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MESOZOIC LITHOSTRATIGRAPHY OF THE JAISALMER BASIN, RAJASTHAN

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ABSTRACT

The Jaisalmer Basin is an integral part of a major tectonic province known as "West Rajasthan Shelf" which is located to the west of Aravalli ranges and represents the eastern shelf part of the Indus Basin. The shelf hosts a number of sedimentary basins, viz. Jaisalmer, Bikaner-Nagaur and Barmer. The present study is confined to the detailed Mesozoic lithostratigraphy of the Jaisalmer Basin which has well documented history for Mesozoic and Cenozoic rock sequences. An exhaustive study of the surface and subsurface sedimentary sequences has been possible in this basin due to availability of voluminous subsurface data generated through drilling in course of oil exploration by ONGC. This basin represents more or less central part of West Rajasthan Shelf and occupies an area of 42,000 sq.km. Tectonically, this entire basin is divisible into four geotectonic blocks which, from north to south, are Kishangarh sub-basin, Jaisalmer-Mari High, Shahgarh sub-basin and Miajlar sub-basin.

The Jaisalmer Basin has a thick sedimentary column of the order of 10,000 meters or so involving alternating sequences of clastics and carbonates. The Mesozoic and Cenozoic formations are exposed in the south-eastern part of the basin. Lithostratigraphic development in all geotectonic blocks of the basin shows slight variance at different stratigraphic levels. Three major unconformities have been mapped in the basin, which differentiate four main sequences belonging to Proterozoic-Early Cambrian, Paleozoic-Mesozoic, Tertiary and Quaternary. The basin experienced first sedimentation on igneous/metamorphic basement during Palaeozoic Era. The sedimentation continued up till Recent. However, in the southern outskirts of Miajlar sub-basin, Proterozoic-Early Cambrian sediments belonging to Randha and Birmania formations are exposed; the extensions of these formations are expected in the Miajlar sub-basin only. In all, nine Mesozoic formations have been mapped in the basin, out of which three formations, namely Bhuana, Goru and Parh do not extend to the surface. Similarly, the Habur Formation is restricted to the outcropping area except in the subsurface of the Bhuana area. Facies changes in basinward areas and thinning of certain formations in shoreward areas have been observed.

The surface and subsurface sedimentary sequences could be tied up precisely based on adequate biostratigraphic control and lithostratigraphy has been standardised. Magnitude of hiatuses, unconformities and disconformities/paraconformities have been recognised. Stratotypes of all formations have been established and their depositional characters alongwith faunal and floral elements and their strartigraphic relationship with succeeding formation have been discussed.

Keywords: Jaisalmer Basin, Mesozoic Lithostratigraphy, stratotypes, Formaminifera

INTRODUCTION

The fossiliferous, isolated outcrops of Mesozoic and Cenozoic formations in the Jaisalmer Basin interspersed within desert sands are known to geologists since the close of 19th century, but due to inaccessibility of the area till middle thirties and non-availability of large scale topographic survey maps, the detailed investigations could not be initiated in first half of the last century. However, second half of the last century witnessed a great activity in this area in terms of geological and geophysical surveys and exploratory drilling by ONGC to pursue the oil exploration programme in the area. Jaisalmer basin is an integral part of a major tectonic province known as "West Rajasthan Shelf" which is located to the west of Aravalli ranges and represents the eastern shelf part of Indus basin. The shelf hosts a number of sedimentary basins viz; Barmer, Jaisalmer and Bikaner-Nagaur. The Jaisalmer Basin represents more or less central part of West Rajasthan Shelf and occupies an area of 42,000 sq.km. This basin has a well documented history for Mesozoic and Cenozoic rock sequences. Tectonically, it is divisible into four geotectonic blocks which, from north to south, are; Kishangarh sub-basin, Jaisalmer-Mari high, Shahgarh sub-basin and Miajlar sub-basin (Fig.1).

The Mesozoic and Cenozoic formations are exposed in southeastern part of the Jaisalmer Basin. In north and north west directions, these outcropping formations go beneath the sand mantle which has manifested in vast expanse of Thar or Great Indian desert. The exploration programme of ONGC has continued for the last four decades and has added enormous wealth of sub-surface data. 73 wells have so far been drilled in different geotectonic blocks of the basin, out of which a few have encompassed the full sequence comprising basement, Paleozoic, Mesozoic and Cenozoic rocks. The deepest well drilled upto 5000 meters depth in Lang area of Shahgarh sub-basin has terminated in upper part of Jaisalmer Formation. This suggests that expected thickness of the sedimentary sequence in this sub-basin is of the order of 10,000 meters or so. The sediments encountered in subsurface sections represent the alternating sequences of clastics and carbonates and range in age from Paleozoic (Permian) to Quaternary (Recent).

The present paper incorporates the evaluated and standardised Mesozoic lithostratigraphy of the Jaisalmer basin. The surface and subsurface sedimentary sequences of this basin could be tied up precisely based on lithological correlation with adequate biostratigraphic control. Magnitude of hiatuses have been worked out wherever possible. Unconformities and disconformities/paraconformities have been recognised. Stratotypes of all the formations have been established and described, indicating lithology, depositional characters, faunal and floral elements, stratigraphic relationship of their lower and upper boundaries and intrabasinal correlation along with lateral lithofacies variations. Moreover, the important Cretaceous planktic forminifera from the Goru and Parh formations correlatable with global datum planes have also

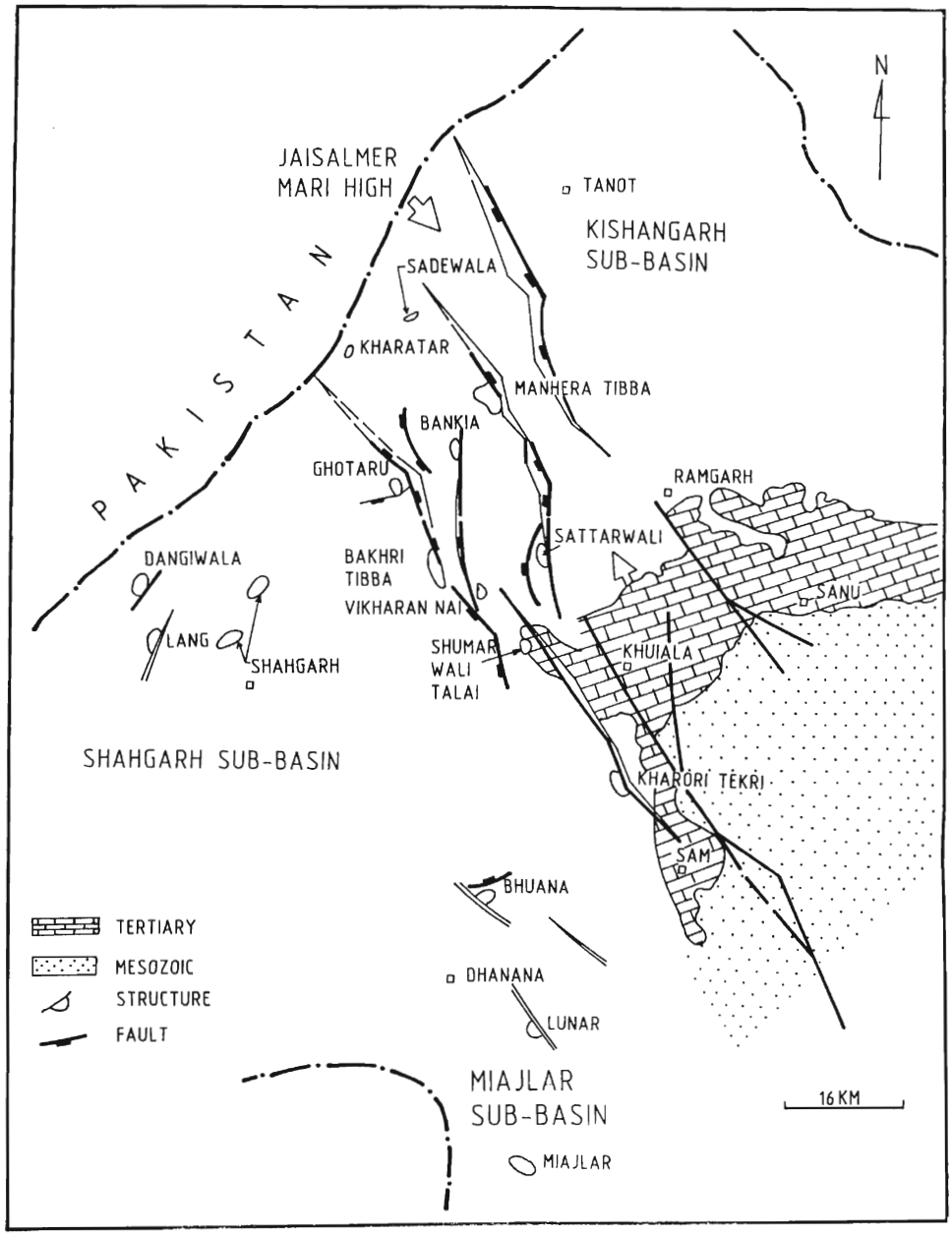

Fig. 1. Location map of the Jaisalmer Basin.

been illustrated. This has been considered relevant as these formations are confined to the subsurface and do not extend to the surface.

TECTONIC SETTING

The Jaisalmer Basin has adequately been covered by various geoscientific surveys. After the inception of ONGC in 1956, these surveys were conducted jointly by ONGC and Geological Survey of India (GSI) in 1957. Bose (1956) of GSI conducted gravity magnetic surveys in the Jaisalmer and Barmer areas in 1955 and 1956. Aeromagnetic surveys under the aegis of the Colombo Plan were also conducted in 1956 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 of the Rajasthan Shelf. It has been possible to trace surface structural features including faults and lineaments to the subcrop areas. The Bouguer anomaly data clearly defines highs and lows distributed over the Western Rajasthan. Devikot-Pokran-Nachna uplift delimits the Jaisalmer Basin in the east. Fatehgarh fault isolates it from the Barmer Basin in southern part and basement ridges bound the basin in the south west. However, the basin opens up towards north west and merges with Indus Shelf (Fig. 2).

The Jaisalmer Basin is a pericratonic basin and represents mainly 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 this basin. Structural style of the basin has been controlled by master faults. Existence of strike-slip regime with its complimentary structural styles governing sedimentation history has been noticed in the basin (Misra and Sharma, 1986). Its maximum effect is limited between Ramgarh and Kanoi master faults which

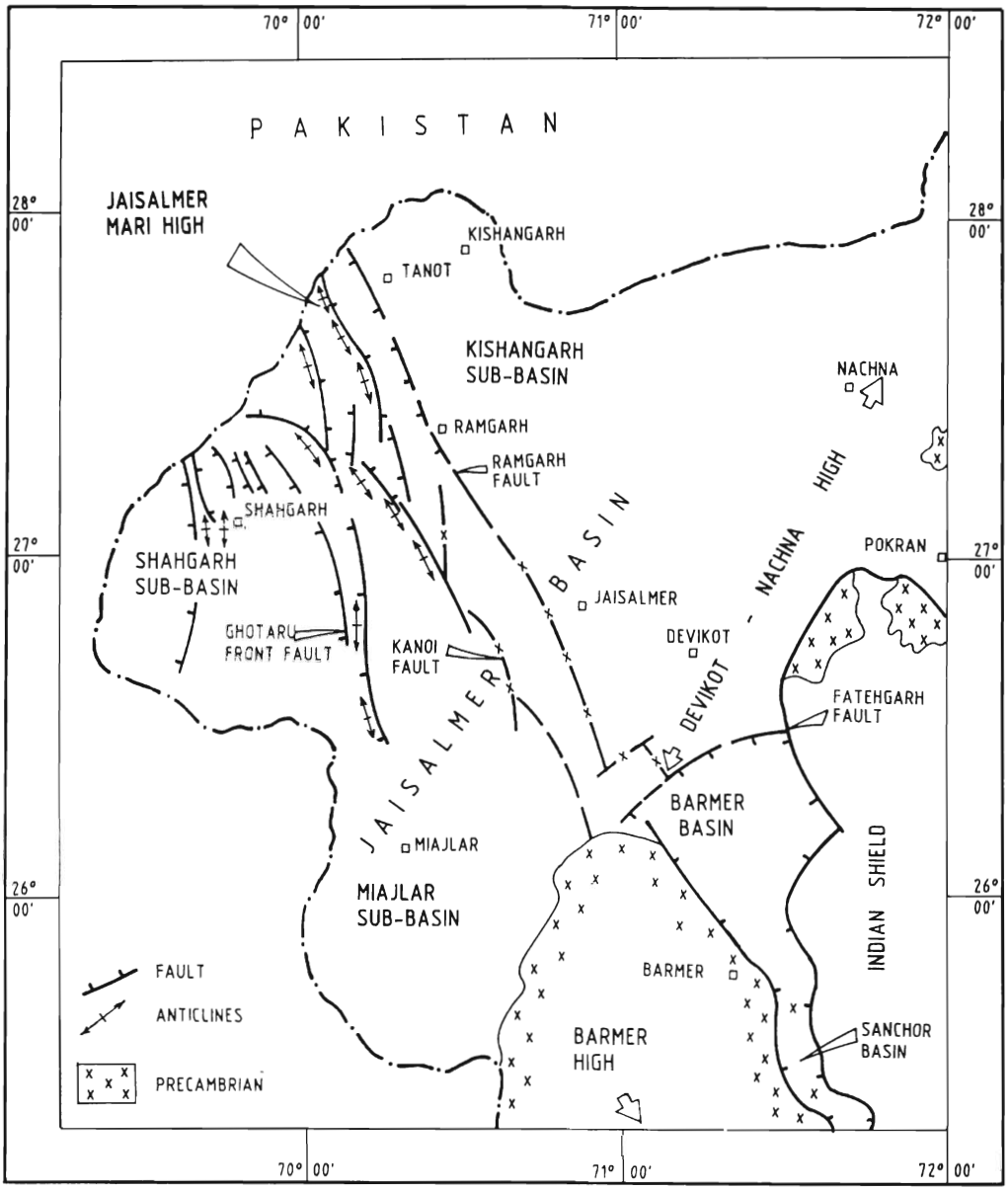

Fig. 2. Tectonic setting in the Jaisalmer Basin, Rajasthan.

are very extensive and can be traced from outcrop to subsurface. Mitra *et al.* (1993) observed that tectonic map of Jaisalmer indicates an arcuate belt of northeast-south west striking Mesozoic and Tertiary sequences. The general dips of outcropping formations are gentle to flat (3^0 to 5^0) with minor system of en-echelon and oblique faults. A broad plunge of the beds towards northwest is manifested by the arcuate trend. The study of seismic profiles on top of the Jaisalmer Formation indicates that most of the structures were initiated from Middle Jurassic time. The structural trends in Jaisalmer basin are mainly NNW-SSE or NW-SE corresponding to Dharwarian trend along with NE-SW trending Aravalli ranges. As mentioned earlier, the Jaisalmer Basin is differentiated from north to south into four geotectonic blocks. The Kishangarh sub-basin is part of north westerly homoclinally gentle dipping shelf with NE-SW depositional strike. 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 a upthrusting and wrench faulting. It is rather a zone of lifted fault blocks. Its western flank is down faulted to the southwest along a series of trending en-echelon step faults. The Shahgarh sub-basin is a deepest depression and is less disturbed having NNW-SSE trending faults, while the structurally simpler Miajlar sub-basin is located in southern extremity of the basin.

The Jaisalmer Basin of north western Indian Shield has a long and well-established sedimentation history from Upper Palaeozoic to Quaternary, although punctuated with tectonic events at the end of Early Palaeozoic, Mesozoic and Tertiary with well-marked transgressive and regressive cycles. The tectonic history prior to Upper Permian is conjectural. The basement configuration simply had westerly and north westerly slope with NE-SW depositional strike. 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

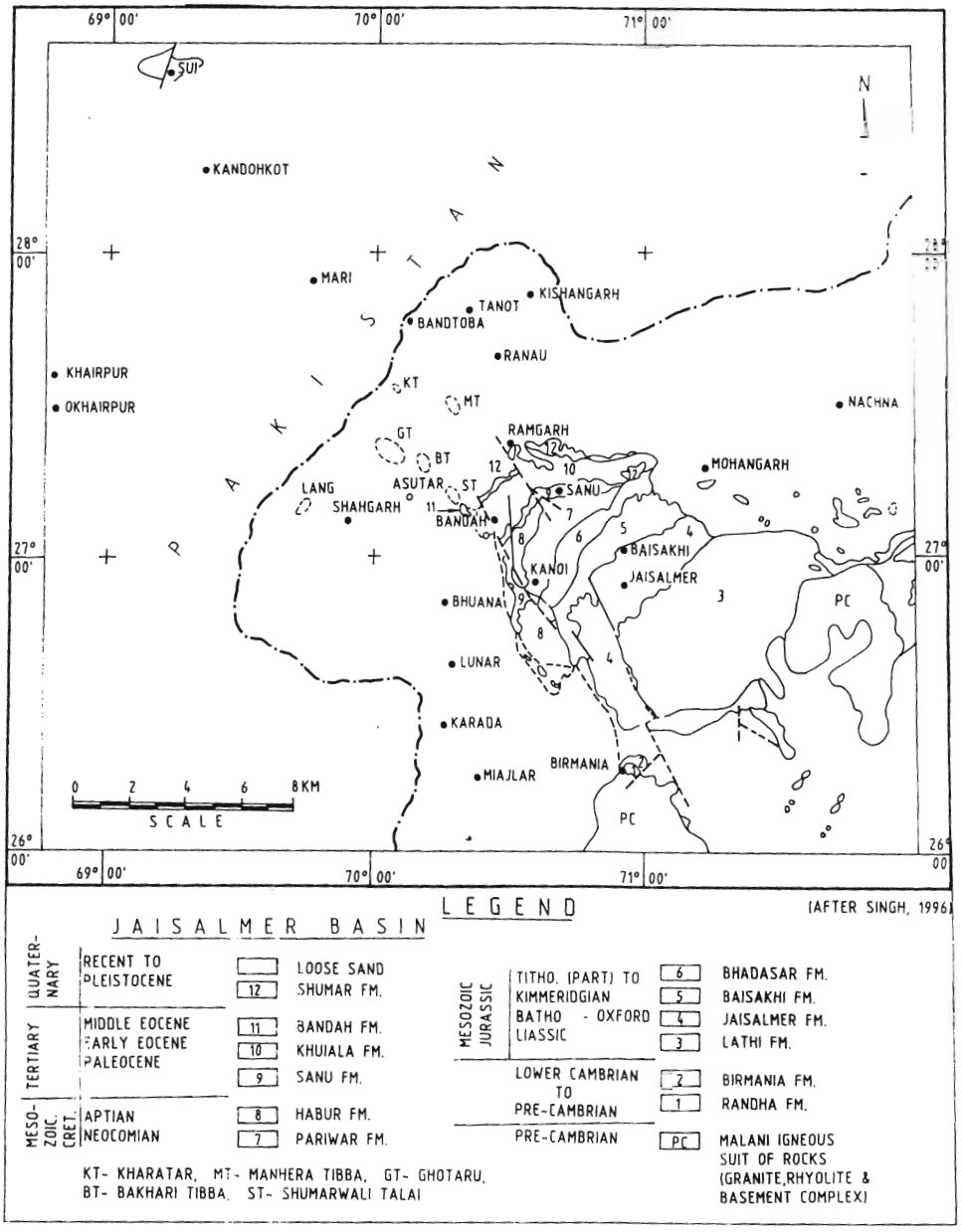

Fig. 3. Geological map of the Jaisalmer Basin, Rajasthan.

up to Ramgarh-Kanoi graben. The major tectonic event at the end of Upper Cretaceous gave rise to major structural styles present in the Jaisalmer basin and also resulted in structural differentiation within the basin.

LITHOSTRATIGRAPHY

The geological records of the Jaisalmer basin had been under active consideration since the initial work of Blanford (1876) who laid the foundation of the stratigraphy of the basin. After a decade, Oldham (1886, 1893) carried out systematic geological mapping of a large part of the erstwhile Jaisalmer State and differentiated Mesozoic and Tertiary stratigraphic units. The area was then re-examined by La Touche (1902). Allison (1938, referred to in Arkell, 1956) did a reconnaissance survey of the region and attempted to measure the thicknesses of different lithounits. This was followed by the meaningful contributions from umpteen number of professional geologists, researchers and academicians and enormous geological data was generated, of which a lion share belongs to ONGC geologists. However, mention may be made for the valuable works of Swaminath *et al.* (1959), Narayanan *et al.* (1961), Narayanan (1964), Shrivastava and Srinivasan (1963), Willm (1964), Lukose (1972), Dasgupta (1974), Dasgupta and Mahesh Chandra (1978), Lukose and Mishra (1980) and Singh (1984). The basin has also been adequately covered by geophysical surveys in order to understand the subsurface stratigraphic set up and structural features.

The Jaisalmer Basin experienced first sedimentation on igneous/metamorphic basement during Late Palaeozoic time which continued up till Recent and sediments of huge thickness of the order of 10,000 meters or so were deposited. However, on southern extremity of the basin, formations of Proterozoic to Early Cambrian age are exposed, which are expected to continue in Miajlar sub-basin but this sub basin has not been

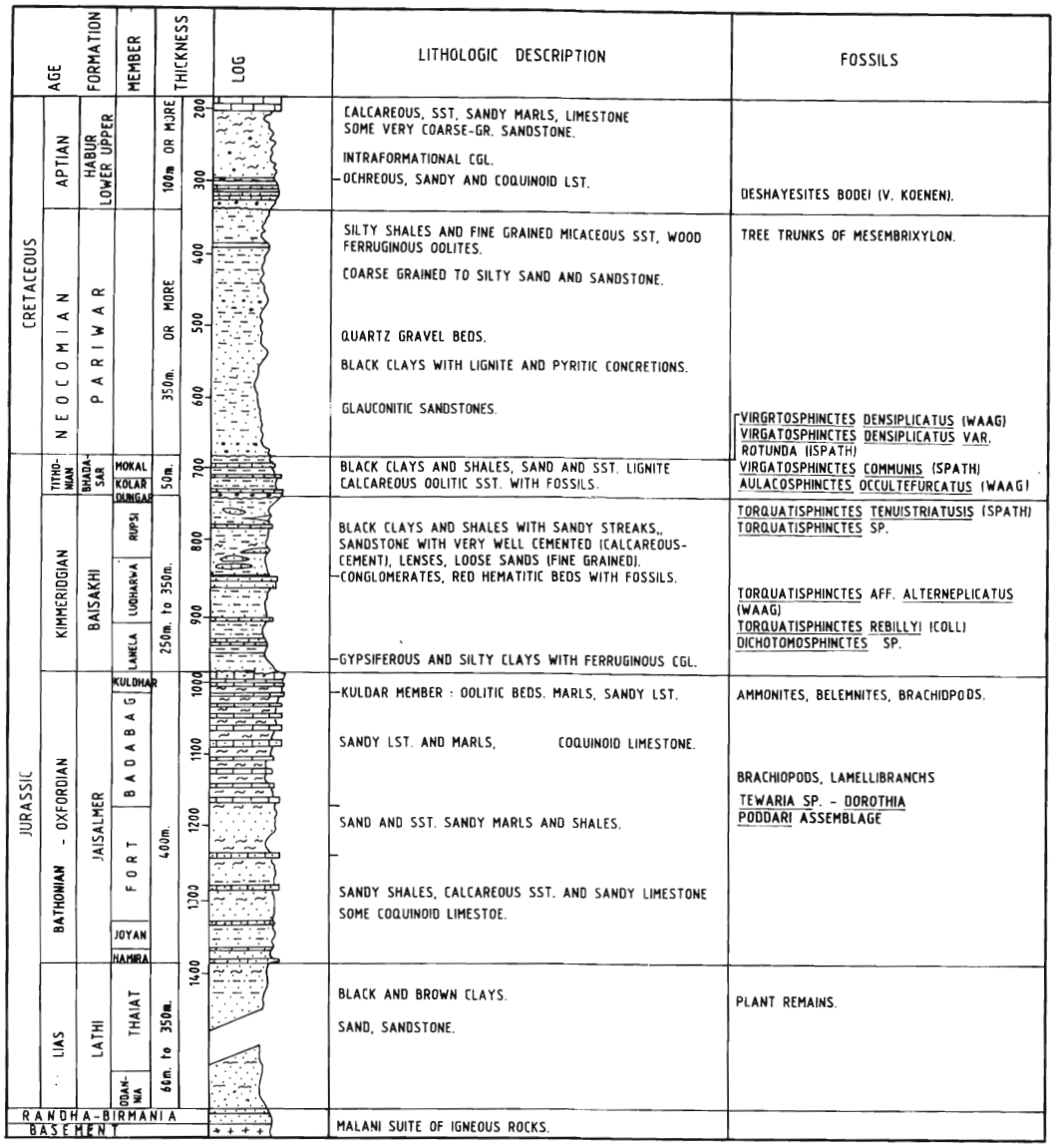

Fig. 4. Generalised Mesozoic stratigraphy of the Jaisalmer Basin (surface).

covered so far; although three wells were drilled earlier for this sub-basin these wells actually fell on the eastern margin of the Shahgarh sub-basin. Lithostratigraphic units of the Jaisalmer basin are well exposed in the eastern extremity of the basin between Ramgarh, Kuri and Lathi (Fig. 3). The maximum development of lithofacies is observed in deeper parts of the basin but some of these do not extend to surface. The author presented the updated Mesozoic-Teriary stratigraphy of the basin while discussing its biostratigraphy in detail (Singh, 1996). The stratigraphic column the of exposed sequence of Mesozoic formations along with their thicknesses, age and brief lithology is given in figure 4.

As mentioned earlier, the maximum development of lithofacies has taken place in deeper parts of the basin in sub-surface. The basin is under active exploration and a voluminous data has been generated in the course of oil exploration. The sub-surface stratigraphy of the basin has been worked out by a number of geoscientists of ONGC. The contributions made by Sigal (1965, 1966, 1967), Sigal *et al.* (1970, 1971) Sigal and Singh (1980), Mehrotra and Singh (1968), Mathur and Mathur (1972), Dasgupta (1975), Lukose (1974), Lukose and Mishra (1980), Singh (1969, 1976, 1978, 1982, 1996, 2003) and Mishra *et al.* (1996) are noteworthy and have helped in evaluation of the stratigraphy of the basin substantially. Misra *et al.* (1993) compiled all the data taking care of the nomenclature of formations and members and presented a composite picture of the stratigraphy of West Rajasthan basins. However, Pandey and Dave (1998) included the formations description of the Jaisalmer basin while compiling the Stratigraphy of Indian Petroliferous Basins but this lacks the previous work, tectonic setting, correlation, necessary maps, stratigraphic columns and figures for each stratotype described and its fossils illustrated. Hence, the present work was undertaken by the author to facilitate the academic world. Recently, the author (Singh, 2003) evaluated the stratigraphy of West Rajasthan basins in light of biostratigraphic studies and discussed in detail the correlation of surface and subsurface sequences. The updated and generalized sub-surface stratigraphy is given in figure 5. Besides, the geological section of subsurface formations along NNW – SSE is also

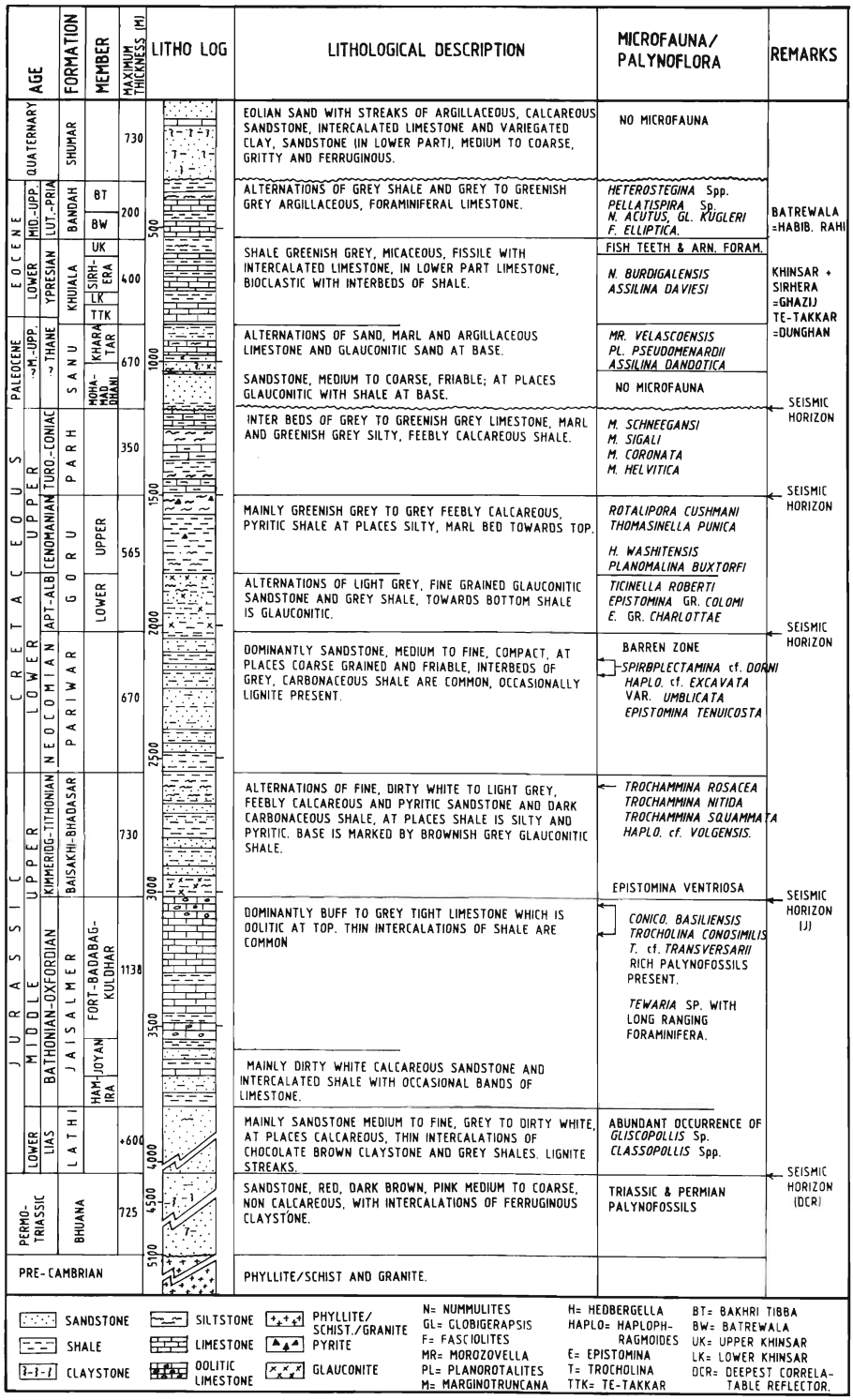

Fig. 5. Generalised subsurface stratigraphy of the Jaisalmer Basin.

drawn to show the lateral behaviour of different formations and unconformities (Fig. 6).

Regional Mesozoic lithostratigraphy of the basin has been worked out in accordance with the guidelines given in International Sub-commission on Stratigraphic Classification (1976). However, the popular names have been preserved. Moreover, while making long distance correlation the adequate biostratigraphic control is taken into consideration. Formalisation of stratotypes of each formation is attempted. However, glaring problems exist as previous workers have not described the formation by citing definite type areas and vertical sections. As a result, the selection of lectostratotype was considered but that too was not easy for the Jaisalmer area where the outcrops are very low dipping (3° to 5°), poorly exposed and isolated. In such a situation, two to three type localities have been taken into account for reconstructing the entire section of a particular formation. Besides, those type localities were essentially considered, which included lower

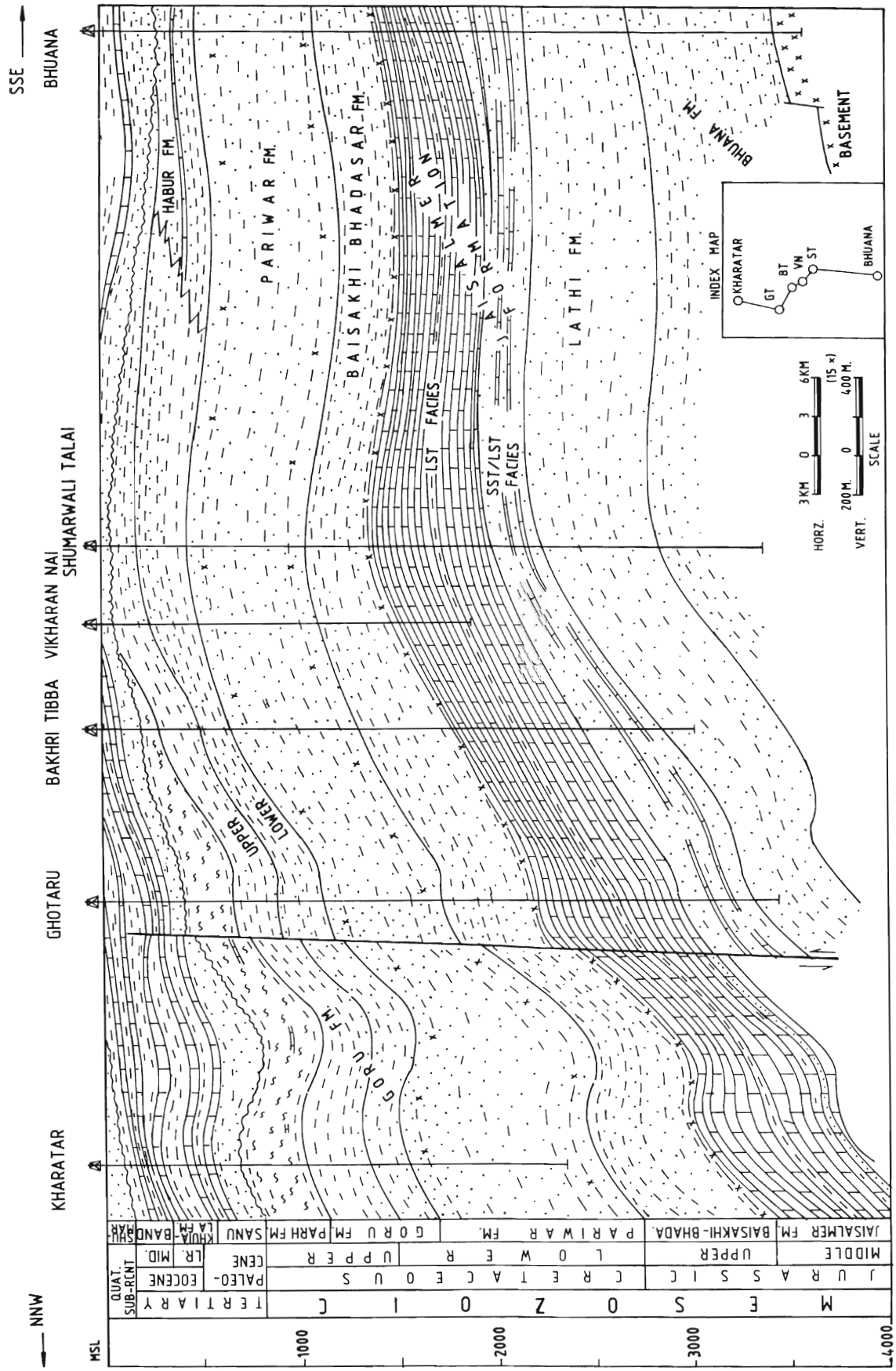

Fig. 6. Geological section across the Jaisalmer Basin (NNW-SSE).

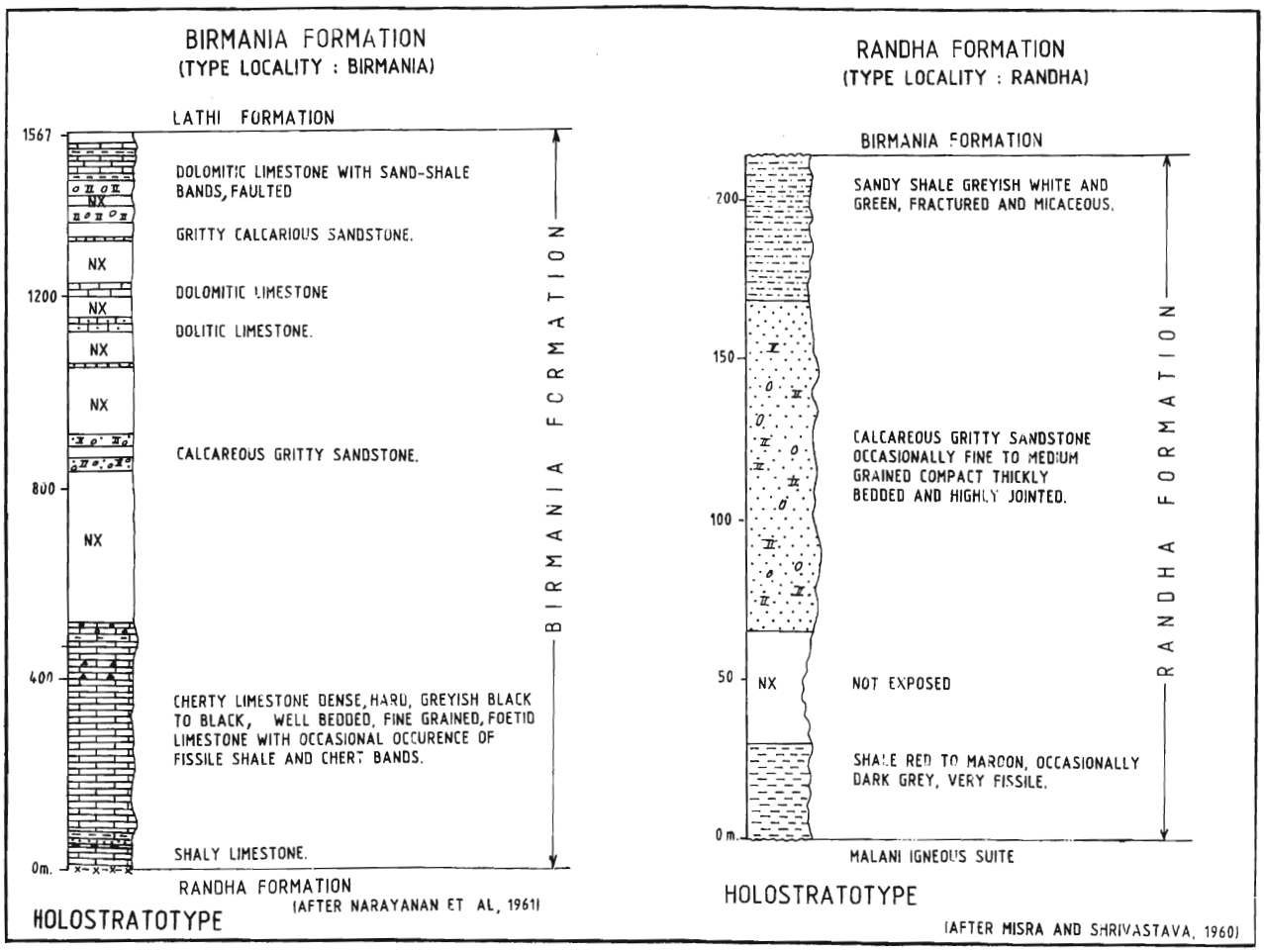

Fig. 7. Stratotype of the Randha Formation and the Birmania Formation.

and upper limits of the formation (boundary stratotype). Under this broad framework, the description of each formation is presented as below.

RANDHA FORMATION

Nomenclature: Authors; Misra and Srivastava (1960). The Randha Formation was first mapped by Narayanan (1959) as a part of the Birmania Formation.

Type area and other reference sections : Outcrop near Randha village is considered type the area. The formation has also been encountered at Birsingha well. Dhar and Mehta (1974) mapped this formation in Kohra – Chimpasani – Math – Birmania Section and Randasar – Randha – Birsingha section. Maximum thickness of the formation is around 200m at type locality.

Lower boundary: The lower contact of the formation is unconformable with the underlying basement complex (rhyolite /granite).

Upper boundary: Cherty red clays indicating slight break in sedimentation represent the contact between Randha and Birmania formations. However, Muktinath (1969) has shown faulted contact.

Lithology: It is dominantly fine to coarse grained, well indurated thickly bedded, calcareous, quartzitic sandstone with shale intercalations (Fig.7). The lowest bed overlying the basement is represented by red to maroon, occasionally grey, very fissile shale whereas towards top sandy shales are present.

Age and depositional environment: Formation is devoid of fauna and flora and hence based on its stratigraphic position, the Proterozoic to Lower Cambrian age has been assigned.

EXPLANATION OF PLATE I

1. ***Hedbergella trochoidea*** (Gandolfi), Spiral view X 120, Late Aptian, Lang well section.
2. ***Biticinella breggiensis*** (Gandolfi), Umbilical view X 145, Albian, Lang well section.
3-4. ***Planomalina buxtorfi*** (Gandolfi), Spiral view X 124, Umbilical view X 133, Albian, Kharatar well section.
5. ***Praeglobotruncana*** stephani (Gandolfi), Spiral view X 148, Late Cenomanian, Kharatar well section.
6. ***Rotalipora cushmani*** (Morrow), Umbilical view X 82, Middle Cenomanian, Kharatar well section.
7. ***Favusella washitensis*** (Carsey), Spiral view X 87, Albian, Kharatar well section.
8. ***Marginotruncana schneegansi*** (Sigal), Spiral view X 95, Turonian – Coniacian, Kharatar well section.
9. ***Gavelinella* gr. *aumalensis***, Sigal, Sprial view X 110, Cenomanian, Kharatar well section.

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Plate I

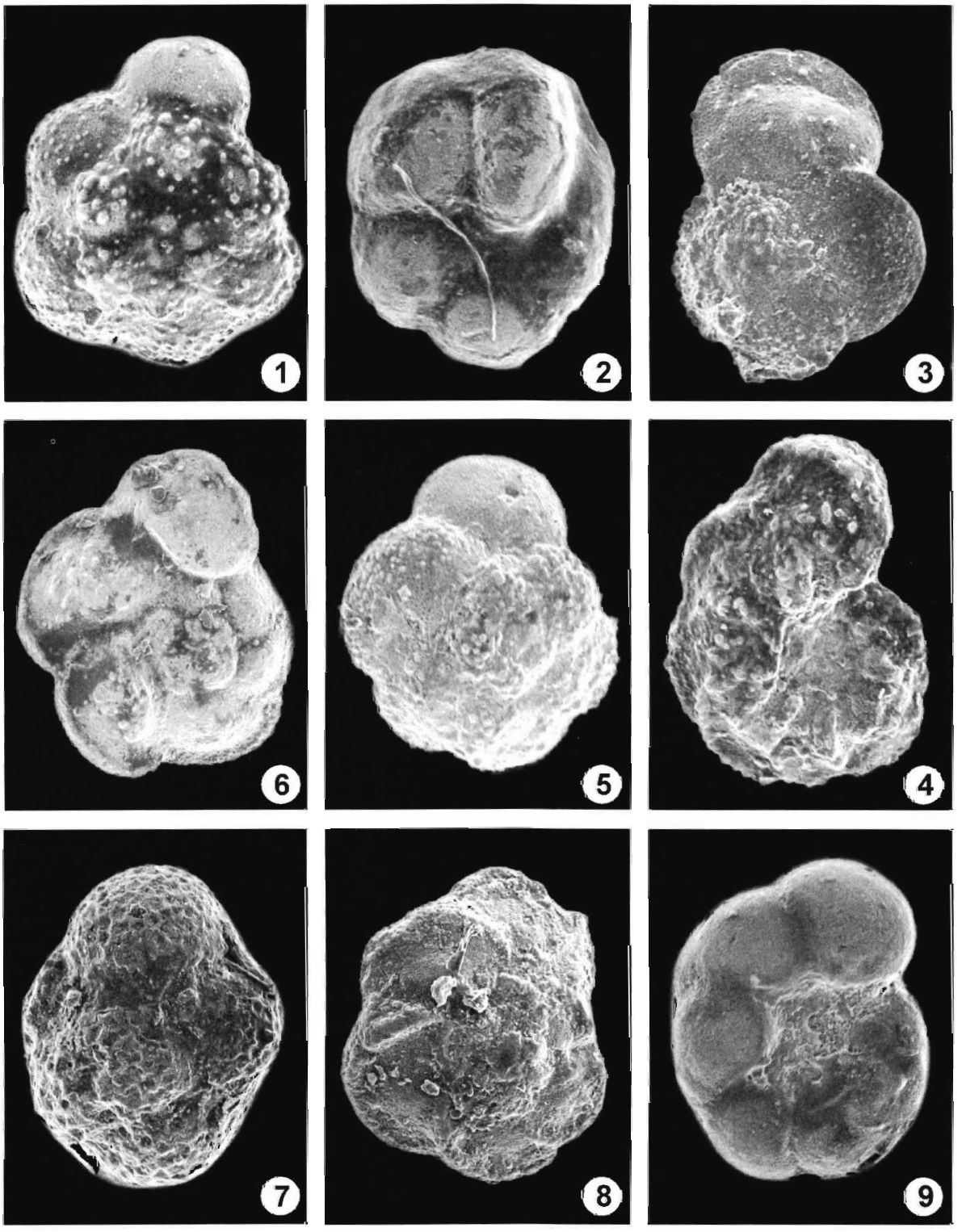


Table 1: Palynozones of Permo-Triassic sequence in the Jaisalmer Basin.

AGE			FORMATION	THICKNESS	CHARACTERSTIC PLYNOFLORA	PALYNO-ZONE	PALEO-ENVIRONMENT
MESOZOIC	LR. JURASSIC		LATHI		*Classopollis, classoides, Exesipollenites tumulus, Araucariacties, Inaperturopollenites,*	*C. classoides-E.tumuluse zone*	Regressive phase
	TRIASSIC	NORIAN	BHUANA	* 300m in ST Area	*Enozonalasporites ignacii, Minutosaccus crenulatus, M.acutus, Lueckisporites singhii, Falcisporites stabilis, F.nuthalensism Infernopollenites parvns*	*E.ignacii-M.Crenulatus zone*	Disconformity Regressive phase
							Shallow marine due to presence of numerous micropalnktons (Transgressive Phase)
		CARNIAN			*Rimaesporites potoniei, Samaropollenites specious, Camerosporites secatus, C. pseudoverrucatus, Ovalipollis pseudoalatus, Staurosaccites, Quadrfidus, S. marginalis.*	*R. potoniei-S. specious zone*	Regressive phase Disconformity
PALEOZOIC	UPPER PERMIAN			* 210m in ST Area	*Guttulapollenites gondwanensis, Striatopodo-Carpites tiwarii, Hamispollenites, Vikkipollenites, Nuskoisporites, Triadispora, Klausipollenites, Rhizomospora, Falcisporites, Sulcatisporites, Florinites, Densipollenites, Lueckisporites, Vitreisporites*	*G.gondwanensis S.tiwarii zone*	Devoid of microplanktons (Refressive Phase) Presence of microplanktons (Transgressive Phase)
PRE-CAMBRIAN			PHYLLITIES/ SCHISTS (Metamorphic basement) no microfossils			* Shumarwali Talai Area (subsurface)	

The lithological association of red shales, calcareous quartzitic sandstone and sandy shale is indicative of fluctuating environment ranging from continental to nearshore.

BIRMANIA FORMATION

Nomenclature: Author; Narayanan (1959). He mapped the cherty limestone and shales of the Birmania Formation along with clastic sequence at its lower part, which was later identified by Misra and Shrivastava (1960) as Randha formation.

Type area and other reference sections: Exposures near Birmania village. Besides, the outcrops can be seen along the track from Lakha to Birmania. The formation is also present in shallow tube-well sections near Jhininiali village. Narayanan *et al.* (1961) estimated its thickness, around 2000m including

EXPLANATION OF PLATE II

1-2. ***Helvetoglobotruncana helvetica*** (Bolli), Spiral view X 80, umbilical view X 95, Turonian, Kharatar well section.

3-4. ***Marginotruncana sigali*** (Reichel), Spiral view X 82, umbilical view X 70, Turonian- Coniacian, Kharatar well section.

5. ***Marginotruncana coronata*** (Gandolfi), Spiral view X 80, Coniacian, Kharatar well section.

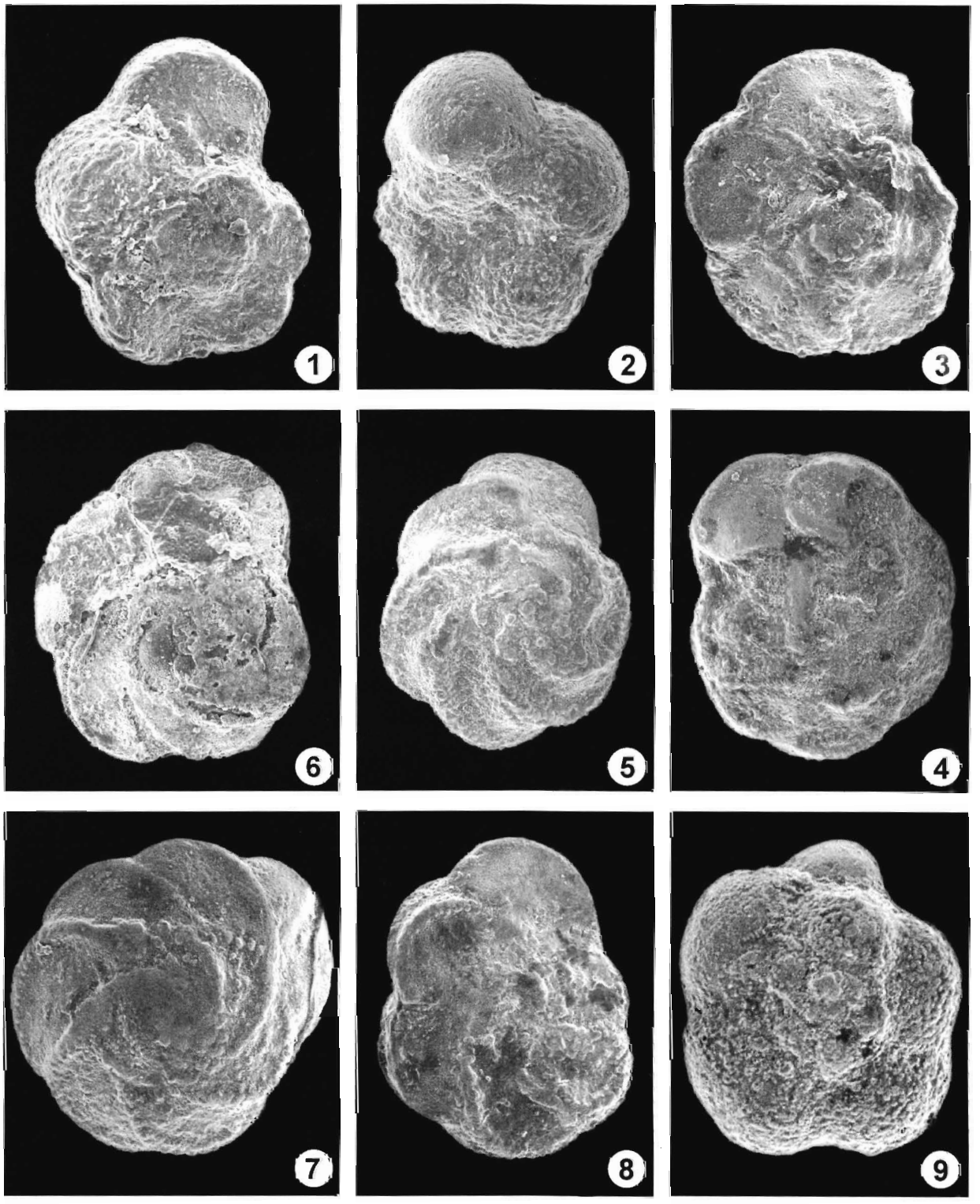
6. ***Marginotruncana renzi*** (Thalmann & Gandolfi), Spiral view X 80, Turonian- Coniacian, Kharatar well section.

7. ***Marginotruncana angusticarinata*** (Gandolfi), Spiral view X 82, Coniacian, Kharatar well section.

8. ***Marginotruncana lapparenti*** (Brotczen), Spiral view X 85, Coniacian, Kharatar well section.

9. ***Archeoglobigerina bosquensis***, Spiral view X 125, Coniacian, Lang well section.

Plate II



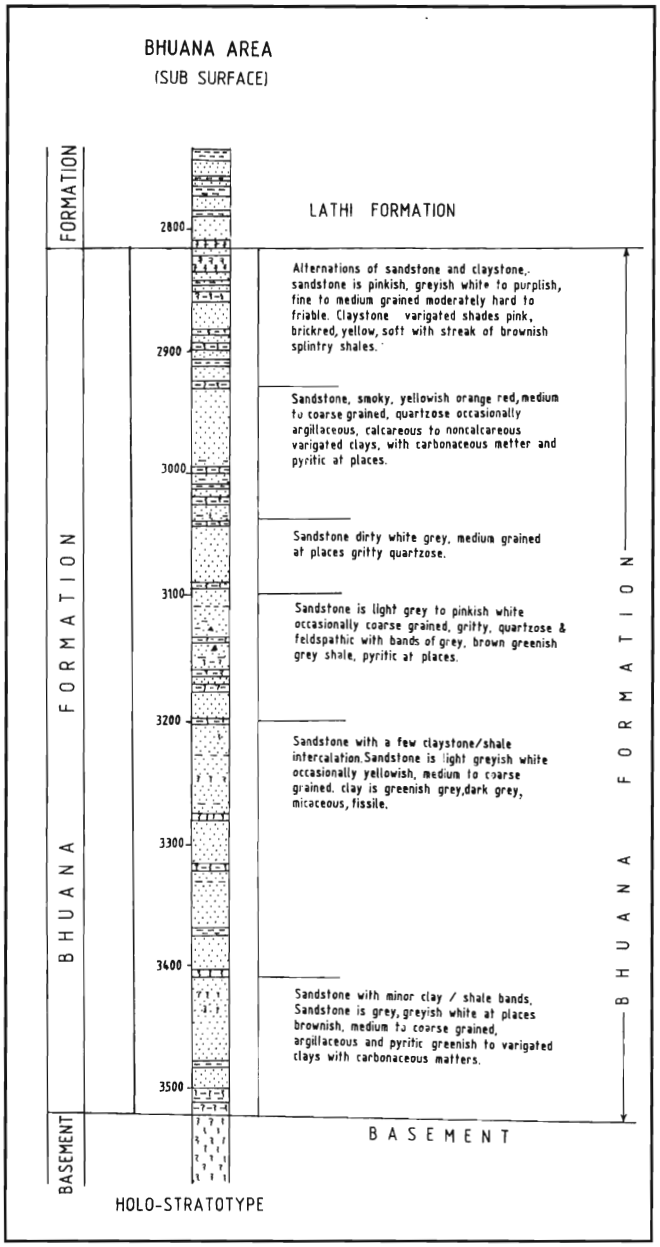


Fig. 8. Stratotype of the Bhuana Formation.

Randha Formation. Muktinath (1969) assessed its thickness around 536m in the type area.

Lower boundary: The formation unconformably overlies Randha Formation in the type area but southwest of Birmania village it directly overlies the basement (rhyolite / granite).

Upper boundary: Formation's upper boundary is unconformable with the overlying Lathi Formation (Narayanan *et al.*, 1961; Muktinath, 1969). However, Dhar and Mehta (1974) reported that the Tertiary sediments directly overly the Birmania Formation with an angular unconformity east of Birmania.

Lithology: The formation is mainly a carbonate sequence of grey, cherty and dolomitic limestone with interbeds of shale and calcareous sandstone (Fig.7). In the type section, the formation is composed of limestone and gritty, calcareous sandstone. The cherty limestone is dense, hard, grey to black, well bedded fine grained, foetid. The associated shales are very fissile, dark grey and form fairly persistent beds. At places, dolomitic and oolitic limestone bands are also noticed. The upper part of the formation gets partly dolomitized.

Age and depositional environment: Fauna and flora have not been recorded from this formation. Based on its stratigraphic position Proterozoic to Lower Cambrian age has been assigned. The lithological association of dark grey shale, dense, dark grey, cherty limestone with interbedded chert is indicative of the deposition in marine setting. The foetid nature of limestone is characteristic of deposition in reducing environment with restricted circulation. The presence of phosphorite in the formation also suggests marine influence.

BHUANA FORMATION

Nomenclature: Authors; Misra *et al.* (1993). The entire Permo-Triassic sequence was first designated by Dasgupta (1974) as the Karampur Formation for the Permian sequence and the Shumarwali Formation for the Triassic sequence but lithologically there is no break to justify two formations; as a result, Misra *et al.* (1993) introduced a new name the Bhuana Formation after the name of the area where it was encountered first in the sub-surface while drilling.

Type area and other reference sections: In Bhuana well restricted to subsurface only. Also encountered in Lunar well. Maximum thickness recorded is 707m in Bhuana well .

Lower boundary: A clastic sequence associated with shale of the formation rests directly on greenish, grey schists and phyllites of Precambrian age indicating a big hiatus from Cambrian to Permian (Fig. 8).

Upper boundary: The upper boundary of the formation is conformable with the overlying Lathi Formation. This boundary is settled between pinkish white, fine to medium grained sandstone and claystone of the Bhuana Formation and grey coarse to medium grained ill-sorted sandstone and shale sequence of overlying Lathi Formation.

Lithology: The formation recorded in the type area Bhuana well is represented by sandstone with intercalations of claystone and shale (Fig.8). The sandstone is grey to greyish white, at places brownish white, medium to coarse grained, occasionally argillaceous and pyritic. In upper part, sandstone is generally pinkish white to pink and even purple coloured fine to medium grained, moderately hard to friable. The intercalated shales are grey to brownish grey, at places greenish grey, fissile, splintery, pyritic with occasional presence of carbonaceous matter. Clay is variegated with shades of pink, brick red, yellow and moderately hard to soft.

Age and depositional environment: The formation is devoid of microfauna. However, a rich palynofloral assemblage is recorded (Lukose and Misra, 1980). Based on this, the entire formation is divisible into two palynozones corresponding to Permain and Triassic. Misra *et al.* (1996) further refined dating and depositional environment (Table 1). The formation seems to have deposited in fluvial to shallow marine environment. Lukose and Misra (Ibid) have interpreted marine and non-marine sequences based on the presence and absence of microplanktons.

LATHI FORMATION

Nomenclature: Authors; Swaminath *et al.*, (1959). Oldham (1886) was first to name this as "Lathi beds" after the village Lathi. Swaminath *et al.* (1959) renamed it as the Lathi Formation without assigning the type locality. Narayanan *et al.* (1961) gave distribution and referred only to a tube-well section for

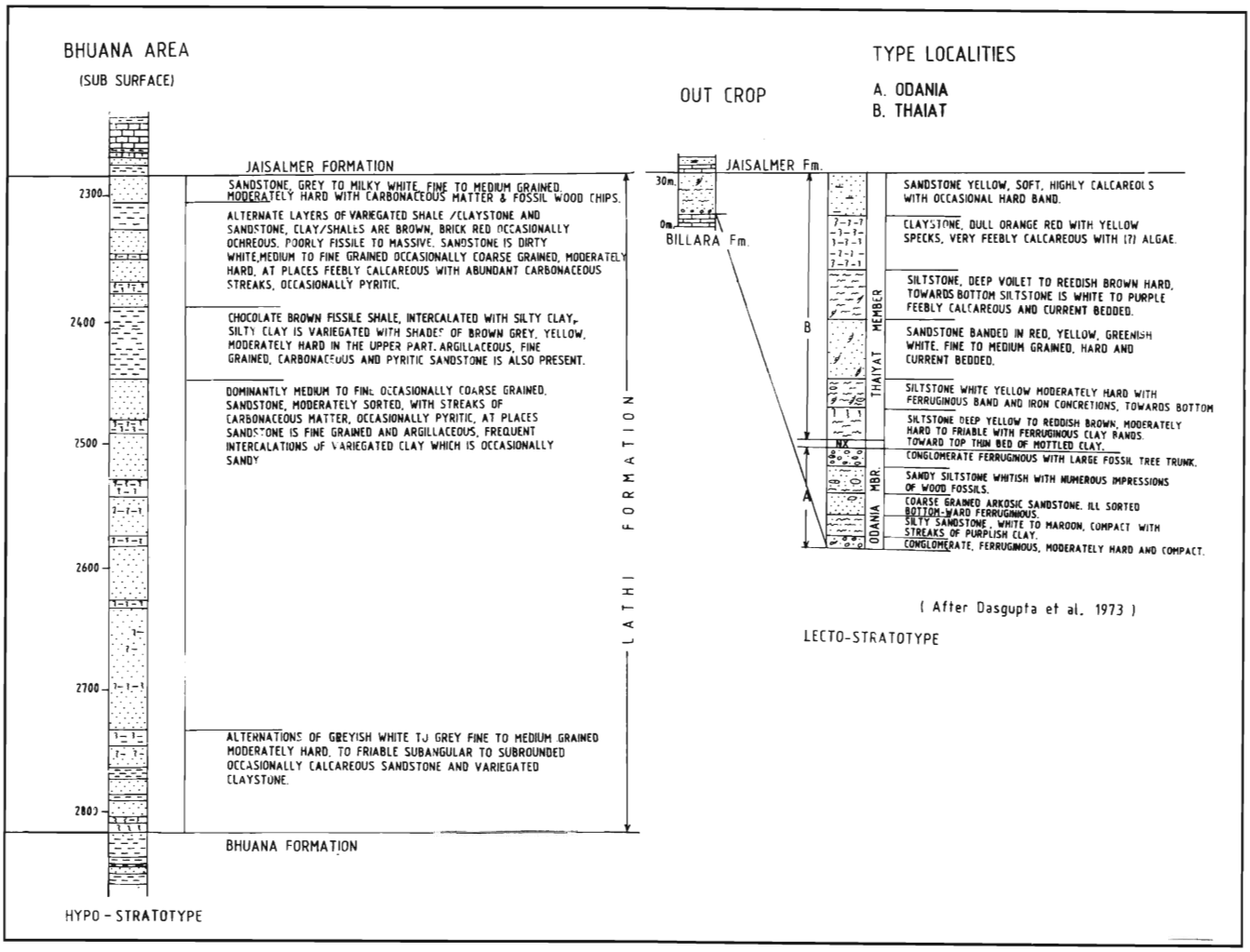


Fig. 9. Stratotype of the Lathi Formation.

maximum thickness. Dasgupta (1975) subdivided this formation into two members, namely Odania and Thaiat and gave partly the vertical, exposed section at Thaiat.

Type area and other reference sections: Exposures at Odania and north west of Thaiat village. Besides, full section of the formation is encountered in the subsurface in Bhuana well. The exposed maximum thickness is 60 m as reported by Swaminath *et al.* (1959). Maximum thickness in subsurface is 600 m in the Shumarwali Talai area.

Lower boundary: In the northern outcrops, the base of the formation is conglomerate with coarse and ill-sorted sandstone which overlies the Bilara-equivalent formation of Proterozoic to Lower Cambrian age and at places, also the Birmania Formation. In other areas, it overlies the volcanic or granitic rocks southeast of Odania, indicating a big hiatus. However, in subsurface it conformably overlies the Bhuana Formation.

Upper boundary: The formation has conformable and intertonguing relationship with overlying Jaisalmer Formation both in surface and subsurface.

Lithology : The formation is well exposed near Lathi, north west of Thaiat, Odania and Akal. It is mainly an arenaceous sequence of medium to coarse-grained sandstone with interbeds of shale, claystone and occasional lignite (Fig.9). The exposed formation has been subdivided into two members namely, Odania and Thaiat by Dasgupta (1975).

Odania Member: It comprises the conglomerate bed at the base followed by white to maroon, sandy siltstone, coarse, grained, dark, ferruginous sandstone, arkosic, coarse-grained, ill-sorted sandstone grading upwards to whitish grey, sandy siltstone with numerous wood fossils. At the top, it has another conglornerate bed with large fossil tree trunks associated with coarse-grained sandstone bands in the scarp section south of Bhojka. This member overlies the Bilara-equivalent Formation in north and south east of Odania village.

Thaiat Member: This member includes alternating sequence of siltstone, sandstone and claystone. Deep yellow to reddish brown, moderately hard to friable siltstone with ferruginous clay bands and iron concretions are exposed towards the base which is followed by sandstone in bands of red, yellow, greenish white, fine to medium grained, hard and current-bedded. The succeeding beds mainly comprise siltstone and claystone. Siltstones are deep violet to reddish brown, hard, occasionally feebly calcareous, purple and current bedded. Claystone is variegated, dull orange, red to yellowish white, soft and very feebly calcareous with algal matter. The top beds are represented by yellow, calcareous, soft sandstone with occasional hard bands. 'Kerboob' structure and "rib"-like structures are generally seen on weathered surface.

In the subsurface, the formation chiefly comprises sandstone

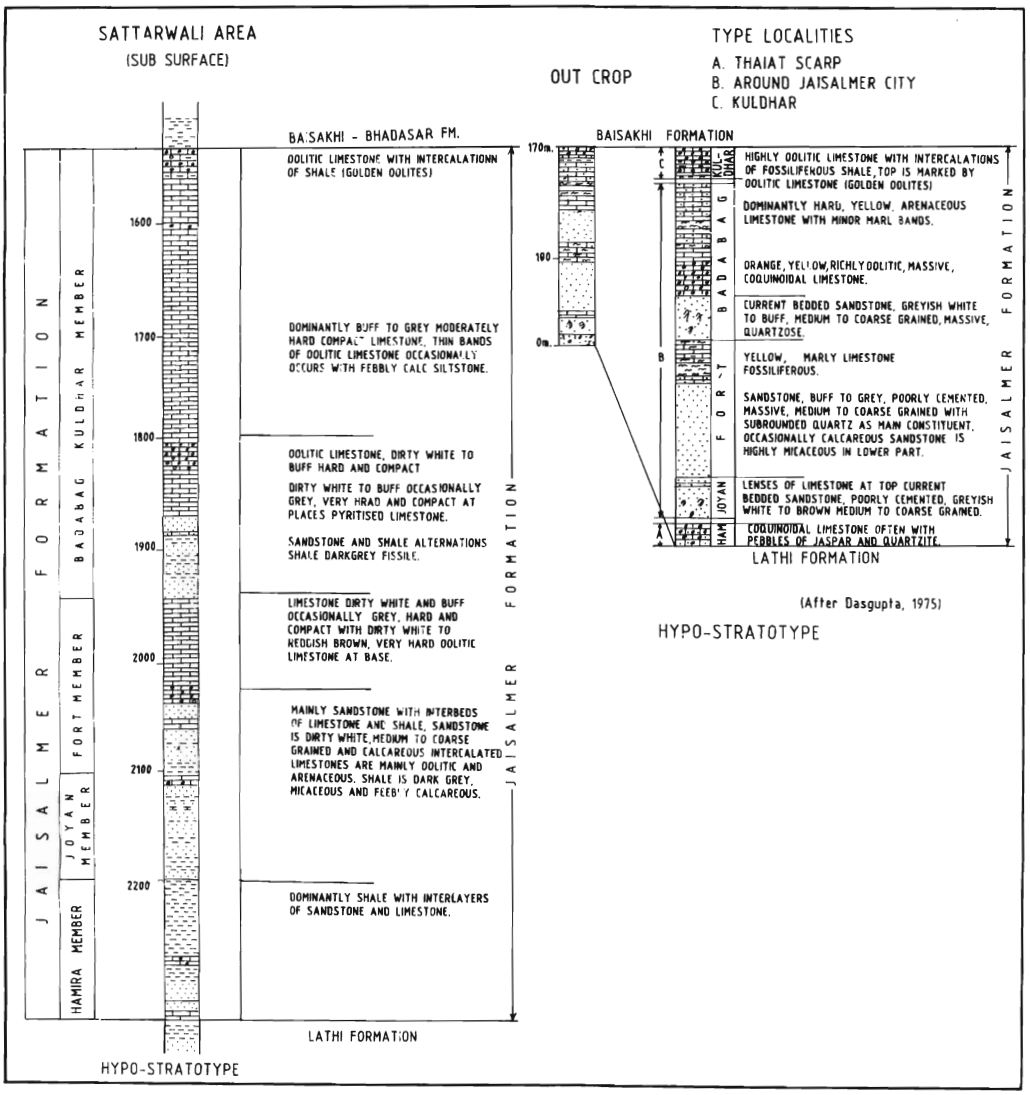


Fig. 10. Stratotype of the Jaisalmer Formation.

shale and variegated claystone. The sandstone is greyish white to grey, fine to medium grained, moderately hard, at places argillaceous, poorly sorted and subangular to subrounded. The shale is grey, fissile, carbonaceous and at places pyritic. In upper part, frequent intercalations of variegated clays and shales are common. Clays are grey, chocolate brown, brick red and yellow, moderately hard and compact.

Age and depositional environment: Ritcher-Bernburg and Schott (1957) reported fossil wood of gymnosperm from the Lathi outcrops. Subsequently, Verma (1960, referred in Narayanan *et al.*, 1961) reported leaf impressions of *Pterophyllum* sp., *Ptilophyllum acutifolium* and *Equisetites* sp. from the sample collected at a locality near Devikot. Lukose (1972) recorded a rich assemblage of palynoflora from Chor tube well which shows abundance of *Spheripollenites*, *Classopollis, Gliscopollis*, *Araucariacites* and *Inaperturites*. Based on this assemblage, the Lower Jurassic (Liassic) age has been assigned. The sediments of the formation were deposited in an overall regressive phase. Presence of fossilised tree trunks, cross-bedding, coarse, ill sorted sandstone in the lower part as well as grey shale, silt and calcareous nature of sandstone along with carbonaceous matter are suggestive of a fluvio-deltaic environment of deposition.

Correlation and regional lithological variation: The formation is sporadically exposed in the south, south-east and east of Jaisalmer district. The topmost part is exposed near Thaiat south of Deora and in the north-east up to Malingra. To the south, the exposures are near Khauriya-Ki-Dhani between Deora and Jogidarshan and along the road from Jaisalmer to Vinjorai, Dabla, Chor and south of Fatehgarh. In the sub-surface the formation has been drilled only in eastern and south-eastern part of the Jaisalmer basin in wells at Sattarwali, Shumarwali Talai, Manhera Tibba, Ghotaru, Bhuana and Lunar. The thickness progressively increases towards northern and western part of the basin. No major lithological variation has been observed in the this formation except the basal conglomerate present in outcrops has not been observed in subsurface. The formation becomes more argillaceous towards the basinal part as observed in the wells of Ghotaru and Manhera Tibba.

JAISALMER FORMATION

Nomenclature: Authors; Swaminath *et al.* (1959). The formation was first described by Oldham (1886) as "Jaisalmer

Limestone" without mentioning the type section and limiting boundaries. Allison (1939) named it "Jaisalmer Group". Subsequently, Swaminath *et al.* (1959) formalised this unit as "Jaisalmer Formation" and redefined upper boundary but did not mention the type area. Narayanan *et al.* (1961) and Dasgupta (1975) gave further details of the formation and identified its type localities.

Type area and other reference sections: A more or less complete section of the formation is exposed on southern flank of Dujero Dungar anticline. However, the entire formation with well developed, different members is not exposed at one place due to isolated, eroded and horizontally bedded outcrops, therefore two or three localities have been selected to reconstruct the formation from base to top. Important localities are north west of Thaiat, Hamira, around Jaisalmer city and Kuldhar. In subsurface, Ghotaru and Sattarwali well sections are taken as reference sections. Narayanan *et al.* (1961) recorded a thickness of 170 m for the formation at Dujero Dungar anticline whereas, Swaminath *et al.*, (1959) reported 362 m around Jaisalmer town. In the subsurface, maximum thickness of 1138 m is encountered in Ghotaru area. Its thickness is likely to be much more in the Shahgarh sub-basin.

Lower boundary: It is conformable, gradational and intertonguing both in outcrops as well as in subsurface sections. In outcrops, dull orange, red to yellow claystone bands represent the lower limit of the formation with underlying Lathi Formation.

Upper boundary: The contact between the Jaisalmer Formation and the overlying Baisakhi Formation is not very clear in outcrops, although it has conformable relationship. However, a sharp facies change from oolitic limestone of the Jaisalmer Formation to gypsiferous clays of the Baisakhi Formation has been noticed near Kuldhar Village. In subsurface, upper boundary is placed between oolitic limestone and glauconitic, plastic clays exhibiting identical condition with that of outcropping area.

Lithology: The formation is well exposed in southeastern part of Jaisalmer–Mari High around Jaisalmer town. It is mainly represented by yellow coloured hard, fossiliferous limestone with interbeds of calcareous sandstone. Dasgupta (1975) sub-divided the formation into five members (Fig.10). These are :

Hamira Member: It is the lower most member which consists of yellowish white, arenaceous, at places, coquinoidal limestone with fragments of bivalve shells. A thin dirty white marl band is noticed within coquinoidal limestone.

Joyan Member: It comprises poorly cemented, greyish white to brown, fine to medium grained, occasionally coarse grained sandstone in the lower part and fossiliferous and peloidal limestone in the upper part.

Fort Member: This member is best seen in Jaisalmer fort escarpment and comprises greyish white, medium to fine grained sandstone at the base which is slightly calcareous and current bedded in the upper part. The sandstone is followed by several beds of yellowish brown, hard, compact, fossiliferous, limestone with thin interbeds of argillaceous limestone containing brachiopods and molluscan shell fragments. The limestone at the top of this member is yellow, sandy, at times oolitic and fossiliferous.

Badabag Member: It is exposed in the escarpment section of the Badabag area. The base of this member is marked by ferruginous greyish white, coarse to medium and friable sandstone. It is overlain by yellowish brown oolitic limestone grading upward into sandy limestone having a few marl bands. An intraformational conglomerate overlies the sandy limestone. This is followed by a cross-bedded highly calcareous sandstone.

Kuldhar Member : It is the topmost member of the Jaisalmer Formation characterized by fossiliferous limestone followed by alternations of fossiliferons limestone and shale. The limestone is oolitic and the top is marked by a golden oolite bed. In subsurface, the formation is mainly represented by limestone with interbeds of shale and sandstone. It is observed that in the lower part of the formation frequent interbeds of calcareous sandstone and shale with thin intercalations of limestone are present, while the upper portion is composed of monotonous limestone with occasional thin intercalated shale.

Age and depositional environment: From the outcropping Kuldhar Member of the formation, Hoffmann (referred by Rithor–Bernburg and Schott, 1957) identified several ammonite species such as *Reineckia,* cf. *R. waggeni, Indosphinctes* sp. *Kinkeliniceras* sp., *Mayaitis* sp, *Dhosaites* aff. D. *otoitoides* etc. Besides, *Turritella* sp. and *Ostrea marshi* were also recorded alongwith above cephalopods. This assemblage suggests Callovion to Oxfordian age. Subbotina *et al.* (1960) studied microfauna from the same member and recorded mostly the species belonging to family laginidae and spirillinidae and dated the sediments as upper part of Callovian to Oxfordian. Dave and Chatterjee (1996) recorded smaller benthies from Fort Member to Kuldhar Member of the formation and recognized four biostratigraphic zones namely *Tewaria* sp-*Dorothia poddari* assemblage zone, *Lenticulina discipiens* range zone, *Tewaria kutchensis* partial range zone and *Epistomina mosquensis* range zone referable to lower Bathonian. Lower Callovian, Middle Callovian and Middle Late Callovian. In sub-surface Sigal (1967) and Singh (1996) carried out detailed biostratigraphic study. The hard, compact, cryptocrystalline limestome of Jaisalmer Formation could be studied only through thin sections which showed the presence of megafossils as wells as microfauna which comprise mostly long ranging taxa. However, Srivastava *et al.* (1995) recorded *Tewaria* sp from this sequence alongwith non-diagnostic taxa, which suggests Middle Jurassic (Bathonian) age. The top most oolitic limestone of the formation is comparatively soft and yielded interesting foraminiferal assemblage comprising *Nautiloculina oolithica, Trocholina* cf. *transversarii, T.* cf. *conosimilis, T.* cf. *elevata, Conicospirillina basiliensis* and *Pseudocyclamina virguliana.* This assemblage suggests same age as that of Subbotina *et al.* (1960). Considering all above inferences Bathonian to Oxfordian age has been assigned to Jaisalmer Formation.

The shelf, after the deposition of the Lathi Formation had morphology of uniform, gentle slope, from east to west. On this wide stable shelf open marine conditions got established at that time. The basal part of the formation is mainly represented by calcareous sandstone, shale with intercalations of oolitic grainstone, mudstone and wackestone microfacies. This lithoassociation is indicative of stable shelf regime and its deposition took place under fluctuating energy conditions in near shore environment. The upper part of the formation is a thick limestone sequence comprising oolitic-bioclastic grainstone, wackestone and mudstone microfacies with frequent intercalations of shale and rarely sandstone, which shows a quite low energy environment over a stable shelf with occasional intertidal effect.

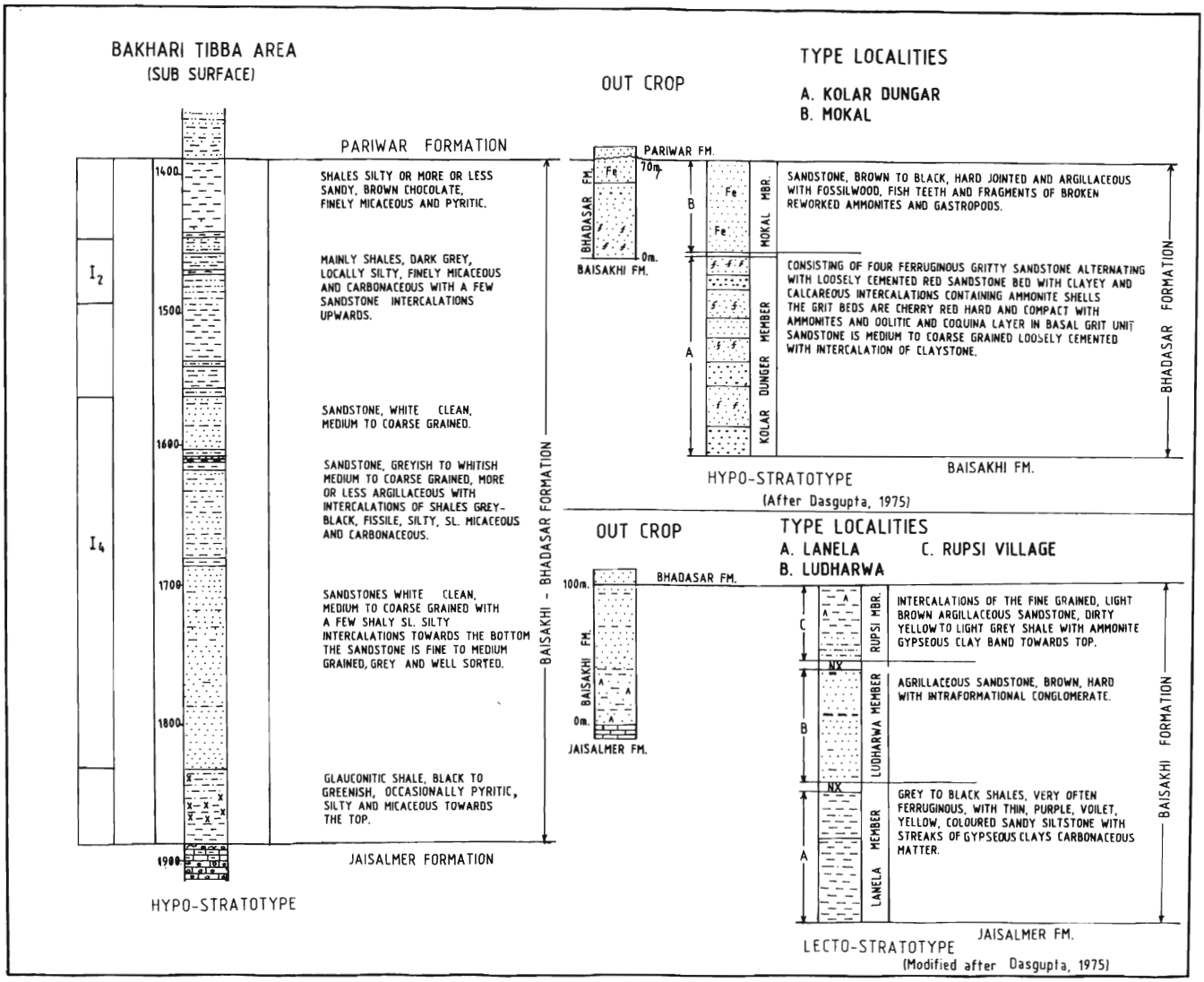


Fig. 11. Stratotype of the Baisakhi-Bhadasar Formation.

Correlation and regional lithological variation: The formation is extensive on surface as well as in the sub-surface. A broad stable shelf came into existence during Middle Jurassic and wide spread thick carbonate depositions took place. The outcrops extend from south, south-east to north and north-west of Jaisalmer. Its southern extension has been reported from scarps of Fatehgarh (Fig.3) around rivdi village. The top of formation has been traced from Kinod Biram to near Dujero Dungar and is best exposed near village Kuldhar. Fort Member outcrops near Jesurana to Gharui Dungar. The basal Hamira Member is exposed at the top of Thaiat scarp. In subsurface, the formation has been fully penetrated in the wells at Sadewala, Ghotaru, Bakhri Tibba, Sattarwali, Shumarwali Talai, Bhuana and Lunar and shows progressively increasing thickness towards west and northwest (Fig. 6). The basal Hamira Member consisting of arenaceous limestone, sandstone and basal conglomerate bed, is correlatable in the subsurface and is present in a well drilled at Ghotaru but it is more shaley in well Sattarwali and arenaceous in Bhuana well. The succeeding Joyan Member shows good correlation between exposure and subsurface. The overlying Fort, Badabag and Kulkdhar members get merged basinward and represent a monotonous lithology of hard, compact, crystalline limestone with increased argillaceous content.

BAISAKHI AND BHADASAR FORMATIONS

Baisakhi and Bhadasar formations have been mapped on surface as separate stratigraphic units but their differentiation in sub-surface could not be made and are considered as a single formation.

BAISAKHI FORMATION

Nomenclature: Authors; Swaminath, J., J.G. Krishnamurthy, K.K. Verma and G.J. Chandak (1959). Baisakhi Formation was mapped earlier as a part of "Jaisalmer Group". Swaminath *et al.* (1959) were first to separate it from Jaisalmer Group as distint lithounit and designated as "Baisakhi Formation". They placed the formation's top below basal grit of Bhadasar Formation. However, Swaminath *et al.* (Ibid) did not mention the vertical section and also did not mention the type section. Subsequently, Narayanan *et al.* (1961) and Dasgupta (1975) gave the lithological account. Besides, latter author subdivided the formation into three members which are Baisakhi Member, Ludherwa Member and Rupsi Member. Misra *et al.* (1993)

renamed Baisakhi Member as Lanela Member as per international code of nomenclature. Narayanan (1964) reported thickness in outcrops 150m but maximum thickness is recorded of the order of 250m on surface.

Type area and other reference sections: Complete section is not exposed at one locality. Therefore the formation is described from three localities which are ; i) West of Baisakhi village ii) Scarp section around Ludharwa and iii) scrap section in west of Rupsi village. Besides this, Bhadasar scarp section shows upper limit of the formation with overlying Bhadasar Formation.

Lower boundary: The formation conformably overlies Jaisalmer Formation which is well exposed near deserted Kuldhar village but here the contact seems to be faulted. Narayanan *et al.* (1961) opined that lower boundary of the formation is seen properly on southern flank of Dujero Dungar anticline whereas in most of areas it is covered by alluvium.

Upper boundary: The upper limit in outcrops is slightly unconformable. A very persistent conglomerate with reworked ammonites from older beds form the basal bed of Bhadasar (Narayanan, 1964). Similarly, Dasgupata (1975) has also mapped a hard compact conglomerate bed between Baisakhi and Bhadasar formations in south eastern part of the baisn near Damodara village. In general the overlapping relation of Bhadasar Formation with the underlying formation is observed. This overlap increases in South west (Narayanan *et al.* 1961). Besides, Willm (1964) has mapped an angular unconformity with negligible dip between Baisakhi and Bhadasar formations in the west along Kanoi fault and in the neighbourhood of Gugadi. In subsurface there is no differentiation between Baisakhi and Bhadasar formations.

Lithology: Baisakhi Formation is represented by grey, greenish grey to black gypseous shale, argillaceous sandstone and intrafromational conglomerate (Fig.11). The formation is divisible into three members which are :

Lanela Member: Dasgupta (1975) proposed Baisakhi Member within Baisakhi Formation which is not in agreement with the code of stratigraphic nomenclature. A new name Lanela Member has been given as already indicated. It comprises grey to black shale very often ferruginous with thin intercalations of purple, violet, yellow, sandy siltstone along with streaks of gypseous clay, carbonaceous bands and rare plant remains.

Ludherwa Member: It is typically exposed around scarps of Ludherwa village and consists of brown, hard, argillaceous, fine to medium grained sandstone and intraformational conglomerate.

Rupsi Member: It is dominantly grey to greenish grey shale intercalated with fine grained light brown, current-bedded sandstone. The shale beds are having abundant ammonites. The uppermost part of this member consists of gypseous clay bands.

BHADASAR FORMATION

Nomenclature: Authors; Swaminath *et al.*, (1959). This formation was first named by Oldham (1886) as "Bedesir beds" after village Bhadasar. Later on Allison (1938, referred in Arkell, 1956) described it as "Bedesir Group". Swaminath *et al.* (1959) dropped the word 'Group' and proposed it as "Bedesir Formation" without giving type section and also did not discuss about vertical and lateral lithofacies. Subsequently, Narayanan *et al.* (1961) and Dasgupta (1975) discussed lithology in detail from the type area. The latter author also subdivided the formation into two members namely Kolar Dunger and Mokal.

Type area and other reference sections: Exposures at Bhadasar scarp. Besides, outcrops of Bhadasar formation are present at Kolar Dungar and Mokal village. Swaminath *et al.* (Ibid) reported thickness of the formation around 372 m but Dasgupta *et al.* (1973) assessed only 70 to 85 m.

Lower boundary: Unconformable in outcrops as already discussed while describing Baisakhi Formation. In subsurface, it is not possible to differentiate Baisakhi and Bhadasar formations.

Upper boundary: The formation is eroded and overlapped by sandy Pariwar Formation. The contact is not very clear but seems to be disconformable in outcropping area whereas, in subsurface it is gradational with the overlying Pariwar Formation.

Lithology: The formation is mainly an arenaceous sequence composed of ferruginous sandstone at places gritty with thin intercalation of clays (Fig.11). The formation is further divisible into two members ; Kolar Dungar and Mokal.

Kolar Dungar Member: This member comprises alternations of ferruginous gritty sandstone and loosely cemented sandstone beds with calcareous clay intercalations containing broken ammonite shells. In Bhadasar scarp a thin coquina bed has been reported from basal gritty sandstone. From its upper section giant ammonites have been collected from Nimar river section in south west of Bhadasar.

Mokal Member: It comprises brown, hard, jointed, fine grained, argillaceous, ferruginous and feebly calcareous sandstone with fossil wood, fish teeth, fragments of broken reworked ammonite, gastropods, bivalves etc.

BAISAKHI-BHADASAR FORMATION

In subsurface, it is difficult to differentiate these two formations from each other and hence, they were clubbed into a single unit as the Baisakhi–Bhadasar Formation by Brajon *et al.* (1967). This formation is encountered in many deep wells drilled on Jaisalmer–Mari High and in the Shahgarh sub-basin. Its thickness varies from 292m to 588m. The formation shows thickening progressively towards west in shahgarh sub-Basin and to the North West in Kharatar and Sadewala area. The formation includes mainly shale and sandstone (Fig.11). Glauconitic brownish black to greenish grey shale characterizes the basal part. At places it is pyritic, micaceous and silty. The middle portion of the formation is mainly composed of sandstone with intercalations of grey to drak grey, carbonaceous, pyritic shale. The sandstone is dirty white to light grey, medium to coarse grained, clean, friable at places fine grained, well indurated, well sorted to moderately sorted, occasionally pyritic and argillaceous. The upper part comprises dark grey, brown to chocolate, fissile, micaceous and carbonaceous shale with interbeds of fine to medium grained greyish to brown, feebly calcareous sandstone. The shales are often associated with thin laminae and intercalations of siltstone.

Age and depositional environment : The outcrops of Baisakhi and Bhadasar formations are rich in fossils, however, it is not applicable to the subsurface sections except two good fossilferous levels at the bottom and the top. Collignon (referred to in Willm, 1964) identified several species of ammonites from the Baisakhi Formation. These are; *Torquatisphinctes similis, T. Habyensis, T. rebillyi, T. tenuistriatus, Katroliceras,*

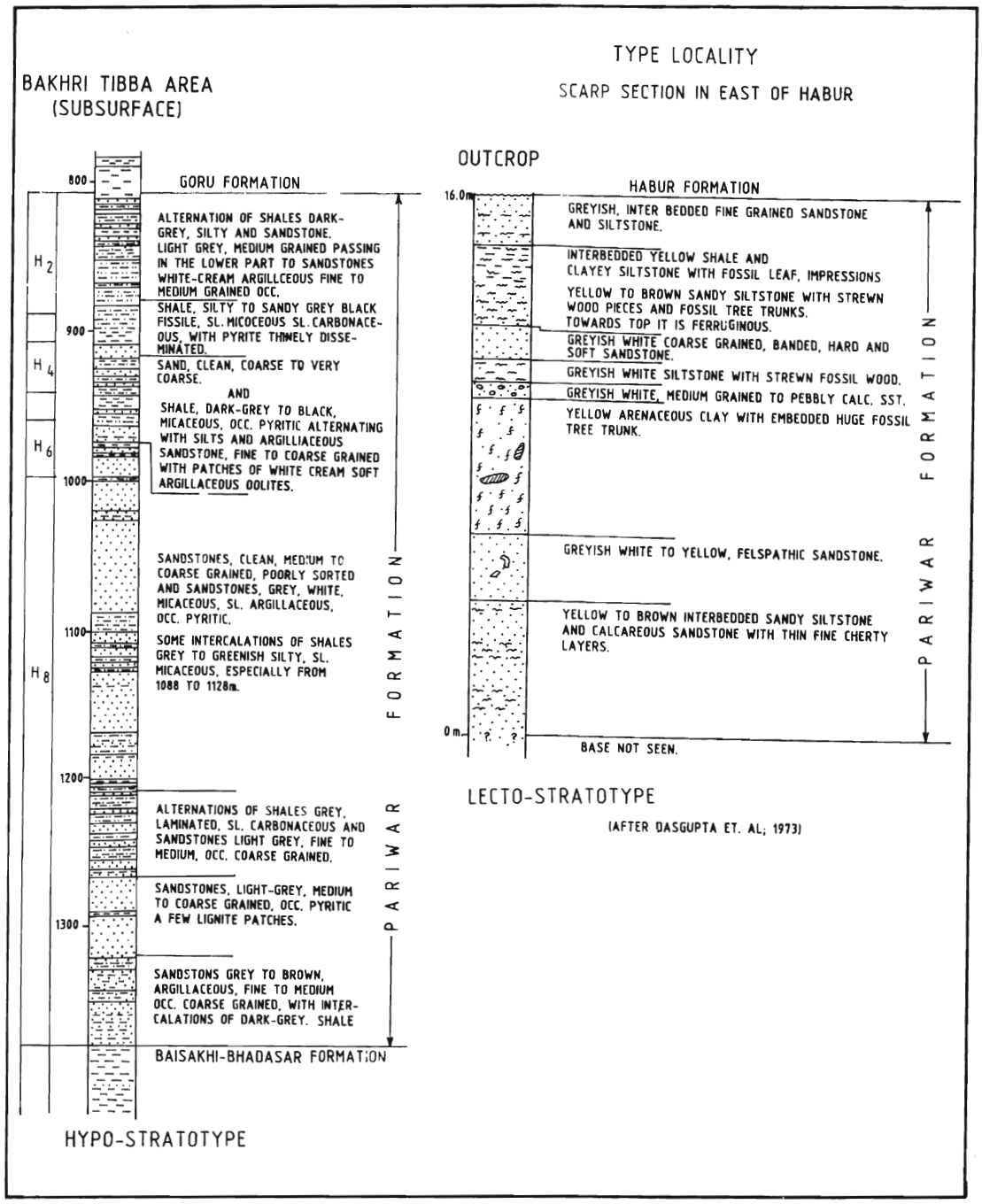


Fig. 12. Stratotype of the Pariwar Formation.

depressum and Dichotomoceras sp. and suggested Lower Kimmeridgian to Lower Middle Kimmeridgian age. Hoffman (referred to in Ritcher-Bernburge and Schott, 1957) studied the outcrop samples of the Bhadasar Formation and identified *Virgatosphinctes densiplicatus, V. communis, Aulacosphinctes occultefurcatus, Hibolites* sp. and *Perisphinctes* spp. along with brachiopods such as *Terebratula* sp. bivalves, gastropods, corals and *Belemnites* sp. This assemblage suggests the Tithonian age. In the sub-surface, Sigal *et al.* (1970) have recorded an index fossil *Epistomina ventriosa* from the glauconitic shale sequence developed at the base of the Baisakhi-Bhadasar Formation. This has precisely indicated Lower Kimmeridgian (Upper Jurassic) age. This formation in the subsurface is generally very poor in fossils but towards top of the formation an arenaceous foraminiferal assemblage with several species of *Trocholina, Haplophragmoides* and *Ammobaculites* is recorded (Sigal *et al.*, 1970), which indicate the Portlandian age.

In outcrops, the formation is mainly arenaceous with grit beds, oolites and abundant species of ammonites. Towards top, the silicified tree trunks are frequent. The presence of oolites indicate strong tidal action. The presence of ammonites suggests shallow marine environment. The sediments towards top part of the formation were deposited in high-energy, near shore environment as evident by presence of fossil wood and current bedding in the sandstones. On the whole, a near shore

to shallow marine environments have been inferred for the formation. In the subsurface, the sandstone beds appear to be the stacked shoreface aggradational deposits. Presence of black carbonaceous shales indicates coastal and swampy environment.

Correlation and regional lithological variation: The change of provenance from the Jaisalmer Formation's limestone to this formation's clastic sequence define the lower boundary very sharply. Dave and Chatterjee (1996) have reported disconformity between the Jaisalmer and Baisakhi formations based on benthic formaminifera. This provenance change was caused due to initiation of intense igneons activity during Upper Jurassic along the axial belt. The resulting clastic sequence representing, Baisakhi–Bhadasar Formation continued to be deposited in an oscillating shallow marine environment. The Baisakhi Formation outcrops as semi-arcuate belt, nearly 10-12 km. wide in the north and west of Jaisalmer extending from Dujero Dungar to Mohangarh. The Bhadasar Formation is mainly exposed in a narrow strip of about 5 km. Trending NE-SW from Boa and Kanoi to Chattral and to the east of Than, the Baisakhi Formation in the outcropping area is represented by gypseous shale (Lanela Member) at its base while in sub-surface the base of this formation comprises glauconitic greenish grey to brownish black pyritic shale. Moreover, the Baisakhi and Bhadasar formations could not be differentiated in the sub-surface and form a single lithounit. There is a progressive lateral change in lithological characters towards the west, i.e. away from the basin margin. In a well drilled at the Lang area, the formation is dominantly argillaceous in its middle portion.

PARIWAR FORMATION

Nomenclature: Authors; Swaminath et al., (1959). Oldham (1886) first described the formation as "Parihar beds" which included the entire arenaceous sequence from Lower Cretaceous to Palaeocene. Swaminath *et al.* (1959) designated it as " Parihar Formation". Dasgupta (1958) suggested informally two subdivisions of this formation as lower and upper members based on lithology. Willm (1964) redesignated the formation as "Pariwar Formation". Dasgupta *et al.* (1973) redefined its limits by restricting it to his earlier defined lower member, which is rich in plant fossils.

Type area and other reference sections: Scarp section east of Habur village. Besides, two Pariwar hills around Pariwar village are the sole representative of this formation. The friable sandstone of the formation gets soiled and forms flat ground in most of the outcropping areas. Dasgupta (1975) has measured about 350 m thickness of the formation on surface. In subsurface, maximum thickness of the order of 850 m is recorded in Lang well.

Lower boundary: In outcrops, the base of the formation is not seen at type locality. However, disconformable relationship with underlying Bhadasar Formation is suspected south west of Pangli by Narayanan *et al.* (1961). The contact has been marked between coarse pebbly to conglomeratic sandstone of Pariwar Formation and brownish black sandstone of Bhadasar Formation. In the subsurface, this contact is conformable.

Upper boundary: Upper boundary in outcrops is unconformable with overlying Habur Formation. The contact is marked between arenaceous limestone of Habur Formation and brown current-bedded sandstone of the Pariwar Formation. In subsurface, it has conformable relationship with the overlying Goru Formation.

Lithology: In outcrops, the Pariwar Formation is mainly an arenaceous unit and is found to be unfossiliferous except plant fossils (Fig.12). The lower part of the formation is chiefly represented by yellow to brown interbedded sandy siltstone and calcareous sandstone. The sandstone at places shows cross bedding feature and is greyish white to yellow and felspathic. The middle part of the sequence consists of yellow arenaceous clay with embedded huge fossil tree trunks. The upper part of the formation comprises medium grained to pebbly sandstone and siltstone with fossil wood at its base which is followed by greyish white fine grained sandstone interbedded with yellow to brown sandy siltstone containing fossil leaf impressions.

In the subsurface, the entire section (except middle part) shows alternations of light grey to brown, fine to medium grained, rarely coarse grained sandstone and dark grey fissile, micaceous and, at places, slightly silty and pyritic shale. The middle part of the formation is mainly a sandstone section. The topmost part of the formation includes glauconitic shale bands. In the basinward areas, there is no marked difference in lithology except increase in argillaceous contents.

Age and depositional environment: The lower part of the formation is devoid of microfauna however, it has yielded rich palynofloral assemblage of Lower Cretaceous age (Mathur and Mathur, 1968). Besides, two species of *Ptilophyllum* indicative of Lower Cretaceous have also been recovered from this part in core samples of a well drilled in Shumarwali Talai area. Dasgupta (1975) reported huge fossilized tree trunks which were identified by Venkatachala (referred to in Dasgupta, 1975) as species of *Mesembrixylon*. Apart from this, the formation in its upper part shows rich plant leaf impressions in yellow coloured argillaceous siltstone. Maheshwari and Singh (1974) reported a rich assemblage of leaf impressions which include *Taeniopteris vittata, T. densinervis T. spatulata, Ptilophyllum acutifolium, Otazamites imbricatus, Elatocladus conferta, Pageophyllum* sp. and *Gleichenites* sp. The assemblage suggests Upper Jurassic to Lower Cretaceous age. In subsurface, Sigal *et al.* (1970) and Sigal and Singh (1980) recorded an arenaceous foraminiferal assemblage along with very rare calcareous foraminifera at the top part of the formation which comprise *Ammobaculities* cf. *volskiensis, A. gr. eocretaceous, A.* cf. *inconstans erectum, Spiroplectammina* cf. *dorni, Epistomina* cf. *tenuicosta* and *Saracenaria* cf. *fortecosta* of Neocomian age.

The formation has been deposited in an overall regressive phase with marine incursions in the upper part of the formation particularly in Shahgarh sub-basin. Presence of glauconitic sandstone and shales are indicative of shallow marine condition, whereas grey shales, ferruginous sandstone with fossil wood and leaf impressions, current bedding and lignite streaks are suggestive of continental to parallic environment. Narayanan (1964) and Swaminath *et al.* (1959) preferred continental environment of deposition. Dasgupta (1975) suggested continental to deltaic environment of deposition. However, Lukose (1977) suggested continental to brackish and marine environment based on palynofossil studies.

Correlation and regional lithological variation: The formation represents regressive phase and is essentially an arenaceous unit with excellent correlatibility. The lower and upper limits are well marked based on lithological characters. The formation is poorly exposed due to soft and

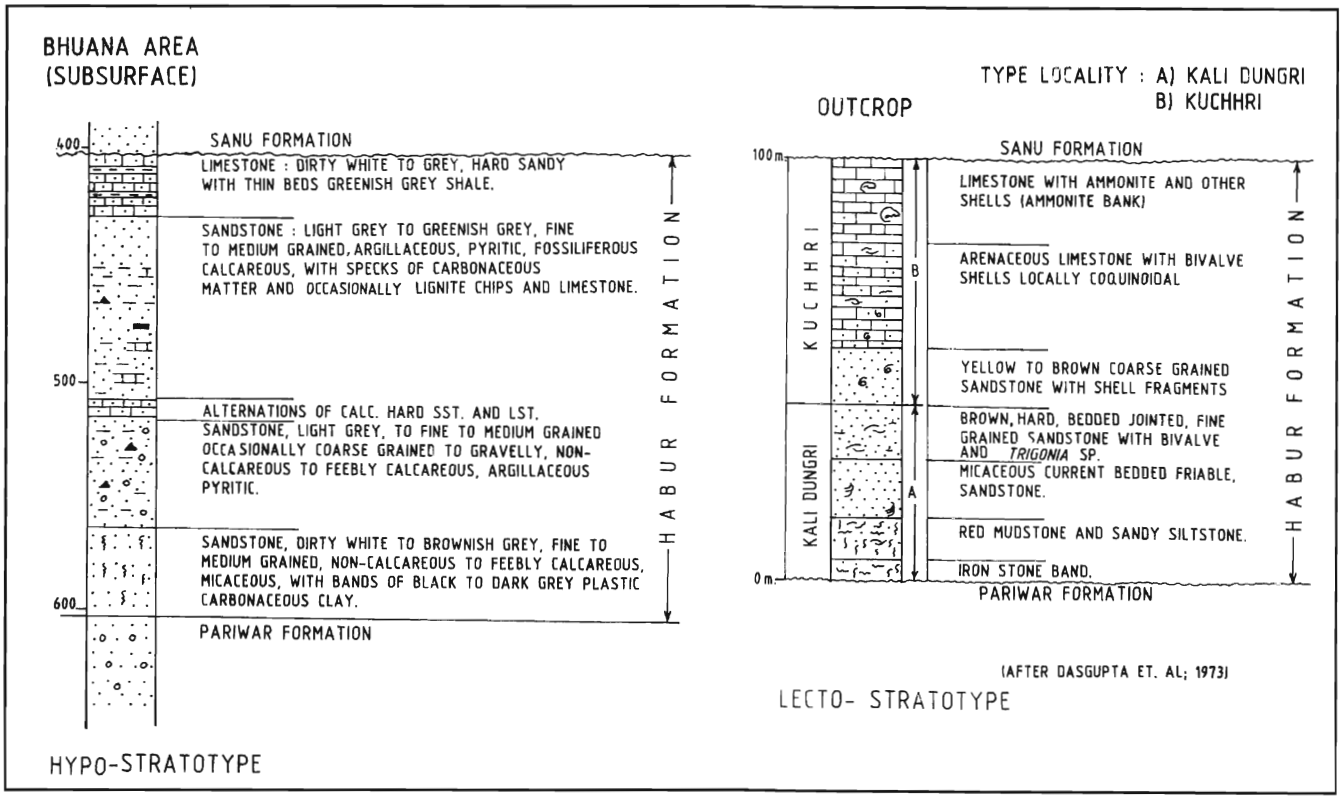


Fig. 13. Stratotype of the Habur Foramation.

unconsolidated nature of silty beds which get soiled forming flat ground. Whitish brown sands generally cover the exposures. The outcrops are trending in NE-SW forming a belt from Khinsar to Bhai Siawala located in north and west of Jaisalmer respectively. In subsurface, Pariwar Formation is extensive throughout the basin. It has been penetrated through in almost all the wells. In sub-surface the formation becomes more argillaceous towards west in Lang area. No major lateral lithological variation has been observed in outcrop except that sandstones are often variegated, coarse, pebbly and ill sorted. In sub-surface, however the sandstones in general are coarse to medium and fine grained in the middle part of the formation with a few shale bands. The lower and upper parts are represented by frequent intercalations of grey to dark grey, pyritic, carbonaceous shale and fine to medium grained micaceous and glauconitic sandstones. Glauconitic shale beds dominate in the upper part of the formation.

HABUR FORMATION

Nomenclature: Authors; Swaminath, *et al.* (1959). The formation was described first by Oldham (1886, 1888) as "Abur beds" and representative outcrops like Kuchri, Habur, Te-Takkar etc. were mentioned. Besides, Carter (1861) and Blanford (1877) mentioned earlier about Kuchri ammonite bank, which forms a part of the formation now. Swaminath *et al.* (1959) dropped the word "beds" and described this sequence as "Abur Formation". Later on, Dasgupta *et al.* (1973) retained the same nomenclature but proposed Habur Formation instead of Abur Formation.

Type area and other reference sections: Outcrops at Habur village and outcrops at Kanoi village. Besides these, the formation is also exposed at Kuchri and Kali Dungri localities. In subsurface, it has been encountered only in Bhuana area. This formation's thickness was first assessed as 65 m by Subramanyam and Mohinuddin (In Narayanan *et al.*, 1961). Swaminath *et al.* (1959) reported it to be 108 m; Willm (1964) indicated roughly 200 m. Subsequently, Dasgupta *et al.* (1973) measured its thickness between 90 and 100 m along the traverse in Kali-Dungri-Serawa, Kuchri and Tetakkar areas. In subsurface, it has been found to be of 203 m in thickness.

Lower boundary: The lower contact between the Habur Formation and underlying Pariwar Formation is a faulted one in the western side between Habur and Kanoi areas. In the scarp section, east of Habur village, the relationship is disconformable as evidenced by the presence of ironstone bands. Near Than, Habur beds are seen overlying Bhadasar Formation. This suggests either a strong overlap or faulted contact. In the subsurface, the formation conformably overlies Pariwar Formation.

Upper boundary: The upper limit of the formation represents a major break between exposed Mesozoic and Tertiary formations. It unconformably underlies Sanu Formation near Mohammad-Ki-Dhani and Kali Dungri. Further in northwest, the formation is directly overlain by Khuiala Formation. In subsurface the formation unconformably underlies Sanu Formation in the well drilled at Bhuana area.

Lithology: The formation comprises mainly alternations of calcareous sandstone, coquinoidal limestone in the lower part and poorly bedded calcareous sandstone, sandy marls and limestone towards top in upper part (Fig.13). The lower most bed of the formation is exposed right at Habur village where it is represented by brown, hard, highly jointed sandy coquinoidal limestone. Orange to brown calcareous sandstones are embedded with this fossiliferous limestone.

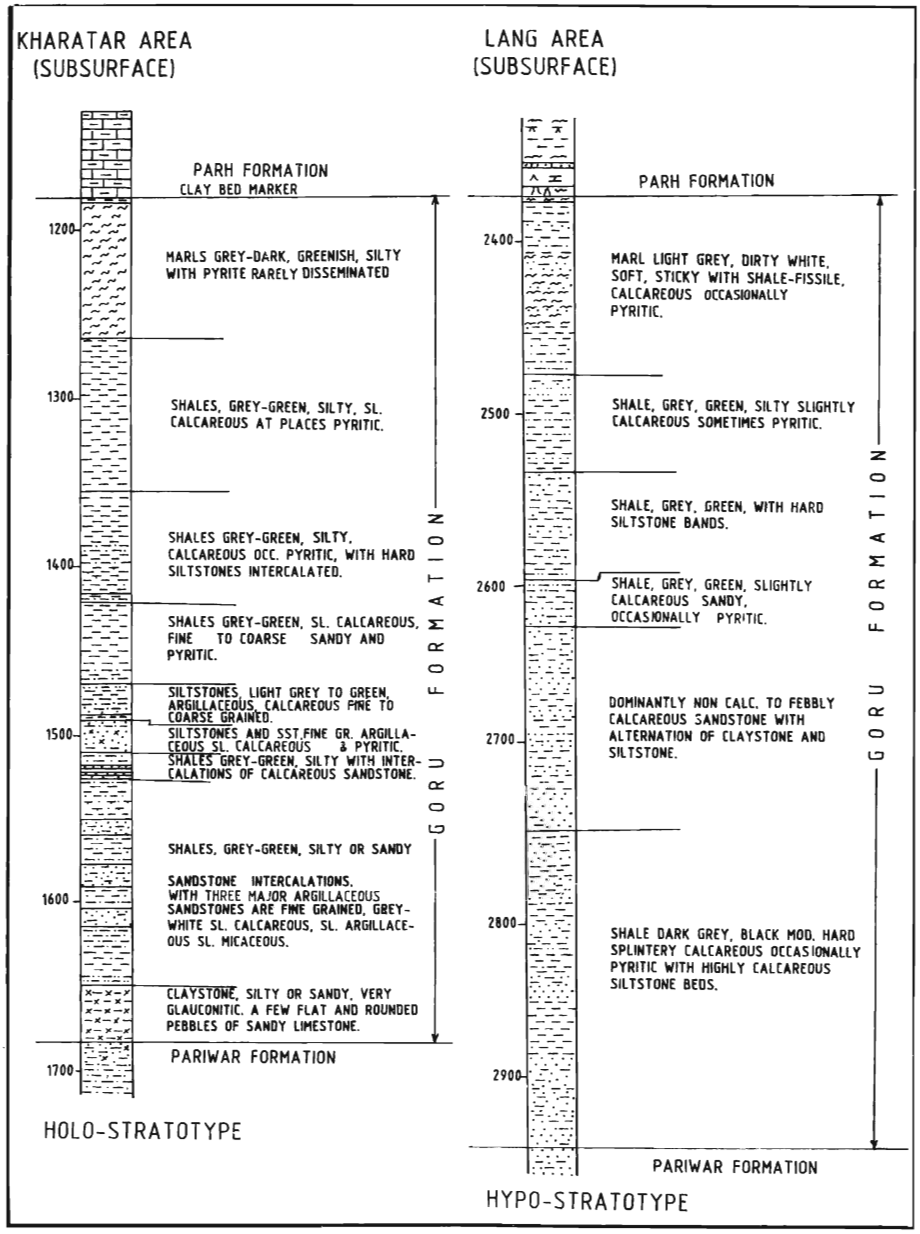


Fig. 14. Stratotype of the Goru Formation.

Very often, such an orange coloured sandstone is the first bed of the formation overlying Pariwar Formation either directly or above a thin conglormerate bed. Intraformational breccia and ferruginous clays are seen intercalated with limestone. The overlying sequence is exposed at Kanoi where it consists of medium to coarse grained, calcareous, arkosic sandstone, at places ferruginous and gritty in the lower part. It is followed by yellow to orange, hard, jointed fossiliferous limestone containing ammonites and belemnites (ammonite bank). The limestone is interbedded with ferrunginous grit and sandstone. The uppermost part is composed of grey coloured limestone, interbedded with shale. In the subsurface, it has been only encountered in the Bhuana well, where it is represented by calcareous sandstone and thin arenaceous limestone in the upper part only.

Age and depositional environment: The lowermost beds of the formation exposed at Habur have been found to be rich in ammonites. Spath (1933) identified ammonites of Lower Aptian age. Schmid (In Ritcher-Bernburg, 1957) recorded several species of *Deshayesites bodei* from this sequence of limestone and dated it as the deepest part of Lower Aptian. Singh and Khanna (referred to in Narayanan *et al.*, 1961) also reported *Saracinella* sp, *S. aff. trezanensis* and S. *subspinosa* suggestive of Valanginian age. Considering mainly ammonite assemblage recorded from the lower part of the formation, the Aptian age has been assigned to the sediments. However, the upper part could not be dated due to nonavailability of megafossils in the outcropping area. In the subsurface, the formation has not yielded fauna. Singh (1978), however, recorded a coquinoidal limestone having broken shell fragments mostly of bivalves from the Bhuana well and equated it with the Habur formation.

The arenaceous limestone, calcareous sandstone with interfingering coquina beds having ammonite shells in the

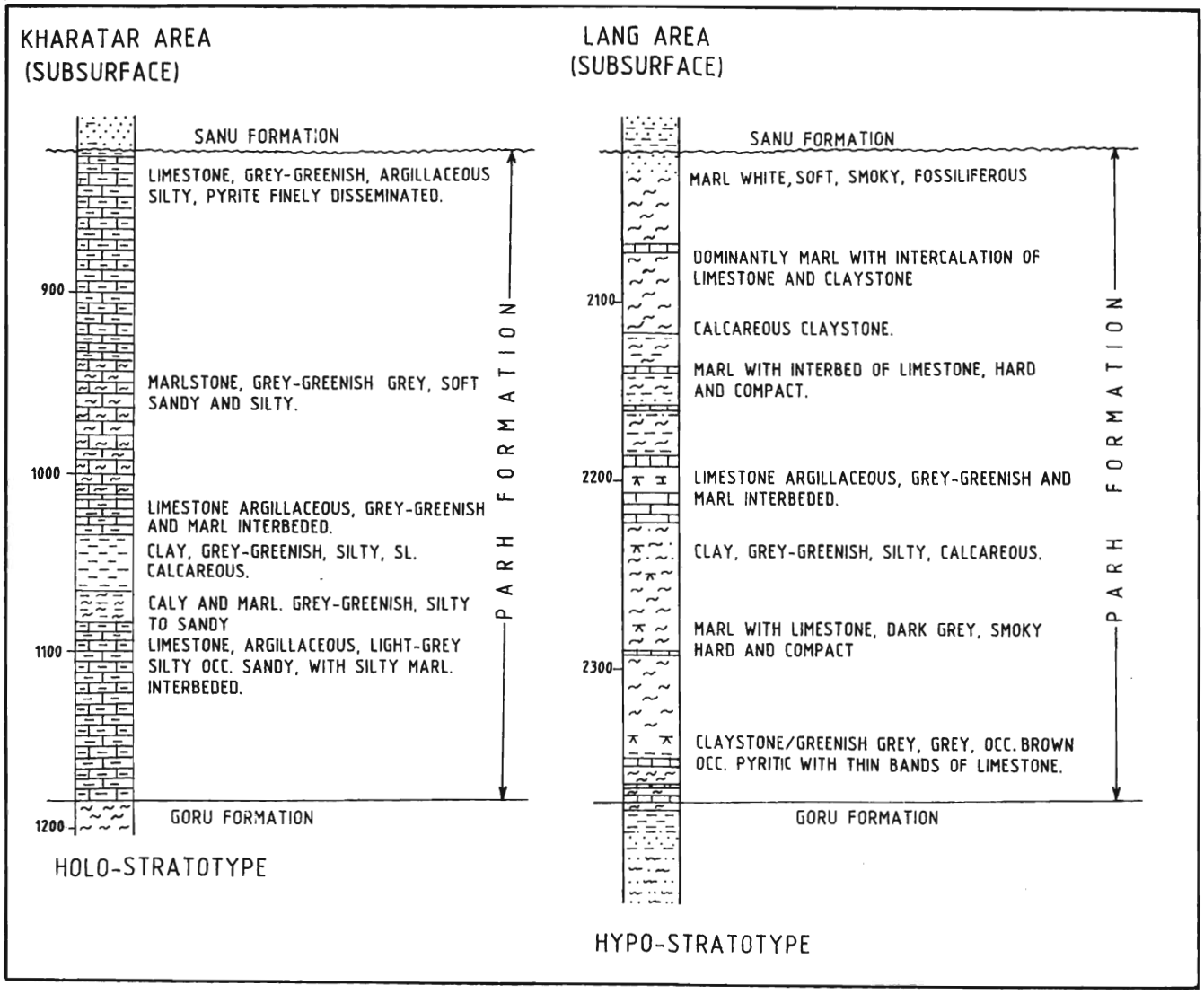


Fig. 15. Stratotype of the Parh Formation.

outcrops, represent a typical basin margin phenomenon. The sediments were deposited in a nearshore environment with occasional effect of storm surges resulting in intercalation of ammonite bank within the litho association.

Correlation and regional lithological variation: The deposition of shallow marine Habur Formation comprising, calcareous sandstone, arenaceous limestone with interfingering coquina beds represents a typical basin margin phenomenon. The formation outcrops 30 km west of Jaisalmer in arcuate fashion, trending approximately, north-south. It tapers off to the north of village Habur and does not extend beyond Ganga Ghar. Towards south, the thickness increases with a wider spread over a large area. The formation makes a low scarp between Habur and Kanoi villages forming a ridge along strike. The arenaceous limestone facies of outcrops grades laterally into medium to coarse-grained calcareous arkosic sandstone in the subsurface (Fig. 6). In Bhuana well, however, thin beds of arenaceous limestone have also been encountered at the top of the formation.

GORU FORMATION

Nomenclature: Authors; Verdier, *et al.* (1967). ONGC initiated exploratory drilling in the Jaisalmer Basin under the joint venture of ONGC and IFP (France) in 1964 and drilled first well in the Kharatar area. Verdier *et al.* (1967) designated the Goru Formation to a sequence of shale, sandstone and siltstone overlying the Pariwar Formation in the subsurface. This formation is confined in the subsurface and does not extend to surface. The nomenclature of this formation is drawn from Pakistan where the formation with same name and age exists. This was originally designated by Williams (1959). Dasgupta (1975) subdivided this formation into Lower Goru and Upper Goru members.

Type area and other reference sections: A well drilled in Kharatar area. Besides, the other reference well is selected from the Lang area. A general thickening of the formation is observed from east to west and northwest. A maximum thickness of 565m has been recorded from a well drilled in Lang area.

Lower boundary: The lower boundary of the formation is conformable with the underlying Pariwar Formation and is settled between grey to olive green highly glauconitic claystone and argillaceous sandstone of Goru and Pariwar formations respectively.

Upper boundary: The upper contact is also conformable with argillaceous limestone of overlying Parh Formation which changes to a dominantly marl sequence in Lang area of Shahgarh sub-basin.

Lithology: In a type well section of the Kharatar area, the lithology is grey to greenish grey, moderately hard, feebly calcareous, occasionally pyritic shale alongwith calcareous siltstone and fine grained argillaceous, micaceous sandstone (Fig.14). The formation is capped by a marl bed. Dasgupta (1975) sub-divided this formation into two members, which are:

Lower Goru Member: The base of the member is marked by the presence of glauconitic greenish grey silty clays. The overlying sequence includes alternations of shale and sandstone. The shales are greenish grey, feebly calcareous, micaceous, occasionally, pyritic at places silty. The sandstone beds are comparatively thin and are light grey to greenish grey, fine grained, calcareous, argillaceous and glauconitic.

Upper Goru Member: It is mainly argillaceous unit composed of shale, siltstone and marl. The shales are grey to green, fissile, slightly calcareous and silty with disseminated pyrite. Siltstone intercalations are light grey, compact and calcareous. Marl beds are dark grey to greenish grey, silty, pyritic and constitute the upper most part.

Age and depositional environment: The Lower Goru Mermber is poorly fiossiliferous particularly in its lower part but consists of distinct assemblage of planktic and benthic foraminifera in its upper part (Sigal, 1965; Sigal and Singh, 1980 and Narayanan and Krishna, 1983). The occurrence of *Hedbergella trocoidea – Globigerinelloides* sp. and *Planomalina buxtorfi. Favusella washitensis* and *Biticinella breggiensis* assigns an Aptian to Albian age to the Lower Goru Member (Singh, 1996). The presence of glauconitic shale just at the base of Lower Goru Member in all the wells of Jaisalmer-Mari High and Shahgarh area perhaps represents topmost event of Early Aptian. The iich and diversified foraminiferal assemblages have been recorded from the Upper Goru Member, which provided the Cenomanian age to this member (Mehrotra and Singh, 1968; Sigal and Singh, 1980). The assemblage correlatable with global biostratigraphic datum plane *Rotalipora cushmani* of Cenomanian age has been established in this member. Thus, Aptian to Cenomanian age has been assigned to the Goru Formation. The most important planktic taxa, except one benthic form, of Goru Formation correlatable with global datum planes, have been illustrated in Pl. I. The lithoassociation and faunal assemblages recorded from the formation suggest an overall transgressive shallow marine environment approaching deeper bathymetery in the upper part. The basal glauconitic shale represents initial marine flooding after the deposition of the Pariwar Formation.

Correlation and regional lithological variation: The Goru Formation is extensive throughout the Jaisalmer basin and is restricted to the subsurface. The sandstone beds are frequent towards shoreward areas, whereas in the basinward Shahgarh area the increase in argillaceous contents has been observed. The Habur Formation outcropping in the eastern area, seems to be homotaxial to the lower part of the Lower Goru Member which has been replaced by the Habur Formation in the basin margin the Bhuana well (Fig. 6).

PARH FORMATION

Nomenclature: Authors; Verdier *et al.* (1967). The argillaceous limestone and marl sequence was first designated as "Parh Formation" by Verdier *et al.* (1967) from Kharatar well where it was first encountered during drilling. The nomenclature seems to have been picked up from the Indus Basin. Blanford (1876) used the word "Parh" to a thick sequence of limestone exposed at Parh hill on Gaj river in the Indus Basin (Pakistan). All subsequent workers have followed it and hence this name, though only time equivalent, has been retained.

Type area and other reference sections: A well drilled in Kharatar area where the formation was encountered for the first time during drilling. Subsequently, the deep wells drilled in the Lang area of Shahgarh sub-basin and from Sadewala area were chosen as reference well sections because the formation is well developed there with appreciable thickness. The formation shows minimum thickness in Bakhri Tibba well of the order of 27m, whereas its maximum thickness (369 m) has been observed in northwestern side in Sadewala well.

Lower boundary: The lower contact has conformable relationship with the underlying Goru Formation and has been marked between the underlying marl bed of the Goru Formation and the argillaceous limestone sequence of the Parh Formation.

Upper boundary: The upper contact represents a well marked unconformity throughout the basin. The contact is marked between marl/limestone of the Parh Formation and chocolate to reddish brown sandy clays of the Sanu Formation.

Lithology: In general, the marl, argillaceous limestone and calcareous clays, represent the formation (Fig.15). The formation in the Kharatar type well section comprises thick, highly argillaceous limestone in the basal part, which is grey, light grey to greenish grey, moderately hard to soft, occasionally pyritic, interbedded with greenish grey, calcareous clay and thin beds of grey to dirty white calcareous siltstone. The lithological sequence in the well of the Lang area is represented mainly by marl, calcareous clay and thin bands of argillaceous limestone. The clay is greenish grey, occasionally brown, soft pyritic and highly calcareous. The associated marl is buff to greenish grey, soft with thin beds of grey, buff, moderately hard, argillaceous limestone.

Age and depositional environment: The argillaceous limestone and marl of the Parh Formation represent Upper Cretaceous sequence which does not extend to the surface. Singh (1996) has worked out detailed biostratigraphy of Cretaceous sequence based on his studies of subsurface sections. Rich and diversified foraminiferal assemablages have been recorded. The important planktic foraminiferal assemblages (correlatable with global biostratigrphic datum planes namely *Helvetoglobotruncana helvetica* and *Marginotruncana coronata – M. Sigali* zones referable to Turonian and Coniacian respectively) have been established in this formation. The biozonal planktic foraminifera of the Parh Formation correlatable with global datum planes have been illustrated in pl.-II. Presence of argillaceous limestone, marl and calcareous clays/shales along with the rich assemblages of planktic foraminifera are suggestive of an open marine environment ranging from middle to outer shelf regime.

Correlation and regional lithological variation: The lower limit is marked on lithological characteristics as the sequence of the Goru shales and marls are overlain by argillaceous limestone of the Parh Formation. The upper limit is marked by a major unconformity. The formation is extensive in the subsurface throughout the Jaisalmer Basin, except in the eastern part where it is absent in the wells drilled at

Sattarwali, Shumarwali Talai, Vikharan Nai, Bhuana and Lunar (Fig. 6). The formation is represented mainly by argillaceous limestone and marl. In the northwest and towards west, it is represented mainly by marl, calcareous clays with occasional limestone bands.

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REFERENCES

Agocs, W.B. 1957. Report on the aeromagnetic survey in Indo-Gangetic plains, Clombo 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 of society*, Bengal **45**(2): 86-103.

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

Brajon, J., Verdier, A.C. and Willm, C. 1967. Completion report on Bakhri Tibba Well No.1 (BT-1), ONGC-IFP report (unpublished).

Carter, H.J. 1861. On the contribution to the geology of Rajputana, *Journal of Royal Asiatic Society*, Bombay Branch volume **6**.

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. *Proceedings of IV^th Colloquim on Indian Micropalaeontology and Stratigraphy*, Dehradun, India : 219-233.

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

Dasgupta, S.K. and Chandra Mahesh 1978. Tectonic elements of the West Rajasthan Shelf and their stratigraphy. *Proceeding of Golden Jubilee Symposinm, Geological Mining Metallurgical Society of India*.

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

Dave, Alok and Chatterjee, T. K. 1996. Integrated foraminiferal and ammonoid biostratigraphy of Jurassic sediments in Jaisalmer basin, Rajasthan, *Journal of Geological Society of India*, **47**: 477-490.

Dhar, C.L. and Mehta V.K. 1974. Compiled geological map of Western Rajasthan, ONGC (unpublished).

International Subcommission on Stratigraphic Classification [ISSC], 1976. *International Stratigraphic Guide* (by H.D. Hodberg. ed.). Jhon Wiley and Sons., N.Y.

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

Lukose, N.G. 1972. Palynological evidences on the age of Lathi Formation, Western Rajasthan, India, Seminar Palcopalynology Indian Stratigraphy (Calcutta University), pp. 155-159.

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.

Lukose, N.G. and Mishra, C.M. 1980. Palynology of Pre-Lathi (Permo-Triassic) of Shumarwali Talai Structure, Jaisalmer, Western Rajasthan, India. *IV International Palynological Conference*, Lucknow (1976-77) **2**: 219-227.

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).

Mathur, Y.K., and Mathur, M. 1972. Angiospermous pollen and associated fossils from the Mid-Cretaceous subsurface sediments of Rajasthan, India, Jour. Palcont. v. III, pp. 89-96.

Maheshwari and Singh, N. P. 1974. On some plant fossils form the Pariwar Formation, Jaisalmer basin, Rajasthan, the Palacobotanist **23**(2): 116-123.

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

Misra, J.S. and Shrivastava, B.P. 1960. Progress report of party no.10, Western Rajasthan, 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).

Mishra, C.M., Prasad, B. and Rawat, R. S. 1996. Triassic palynostratigraphy from the subsurface of the Jaisalmer basin, Western Rajasthan, *Contributions to XV Indian Colloquium on Micropalaeotology and Stratigraphy*, Dehradun : 591-600.

Mitra, P., Mukherjee, M.K., Mathur, B.K., Bhandari, S.K., Qureshi, S.M. and Bahukhandi, G.C. 1993. Exploration and hydrocarbon prospect in Jaisalmer basin, Rajasthan, *Proceedings of II Seminar on Petroliferous Basin of India* : 235-284.

Muktinath, M. 1969. Phosphate deposits in Rajasthan. *Indian Minerals*, **23**(7): 29-42.

Narayanan, K. 1959. Progress report on the geological work in 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 Symposium on Problems of Indian Arid zone, Jodhpur*. Govt. of India publication, New Delhi : 92-100.

Narayanan, V. and Krishana Ajay 1983. Biostratigraphy of Ghotaru-1 well, Jaisalmer basin, Rajasthan, ONGC report (unpublished).

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

Oldham, R.D. (1888). Memorandum on the results of an exploration in Jaisalmer with a view to discovery of coal, *Records of Geological Survey India*, **21**(1).

Oldham, R.D., 1893. *A manual of Geology of India*.

Pandey, J and Dave, Alok. 1998. Stratigraphy of Indian Petroliferous Basin, Presidential Address. *XVI^th Indian Colloquium on Micropalaeoleontology and Stratigraphy*, Goa : 1-248.

Ritcher-Bernburg, G. and Schott, W. 1957. Researches of oil and gas possibilities of India. Report submitted to Govt. of India.

Shrivastava, B.P. and Srinivasan, S. 1963. Geology of Bikaner-Barmer area, ONGC report (unpublished).

Shrivastava, Shekhar, Pandey, V. J., Sharma, D. C. and Singh, N. P. 1995. Palcoenvironmental reconstruction for subsurface sedimentary sequence around Shahgarh sub-basin, Western Rajasthan, India, Proceedings Petrotech-95, New Delhi : 149-160.

Sigal, J. (1965). First microstratigraphical report on Kharatar well No.-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 ala base du Cretace, *C.R. Academy of Science, Paris*, **271**: 24-27.

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

Sigal, J. and Singh, N. P. 1980. Cretaceous biostratigraphy of Jaisalmer subsurface, Rajasthan, India: *VIIIth Colloq. Ind. Micropal. Strat.* (Abstr.), pp.22-23.

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

Singh, N.P. 1976. Micropalcontological control in subsurface Tertiary sequence of Jaisalmer basin, West Rajasthan, India, IV Indian Colloquium on Micropalacontology and Stratigraphy pp. 259-278.

Singh, N.P. 1978. Micropalacontological report on a few samples of Bhuana deep well No.1, Rajasthan. ONGC report (unpublished).

Singh, N.P. 1982. Subsurface Post-Eocene deposits of Jaisalmer basin, Rajasthan, *First National Seminar on Quaternary Environment. Recent Researches 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, Contrs. XV Indian Colloq. Micropal. Strat., Dehradun, pp. 63-89.

Singh, N.P. 2003. Contribution of biostratigraphic studies in stratigraphic evaluation of West Rajasthan Shelf. *Gondwara. Geological Magzing Spl.* **6**: 79-104.

Spath, L.F. 1933. Revision of Jurassic Cephalopods from Kutch (1927-34), Palaeontologica Indica, *New series, V-IX Mem.* **2** (I-VI).

Subbotina, N. N., Dutta, A. K.and Srivastava, B. N. 1960. Foraminifera from the Upper Jurassic deposits of Rajasthan (Jaisalmer) and Kutch, *Bulletin of Geological Mining Metallogical Society of India.* **23**: 1-48.

Swaminath, J., Krishnamurthy, J.G., Verma, K.K., and Chandak, G.J., 1959. General geology of Jaisalmer area, Rajasthan, *ECAFE Symposium, Mineral 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).

Williams, M.D. 1959. Stratigraphy of the Lower Indus basin. West Pakistan. *5th World Petroleum Congress, New York, Proc. Soc.I, paper* 19.

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

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