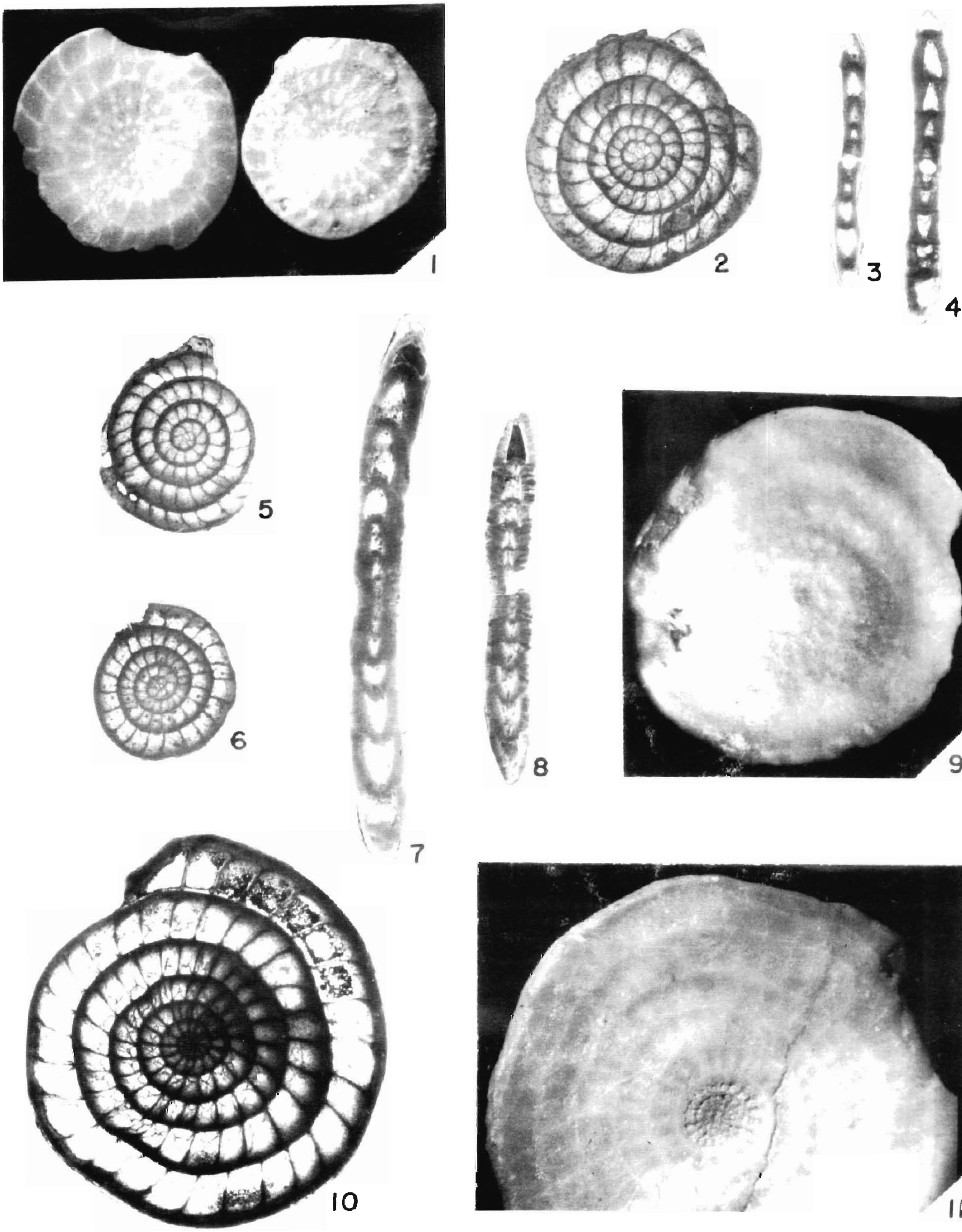
EXPLANATION OF PLATE II

1-6. ***Assilina leymerie*** (D' Archiac and Haime) early Eocene, Loc. Phulonwali Talai. 1 : External view X 10;
2, 5-6 : Equatorial sections 2, X 12, 5 & 6, X 7.
3-4 : Axial sections, both X 11.
All specimens belong to megalosphaeric generation.

7-11. ***Assilina granulosa*** (D' Archiac), early Eocene, Loc. Phulonwali Talai.
7-8 : Axial sections 7, X 10, 8, X 8.5 ; 9 : External view, X 7.5
10 : Equatorial section, X 12.5 ; 11 : External view, X 7
All specimens belong to microsphaeric generation.

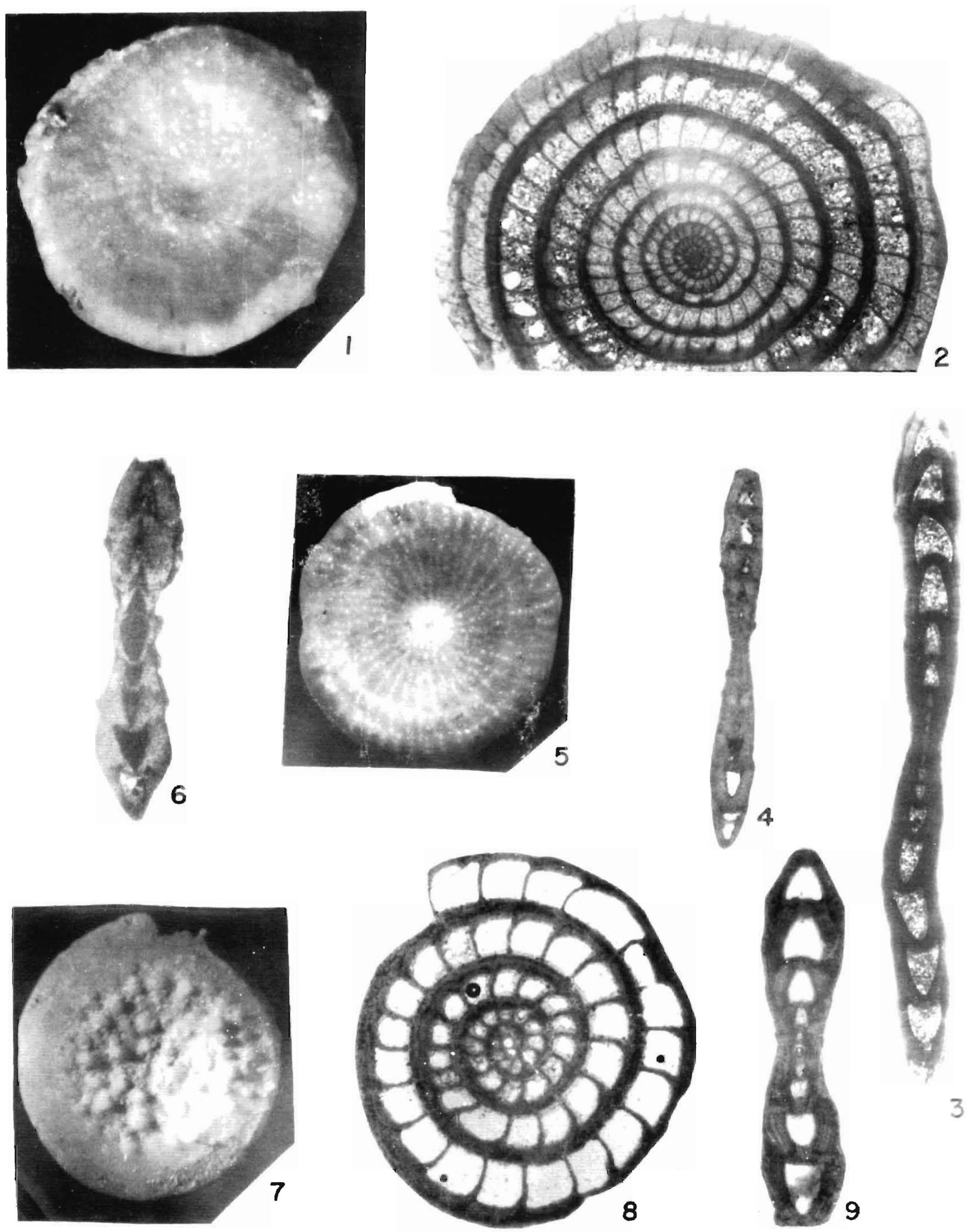
Journal of the Palaeontological Society of India
Volume, 52(2), December 2007

Plate II



Journal of the Palaeontological Society of India
Volume, 52(2), December 2007

Plate III



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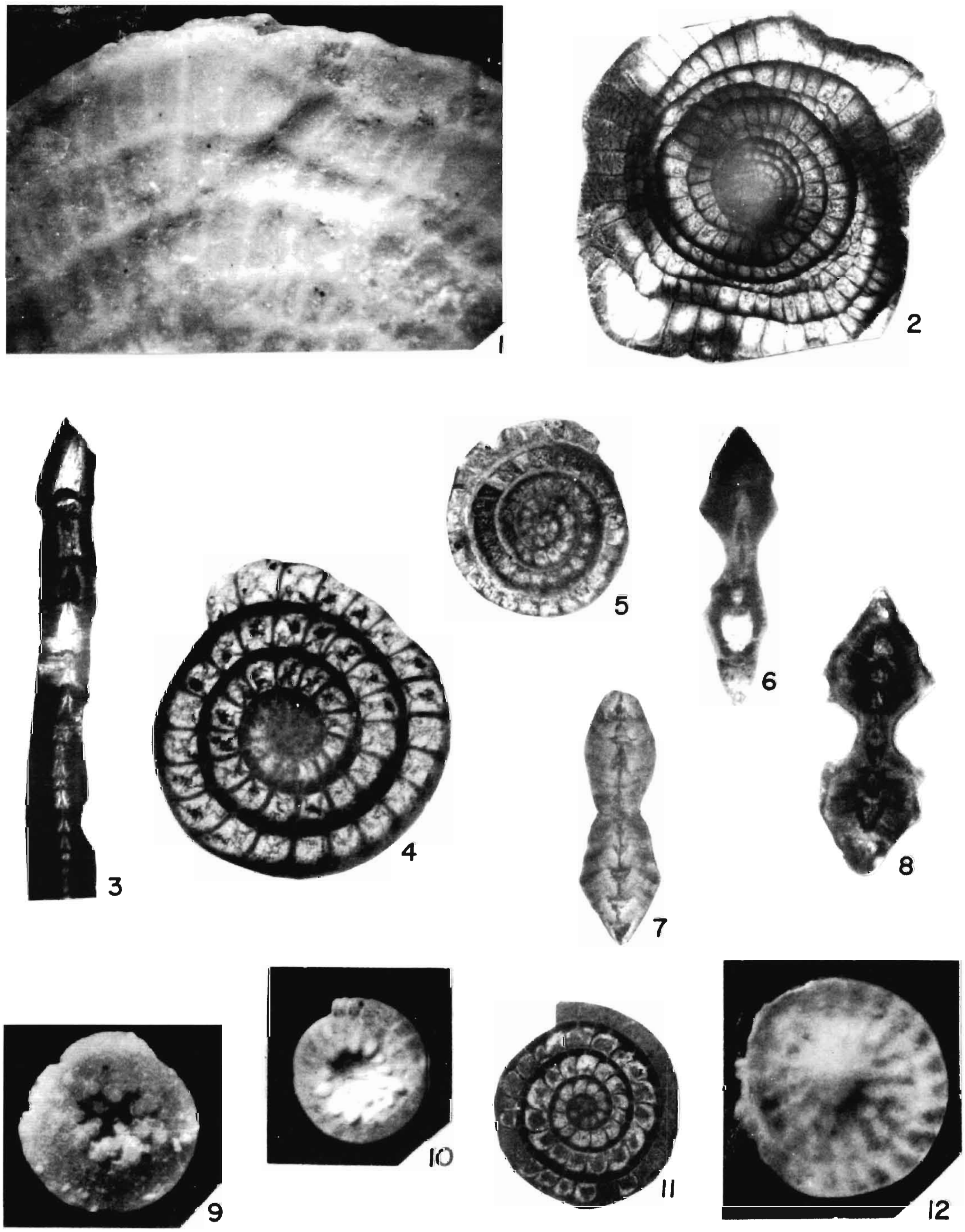
EXPLANATION OF PLATE III

1-9 *Assilina daviesi* Cizancourt, early Eocene, Loc. Tetakkar Scarp
1, 5 : External views 1, X 9, 5, X 7.5
2 : Equatorial section, X 8.
3-4 : Axial section 3, X 11, 4, X 10 6, 9 : Axial sections 6,X 21, 9,X 24 7 : External view, X 17 8 : Equatorial section, X 24

1-5. Specimens are of microphaeric generation and 6-9 of megalosphaeric generation.

Journal of the Palaeontological Society of India
Volume, 52(2), December 2007

Plate IV



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EXPLANATION OF PLATE IV

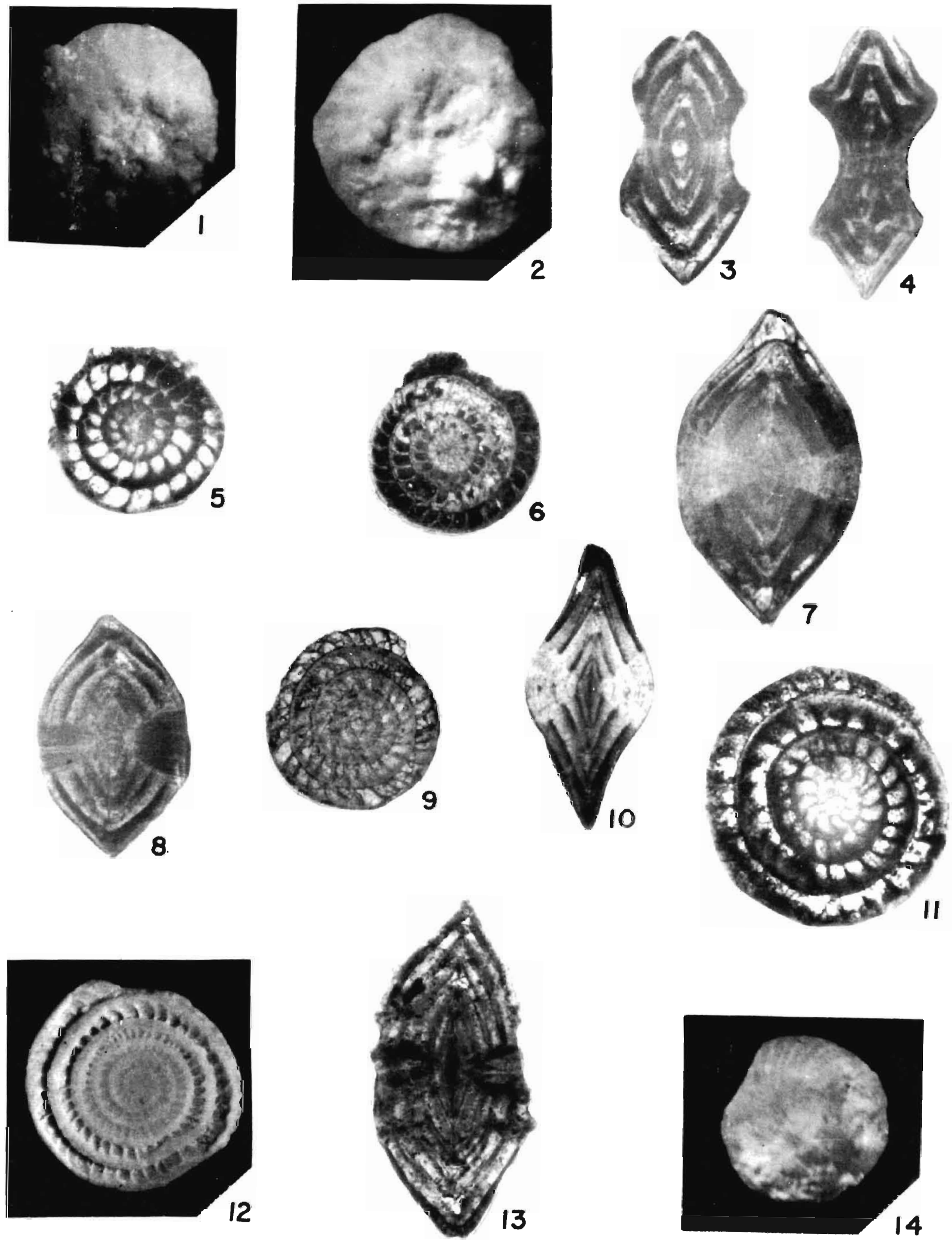
1-3. ***Assilina spria*** de Roissy, early middle Eocene, Loc. Batrewala Tibba 1 : A part of external view X 10 2 : Equatorial section, X 6.5 3 : Axial section, X 7

4-12. ***Assilina lacunata*** Cizancourt, early Eocene, Loc. Sam Nala section 4-5 : Equatorial sections, 4,X 34, 5 X 15 6 : Axial section X 34, 7 : Axial section, X 12 8 : Axial section, X 23.5 9-10, 12 : External views 9, X 16, 10, X 29 and 12, X 21, 11 : Equatorial section X 21,

All specimens belong to magalosphaeric generation except the specimen at serial no. 7 which is microsphaeric.

Journal of the Palaeontological Society of India
Volume, 52(2), December 2007

Plate V



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EXPLANATION OF PLATE V

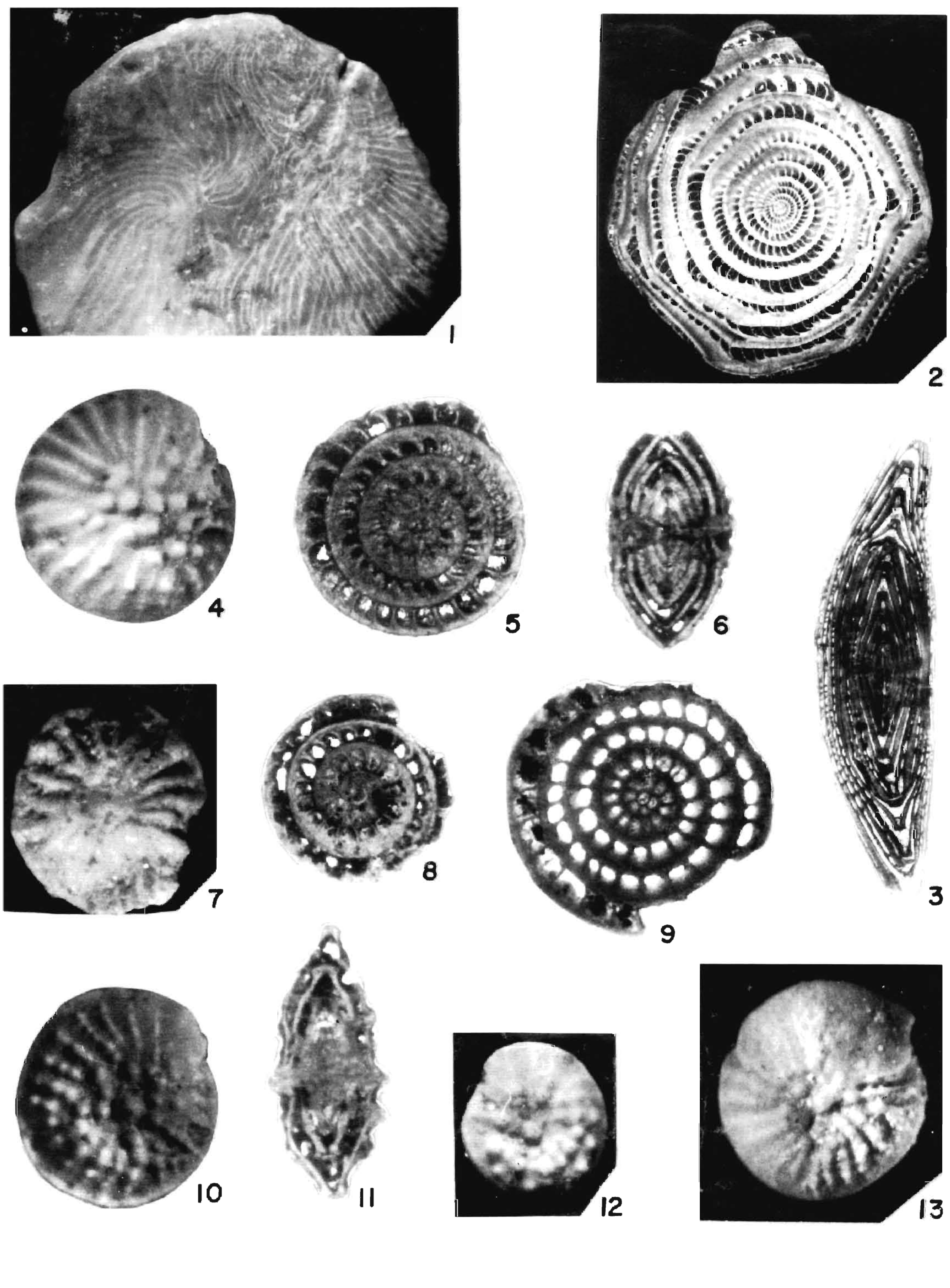
1-5 ***Nummulites cuvillieri*** Sander, middle Eocene, Loc. Bakhri Tibba well section 1-2 : External views both figures, X 20 3-4 : Axial sections 3, X 23, 4, X 26.5, 5 : Equatorial section; X 20 All specimens belong to megalosphaeric generation.

6-11,14. ***Nummulites mamilla*** (Fitchel & Moll) late Paleocene to early Eocene, Loc. Along Eocene Scarp 6, 9 : Equatorial sections 6, X 23, 9, X 27 7-8 : Axial sections 7, X 43, 8, X 26, 10 : Axial section, X 30.5 11 : Equatorial section, X 21.5 14 : External view, X 22.5 All specimen, belong to megalosphaeric generation.

12-13 ***Nummulites burdigalensis*** (de la Harpe), early Eocene Loc Khinsar, Biprasar and Phulonwali Talai. 12 : Equatorial half cut section, X 14 14 : Axial section, X 21.5 Both specimens belong to microsphaeric generation.

Journal of the Palaeontological Society of India
Volume, 52(2), December 2007

Plate VI



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EXPLANATION OF PLATE VI

1-3. ***Nummulites cf. N. irregularis*** Deshayes, early Eocene, Loc. Khinsar & Ekal Beri.
1 : External view, X 7 ; 2 : Equatorial section, X 5; 3 : Axial section X 7.5

4-13. ***Nummulites burdigalensis*** (de la Harpe), early Eocene, Loc. Khinsoer, Biperasar and Phulonwali Talai.
4, 7, 10, 12-13 : External views 4, X 28; 7, X 25; 10, X 22.5; 12, X 23 and 13, X 30; 5, 8, 9 : Equatorial sections 5 X 28; 8 X 23; and 9, X 29; 6, 11: Axial sections 6 X 29 and 11 X 35.5
All specimens belong to megalosphaeric generation.

generally overlying the Eocene rocks after the type locality Shumarwali Talai.

Type area and other reference sections: The formation is best exposed in Shumarwali Talai area. Kharatar and Lang wells are taken as other reference sections. The thickness in type section is 9.5 m (Narayanan *et al.*, 1961). In the subsurface, it has attained a thickness of 761 m in the western part of the Shahgarh Sub-basin (Dangiwala well) and a minimum of 10 m in well Bakhri Tibba well. It has been completely eroded in the east and south-east of the Jaisalmer Basin.

Lower boundary: The formation unconformably overlies the Bandah Formation.

Upper boundary: The formation is overlain by wind blown Recent dune sand.

Lithology: The formation in the outcrop is mainly composed of conglomerate with streaks of sandstone and silty clays. The topmost surface shows lateritisation (Fig.9). In subsurface, the formation is mainly represented by sandstone, conglomerate gravels, variegated clay and thin bed of arenaceous limestone. The lower part of the formation dominantly comprises fine grained sandstone, conglomerate at places with streaks of variegated clay and ferruginous matter. This unit grades upward into conglomerate/gravels, fine to medium-grained sandstone with gravels of quartz, occasional thin intercalations of variegated clay and limestone streaks. The succeeding litho-association is of buff to orange, hard, sandy limestone and thin intercalations of calcareous sandstone. The topmost part is of wind blown sand, buff to grey argillaceous sand and sandy clay.

Age and depostional environment : After the deposition of a thin veneer of late Eocene sediments, the sea completely withdrew from the Jaisalmer Basin. This seems to be linked with the major tectonic activity. During the late Palaeocene and early Eocene, the Indian plate started colliding with the Asian plate resulting in the final phase of regression of the sea during middle

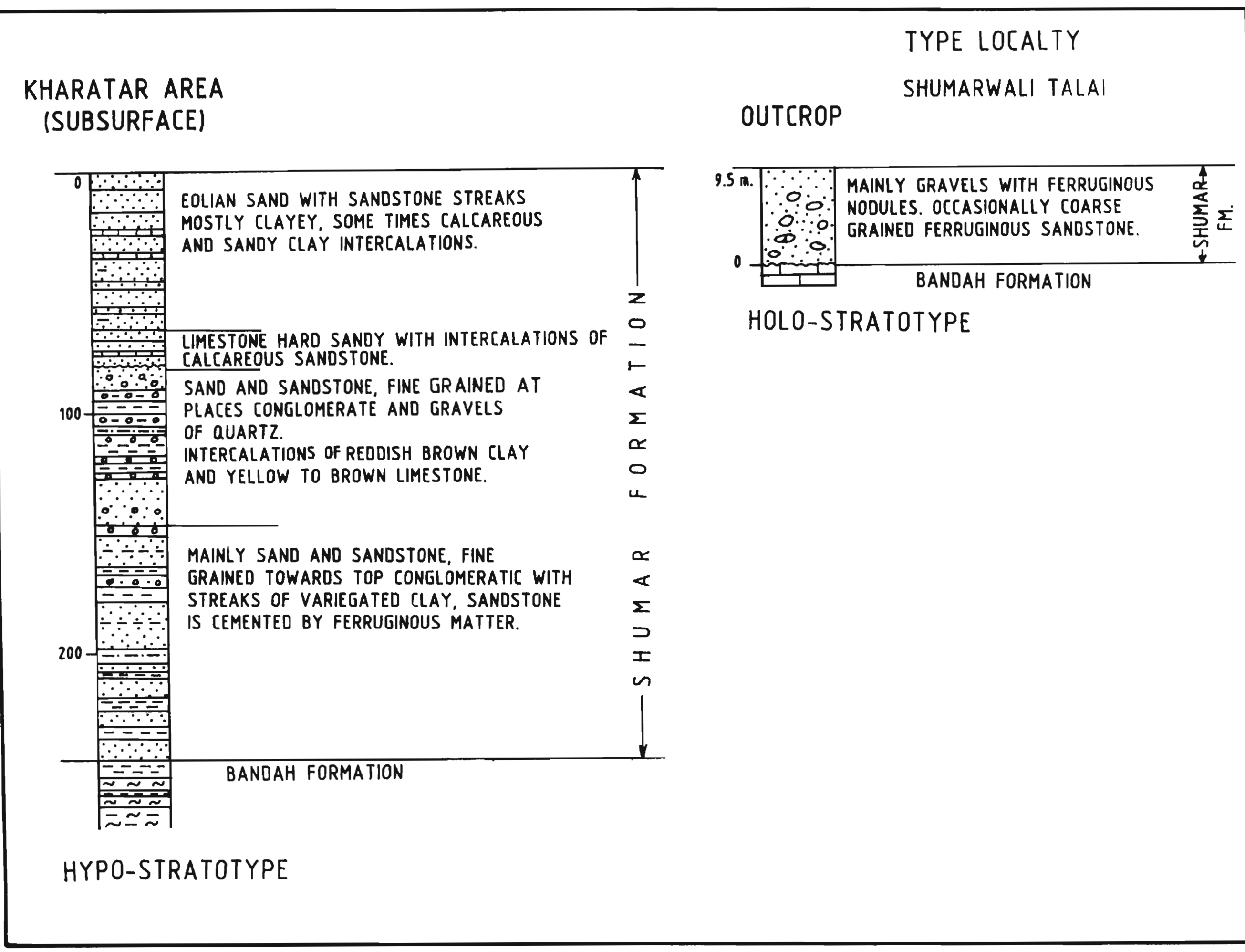


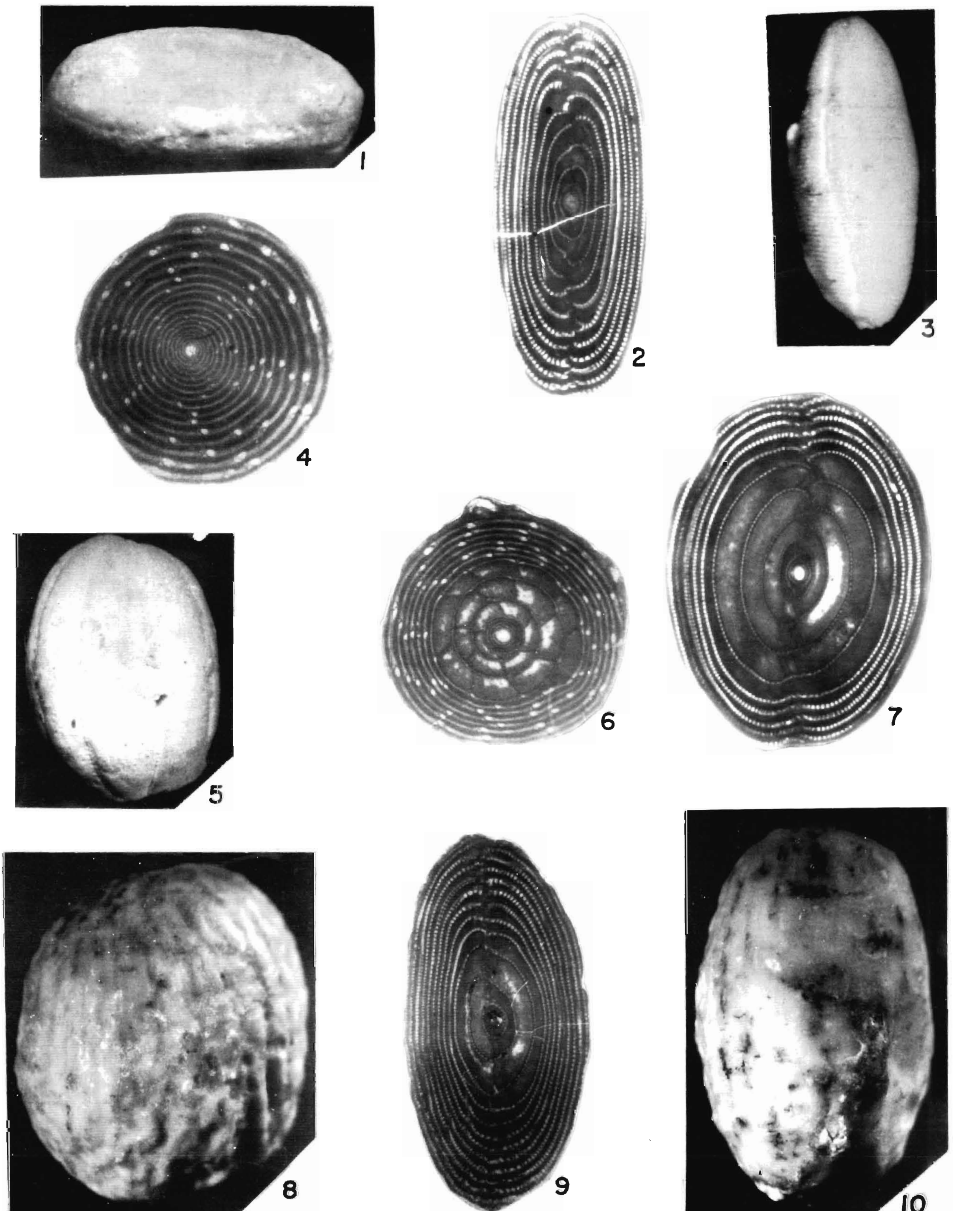
Fig. 9. Stratotype of the Shumar Formation.

EXPLANATION OF PLATE VII

1-4. ***Fasciolites (Fasciolites) elliptica*** (sowerby), early middle Eocene, Loc. Batrewala Tibba
1, 3 : External views 1, X 10.5 and 3, X 13
2 : Longitudinal section, X 11 ; 4 : Transverse section, X 16.

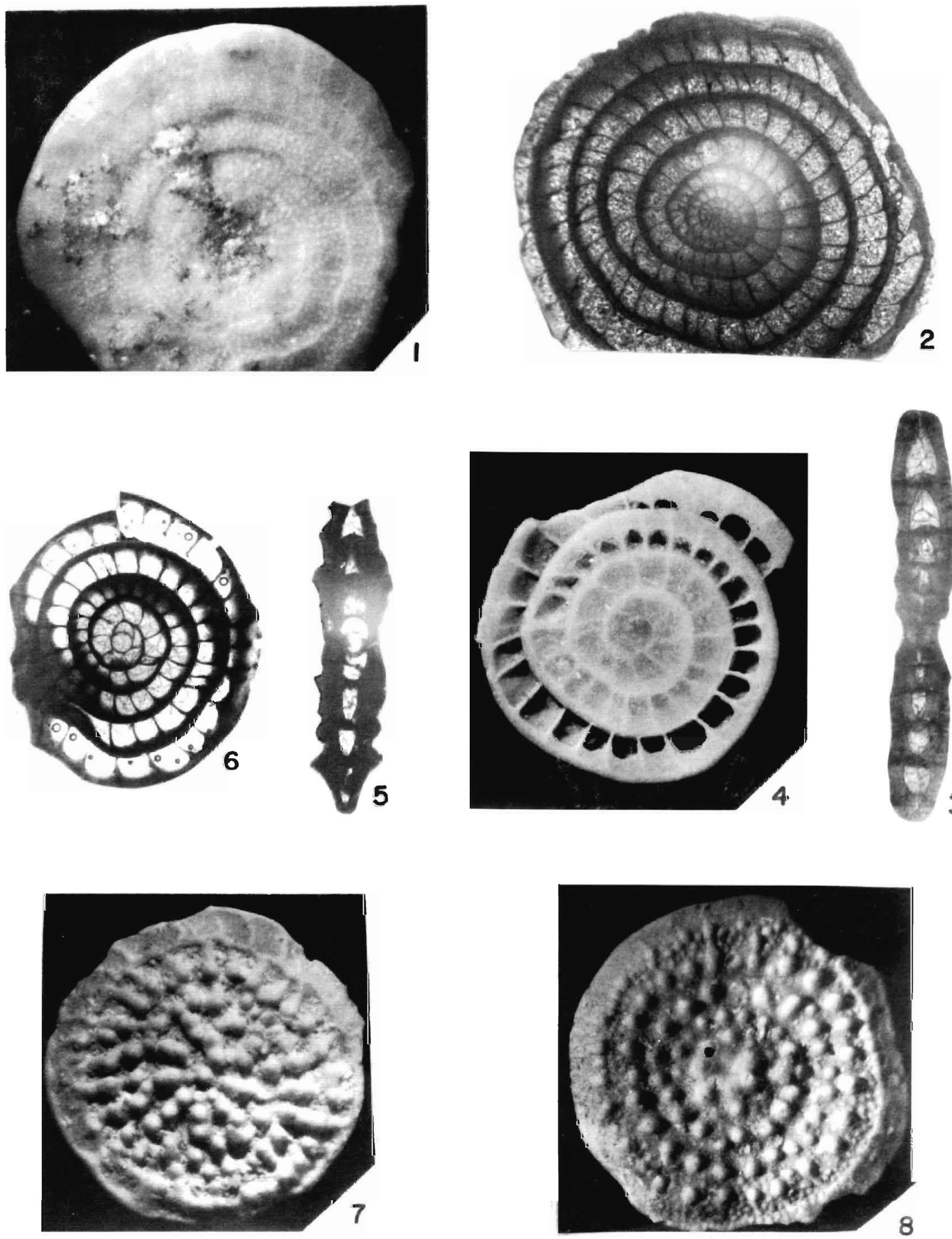
5-10. ***Fasciolites (Flosculina) elliptica*** var. ***nuttali*** Davies middle Eocene, Loc. Batrewala Tibba & Bangarwali Nay
5 : External view, X 14 6 : Transverse section, X 10.5
7, 9 : Longitudinal sections 7, X 12.5, 9, X 10.5
10 : External views, both figures X 6
All specimens belong to megalosphaeric generation.

Plate VII



Journal of the Palaeontological Society of India
Volume, 52(2), December 2007

Plate VIII



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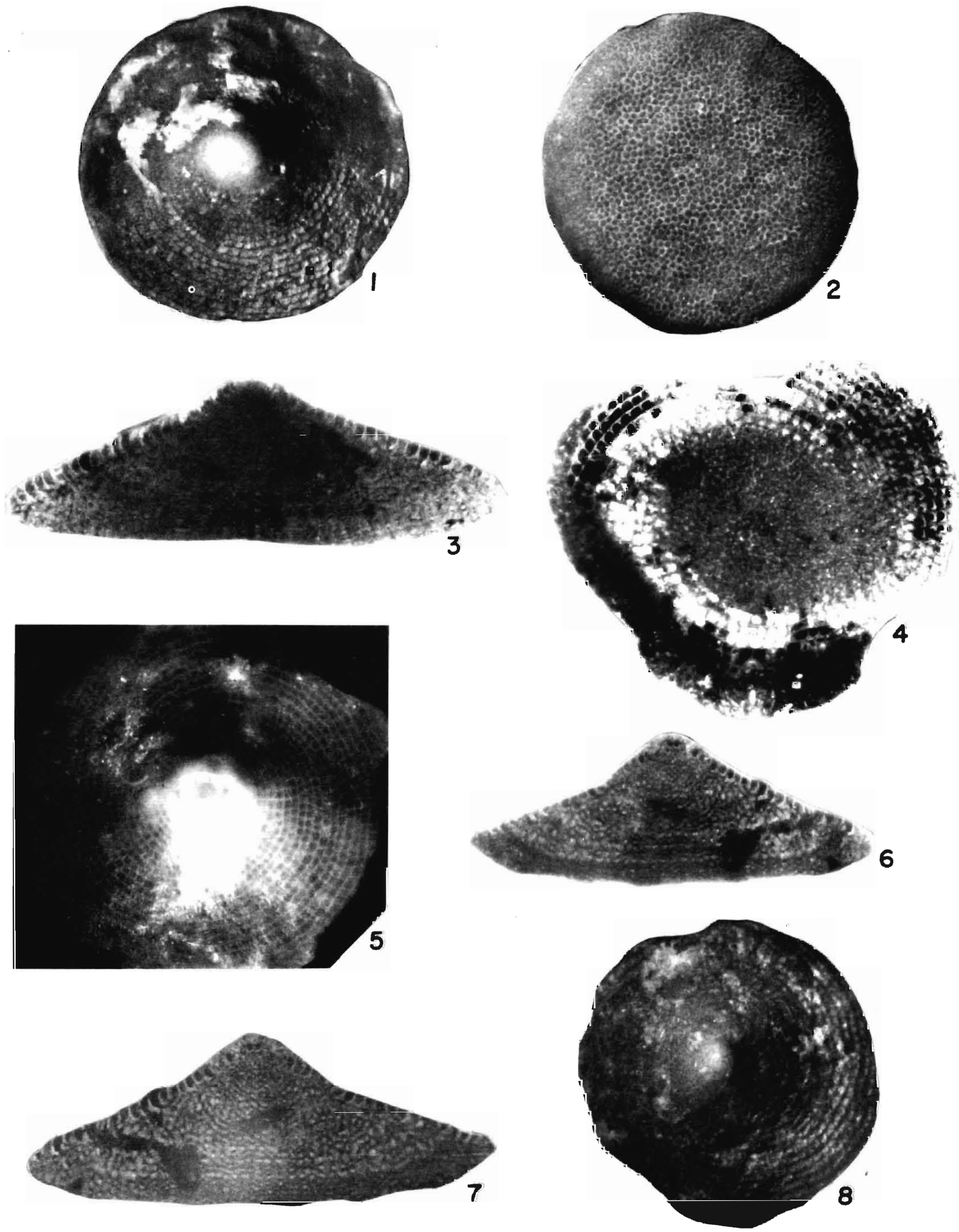
EXPLANATION OF PLATE VIII

1-3. ***Assilina papillata*** : Nuttall, early middle Eocene, Loc. Batrewala Tibba and Ekal Beri.
1 : External view, X 8 ; 2 : Equatorial section, X 8 ; 3 : Axial section, X 14.

4-8. ***Assilina subpapillata*** var. ***Jaisalmerica*** n. Var. Singh, early middle Eocene, Loc. Bakhri Tibba well section.
4 : Equatorial half cut section, X 10.5 ; 5 : Axial section, X 9.5
6 : Equatorial section, X 7.5 ; 7-8 : External views, both X 7.5
Specimens 1 to 3 belong to microsphaeric generation and specimens 4 to 8 belong to megalospaeric generation.

Plate IX



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EXPLANATION OF PLATE IX

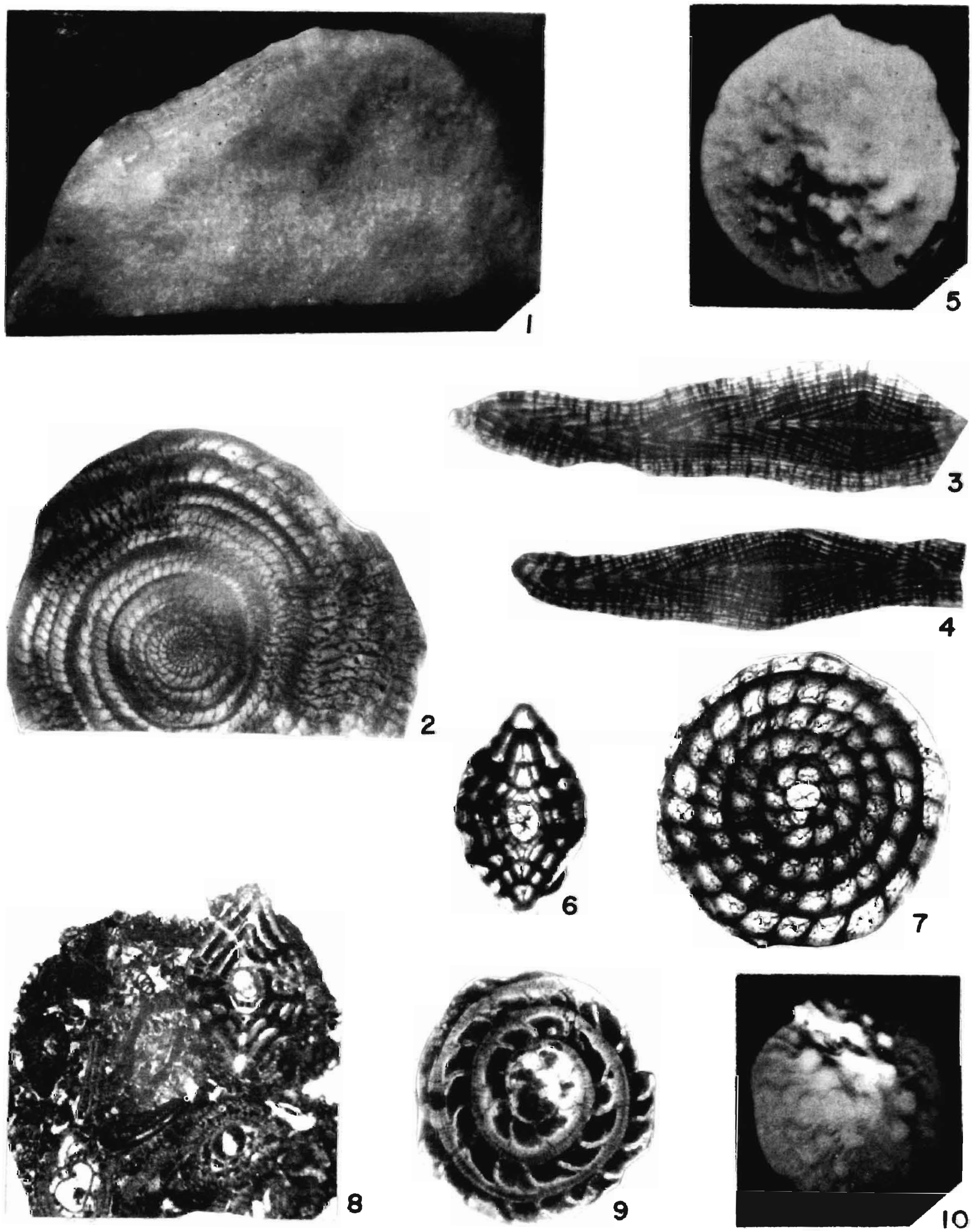
1-8 ***Dictyoconoides cooki*** (Carter), middle Eocene (Lutetian), Loc. Bangarwali Nay, Phatehwalai Talai

1, 5, 8 : External dorsal views, all the three figures, X 7.5

2 : External ventral view, X 7.5 ; 3, 6-7 : Vertical sections 3, X 11, 6, X 8 and 7, X 9.

4 Horizontal section of the specimen from upper surface, X 9.5

Journal of the Palaeontological Society of India
Volume, 52(2), December 2007



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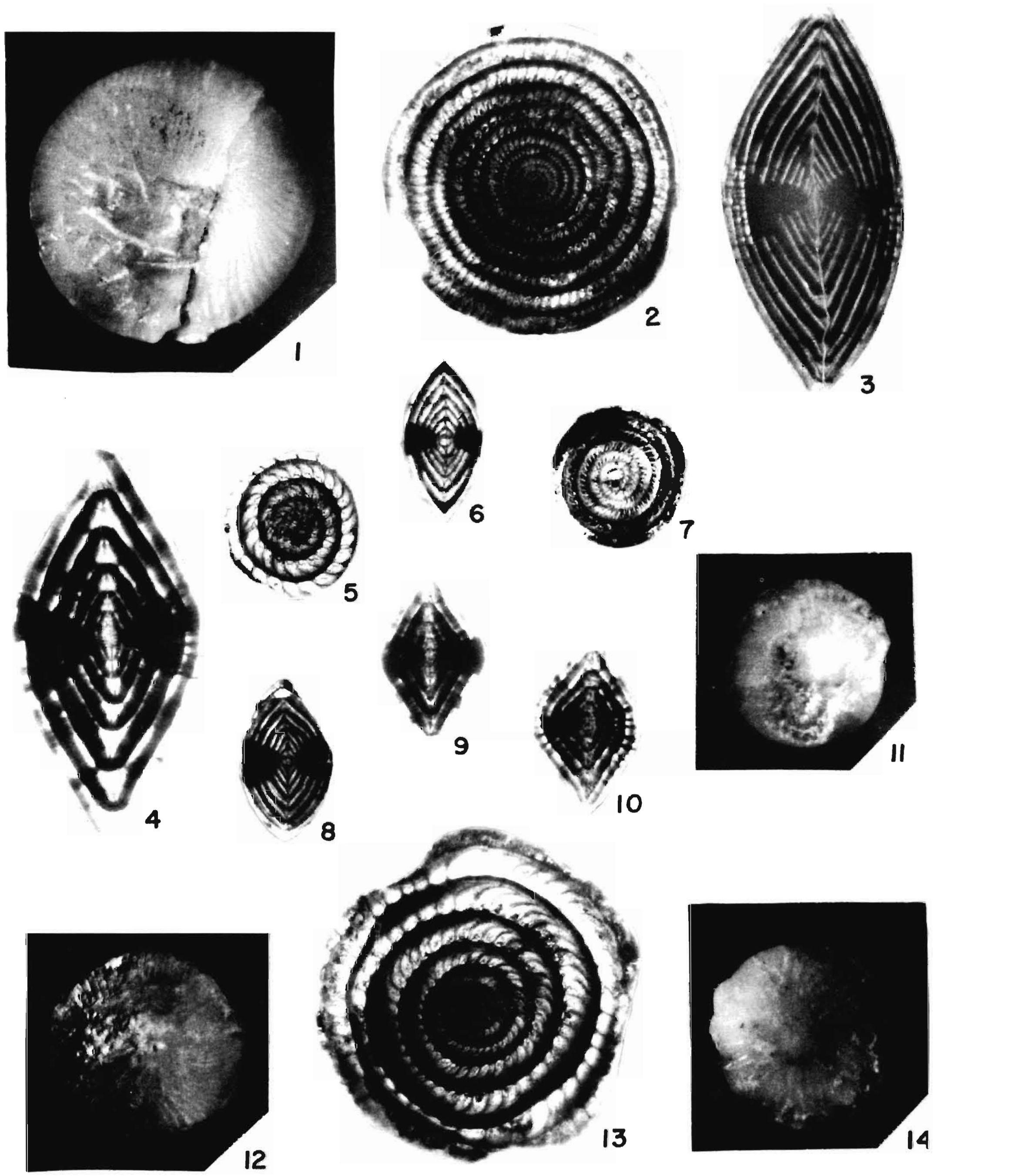
EXPLANATION OF PLATE X

1-4. ***Nummulites maculates*** Nuttall, late middle Eocene, Loc. Shumarwali Talai & Bangarwali Nay
1 : External view of half portion of the specimen X 8
2 : Equatorial section X 6.5; 3, 4: Axial sections 3 X 6.5 and 4 X 7

5-10. ***Nummulites bagelensis*** verbeek, middle Eocene (Lutetian), Loc. Batrewala Tibba, Phatch wali Talai.
5, 10 : External views, 5, X 19 and 10, X 14
6, 8 : Axial sections 6, X 10 and 8, X 12.
7, 9 : Equatorial sections 7, X 21 and 9, X 16.5
Specimens 1 to 4 belong to microspaeric generation and specimens 5 to 10 belong to megalospaeric generation.

Plate XI



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EXPLANATION OF PLATE XI

1-3. ***Nummulites beaumonti*** d' Archiac & Haime, middle Eocene (Lutetian), Loc.
6-8,11. Batrewala Tibba, Phatehwali Talai.
1 : External view, X 10 ; 2 : Equatorial section, X 12.5
3 : Axial section, X 12.5. 6, 8 : Axial sections, 6 X 15, 8, X 14
7 : Equatorial section, 12.5 11 : External view, X 16.5
Specimens 1 to 3 belong to microsphaeric generation form whereas remaining specimens belong to megalosphaeric generation.

4-5. ***Nummulites pengaronensis*** Verbeck middle Eocene (Lutetian), Loc.
9-10 Phatehwali Talai.
12-14. 4 : Axial section, X 15; 5 : Equatorial section, X 13.
9-10: Axial sections, X 14.5 ; 12 : External view, X 7 ;
13 : Equatorial section, X 12.5 ; 14 : External view, X 11
Specimens 4, 12 and 13 belong to microsphaeric generation remaining specimens belong to megalosphaeric generation.

Eocene from eastern flank of the Indus Basin including the Jaisalmer Basin (Datta, 1983). The uplifted Tertiary rocks supplied clastics to the fluvial basin to the west and southwest during the Quaternary Period. This phase was culminated during lower Miocene when axial belt was completely uplifted and sea retreated totally from the foredeep and the Indus Shelf.

The overlying sequence of the Shumar Formation got deposited after a considerable hiatus. The formation has not yielded microfauna or palynoflora. However, Singh (1982) has opined that the sediments of this formation penetrated through different well sections of the basin are not typical Sub-recent or Recent type such as alluvium, Terraces, Kankar boulder beds, etc. It may, therefore, be logical to tentatively assign Pleistocene to Sub-recent age to the Shumar Formation. Presence of conglomerate beds, gravels, coarse sand, nodular and ferruginous sandstone (often lateritic) and occasional thin limestone bands suggest deposition in complex depositional environment such as fluvial, lacustrine and eolian.

Correlation and regional lithological variation: It is well correlatable throughout the basin (Fig. 5) and there is practically no lateral facies variation except that some arenaceous limestone bands are developed in the western part of the basin in the Shahgarh area. A considerable increase in thickness in Shahgarh sub-basin as compared to the Jaisalmer-Mari High is observed. The formation is exposed from the south of Shumarwali Talai and extends north-eastward up to Ramgarh. In general, the formation is covered by wind blown sands in the west of the outcropping area.

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REFERENCES

Agocs, W.B. 1957. Report on the aeromagnetic survey in Indo-Gangetic plains. *Columbo Plan Project* (*unpublished*).

Arkell, W.J. 1956. *Jurassic Geology of the world*. Oliver and Boyd, London.

Blanford, W.T. 1876. On the physical geography of the Great Indian desert with special reference to the former existence of the sea in the Indus Valley and on the origin and mode of formation of the sand hills. *Journal Asiatic soc.* Bengal **45**(2). pp. 86-103.

Bose, M.N. 1956. Gravity-magnetic survey for exploration of oil in Jaisalmer area. *Rajasthan Report, GSI* (*Unpublished*).

Dasgupta, S.K., Depura, V.S. and **Rao K.L.N.** 1958. Progress report of geological work carried out in Jaisalmer District during field season 1957-58. *ONGC Report (unpublished).*

Dasgupta, S.K., Dhar C.L. and **Mehta V.K.** 1973. Progress report in Western Rajasthan Shelf. *ONGC report (unpublished).*

Dasgupta, S.K. 1974. Stratigraphy of Western Rajasthan Shelf. p.219-233. In: *Proceedings IVth Colloquim, on Indian Micropalaeontology and Stratigraphy,* (Ed.) *Dehradun, India.*

Dasgupta, S.K. 1975. Revision of the Mesozoic-Tertiary stratigraphy of the Jaisalmer basin, Rajasthan. *Indian Journal Earth Science* **2**(1) : 77-94.

Dasgupta, S.K. and **Chandra Mahesh** 1978. Tectonic elements of the West Rajasthan Shelf and their stratigraphy. *Proceedings Golden Jubilee Symposium Geological Mining Metaelurgical Society of India, Calcutta.*

Datta, A.K. 1983. Geological evolution and hydrocarbon prospect of Rajasthan basin. *Petroleum Asia Journal*, **6** : 93-100.

Ghosh, P.K. 1952. Western Rajputana – its tectonics and minerals including evaporites, *Bulletin National Institute of Science India.* New Delhi, **1**: 101-130.

Hedberg., H.D., Jhon Wiley and **Sons., New Yorks** International Subcommission on Stratigraphic Classification [ISSC], 1976. *International Stratigraphic Guide*

La Touche, T.H.D. 1902. *Geology of Western Rajputana. Memoir Geological Survey of India*, **35**: 1-116.

Lukose, N.G. 1974. Palynology of the subsurface sediments of Manhera Tibba Structure, Jaisalmer, West Rajasthan, India. *Paleobotanist.* **21**(3) : 285-297.

Lukose, N.G. 1977. Palynological evidence on paleoclimate of Jaisalmer basin and desertification of Thar desert, Annals of Arid Zone. **16** (3): 342-348.

Mathur, Y.K. and **Mathur, M.** 1968. Palynological report on wells KT-2, MT-1 and VN-1 with addition and comparison with wells KT-1 and BT-1, ONGC report (unpublished).

Mehrotra, R.B. and **Singh, N.P.** 1968. Micropalaeontologoical report on wells drilled in Jaisalmer Area (KT-1, KT-2, MT-1, BT-1, VN-1 and ST-1). *ONGC report (unpublished).*

Misra, P.C. and **Sharma P.C.** 1986. Geological analysis of Lower Goru Formation with special reference to hydrocarbon occurrence. Jaisalmer basin, Rajasthan. *ONGC report (unpublished).*

Misra, P.C., Singh, N.P., Sharma, D.C., Upadhyay, H., Kakroo, A.K. and **Saini, M.L.** 1993. Lithostratigraphy of West Rajasthan basins. *ONGC report (unpublished).*

Narayanan, K. 1959. Progress report on the geological work i Jaisalmer, ONGC report (unpublished).

Narayanan, K., Subramanyam, M. and **Srinivasan. S.** 1961. Geology of Jaisalmer. *ONGC report (unpublished).*

Narayanan, K. 1964. Stratigraphy of Rajasthan Shelf. *Proceedings of Symposium on Problems of Indian Arid zone.* Jodhpur. Govt. of India publication. New Delhi, 92-100.

Oldham, R.D. 1886. Preliminary notes on the Geology of North Jaisalmer *Records Geological Survey of India.* **19**(3).

Pandey, J and Dave, Alok. 1998. Stratigraphy of Indian Petroliferous Basins, Presidential Address, *XVIth Indian Colloquium Micropaleontology and Stratigraphy, Goa* : 1-248.

Rahman, H. 1963. Geology of petroleum in Pakistan. *Proceedings* of 6th W.P.C., Section: I 659-683

Sigal, J. 1965. First microstratigraphical report on Kharatar well No.-

EXPLANATION OF PLATE XII

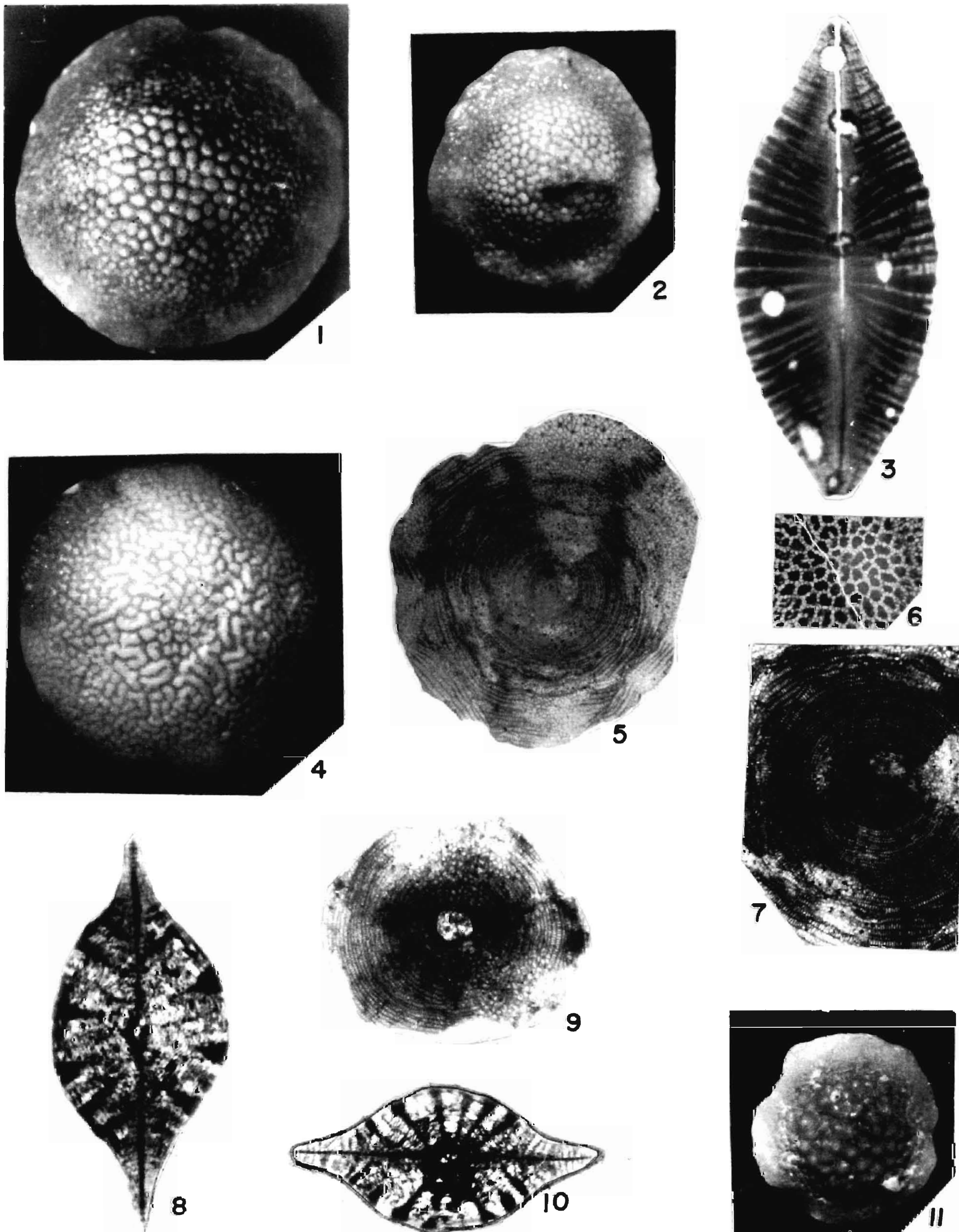
1-11 ***Discocyclina dispansa*** (Sowerby) middle Eocene, Loc. Patchwali Talai

1-2, 4 : External views 1, X 6, 2, X 7.5 and 4, X 8

5, 7 : Equatorial sections 5, X 8, 7, X 12; 6 : Tangential section showing shell columns surrounded by a rossettee of 9 to 15 septa, X 14;

8, 10 : Axial sections, 8 X 16, 10, X 12 9 : Equatorial section, X 12 11 : External view, X 9.5

Specimens 1 to 7 belong to microsphaeric generation whereas remaining 8 to 11 specimens belong to megalophaeric generation.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1 & 2 (KT-1 & 2), *ONGC-IFP report (unpublished).*

Sigal, J. 1967(a). First microstratigraphical report on Shumarwali Talai-1 (ST-1). *ONGC-IFP report (unpublished).*

Sigal, J. and **Singh, N. P.** 1967(b). First Microstratigraphical report on Manhera Tibba well-1 with complements and comparison with previous wells. *ONGC-IFP report (unpublished).*

Sigal, J., Singh, N. P., Canon A. et Ernst, M. 1970. Sur l age et les affinites "Gondwaniennes" de microfaunes (Foraminiferes et ostracodes) malgaches, indiennes et chilliennes au sommet du Jurassique *et al*a base du Cretace, C.R. Acad. Sc. Paris t. **271**: 24-27.

Sigal, J., Singh, N. P. and **Lys, M.** 1971. The Paleocene-Lower Eocene boundary in the Jaisalmer area India. *Journal Foraminiferal Research*, **1**(4) : 190-194.

Sigal, J. and **Singh, N. P.** 1980. Cretaceous biostratigraphy of Jaisalmer subsurface, Rajasthan, India: *VIII[th] Colloquium on Indian Micropaleontology and Stratgraphy* (Abstr.) : 22-23.

Singh, N.P. 1969. First micropalaeontological report on Manhera Tibba well No-2 (MT-2). ONGC report (unpublished).

Singh, N.P. 1976. Micropaleontological control in subsurface Tertiary sequence of Jaisalmer basin, West Rajasthan, India, *IV Indian Colloquium Micropalaeology Stratgraphy*. 259-278.

Singh, N.P. 1982. Subsurface Post-Eocene deposits of Jaisalmer basin, Rajasthan. *First National Seminar Quaternary Environment Recent Research Geology*, **9**: 234-243.

Singh, N.P. 1984. Addition to the Tertiary biostratigraphy of Jaisalmer basin, *Petroleum Asia Journal*, **II**(1): 106-128.

Singh, N.P. 1996. Mesozoic-Tertiary biostratigraphy and biogeochronological datum planes in Jaisalmer basin, Rajasthan. P.63-89. *Contributions to XV Indian Colloquium on Micropalaeontology and Stratigraphy,*(Eds. Pandey, J. et al.) K.D.19.I.P.E., ONGC, Dehradun.

Singh, N.P. 2003. Contribution of biostratigraphic studies in stratigraphic evaluation of West Rajasthan Shelf, *Gondwana Geology Magzazine Special* volume **6**: 79-104.

Singh, N.P. 2006. Mesozoic Lithostratigraphy of the Jaisalmer basin, Rajasthan, *Journal Palaeontological Society of India*. **51**(2): 1-25.

Singh, N.P. and **Sharma, D. C.** 1991. Paleocene planktonic foraminifera in Shahgarh sub-basin, Rajasthan *VIII Indian Geological Congress, Ujjain*, Abstract.

Srivastava, D.K. and **Mathur, U.B.** 1996. New fibulariid echinoid from the middle Eocene rocks of Rajasthan, India. *Journal of the Palaeontological Society of India*, **41**: 53-56.

Swaminath, J., Krishnamurthy, J.G., Verma, K.K., and **Chandak, G.J.,** 1959. General geology of Jaisalmer area, Rajasthan, ECAFE Symposium, *Mining Research and Development Series*, **10**: 154-155.

Verdier, A.C., Willm, C and **Brajon, J.** 1967. Completion report on Kharatar wells No.1 and 2 (KT-1 and KT-2) Jaisalmer project. *ONGC-IFP reporrt (unpublished).*

Willm, C. 1964. A contribution to the geology of Jaisalmer and oil possibility. *ONGC-IFP report (unpublished).*

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