CHAPTER - 2

LITHO-STRATIGRAPHIC AND TECTONIC FRAMEWORK

LITHO - STRATIGRAPHIC AND TECTONIC FRAMEWORK

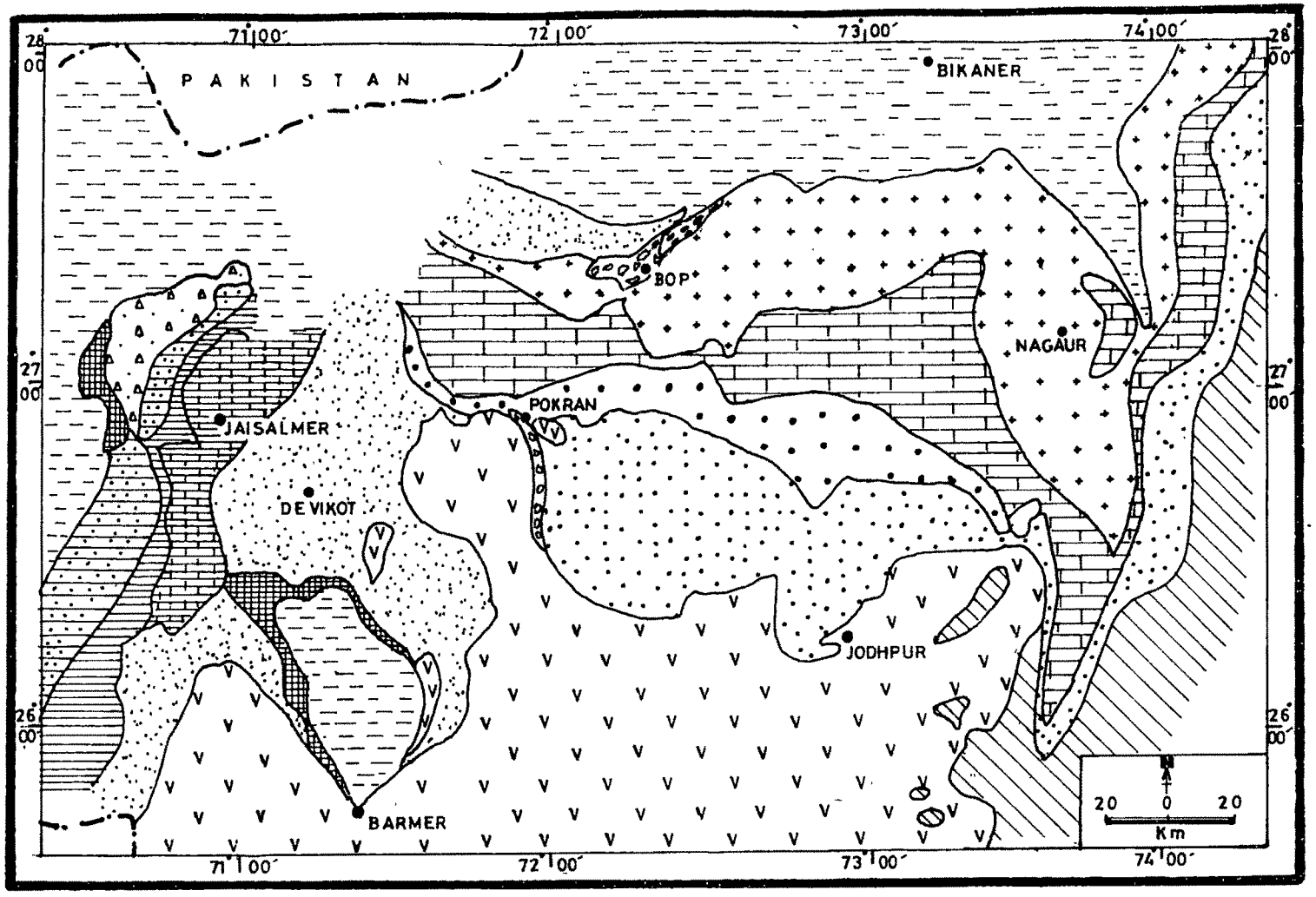
INTRODUCTION

The rock and sand glut Rajasthan state is very enchanting from the geological perceptions. Geologically this state - with one of the oldest mountain chains, the **Aravalli Mountain Chain** - forms the northwest part of the Indian Peninsular Shield.The fascination towards Rajasthan for the earth scientists is due to the well documented stratigraphic record that it possesses from Archaean to the Present day (Figure 2.1). The NE - SW trending Aravalli mountains mark an important physiographic divide that separates the older group of rocks (Archaean, Pre-Cambrian) of the east from the younger ones (Palaeozoics, Mesozoics, Cenozoics and Quaternaries) of the west. Interestingly, Rajasthan also harbours well documented records on tectonic events ranging between Archaean and Recent.

LITHO-STRATIGRAPHIC SET UP

PROTEROZOICS

Proterozoics of Rajasthan, even after a great deal of study, remains perplexing due to their complex stratigraphy and structural style. The pioneering work that provides the basic framework for the Proterozoic rocks of Rajasthan includes the contributions of La Touche (1902) and Heron (1917,1953) The four fold classification envisaged by them for the evolution of these Proterozoics through different orogenic cycles still remains the basis for



Tertiaries

Abur Limestone (Aptian)

Pariwar Sandstone (Neocomian)

Bedesar Sandstone (Tithonian)

Baisakhi Shale (Kimmeridgian)

Jaisalmer Limestone (Callovian - Oxfordian)

Lathi Sandstone (Liassic)

Badhaura Sandstone (Sakmarian - Antinskian)

Bap Boulder Bed / Spread (Lower Permian)

Marwar Supergroup

Nagaur Group

Bilara Group

Jodhpur Group - Girbhakar Sandstone

(Camb-

Jodhpur Group - Sonia Sandstone

Jodhpur Group - Pokaran Boulder Bed

-rian)

Basement Rocks - Malani igneous Suit

Pre Cambrian

Basement Rocks - Metamorphites & intrusives

Fig. 2.1. Pre-Quaternary geology of study area. (After Parikh 1981)

stratigraphic classifications. Eversince the work of Heron (op cit), much light have been thrown on these rocks by a bee line of successive workers viz. Raja Rao et al.(1971), Crawford (1970), Roy (1988) , and Gupta et al.(1992). The voluminous work enabled the latter workers to classify the Proterozoics into four Supergroups viz. (i) The Bhilwara Supergroup (3200 - 2500 m y) (ii) The Aravalli Supergroup (2500 - 2000 m.y), (iii) The Delhi Supergroup (2000 - 800 m.y) and (iv) The Vindhyan Supergroup (700 - 600 m.y). Each of the above groups are well developed and defined by regional unconformities and /or structural styles.

Bhilwara and Aravalli Supergroups

The lithostratigraphic sequences of Bhilwara and Aravalli Supergroups are observed in the eastern parts of the Delhi Mountain Range. The Bhilwara Supergroup of rocks are characterized by high grade metamorphic rocks, while the Aravalli's represent low grade metamorphics However, both the supergroups display four phases of folding (Roy, op.cit)

Delhi Supergroup

Rocks of Delhi Supergroup lie unconformably over the Bhilwara and Aravalli Supergroups. They extend for about 850 km length in a NE - SW trend from Delhi in the north to Himmatnagar in the south. The Delhi's are principally marine clastics with subordinate chemogenic sediments and are characterized by several phases of intrusives and extrusives. The Aravalli Mountain Range is predominantly composed of rocks of Delhi Supergroup forming the Aravalli orographic axis that separates the western Marwar plains from the eastern Mewar hilly tracts. Stratigraphically ,the Delhi Super Group of rocks have been divided into three groups with pronounced unconformities in between. They include : (i) The youngest **Ajabgarh Group**, comprising a sequence of argillites with intercalated arenites and subordinate carbonate deposits (Gupta et al., 1992) (ii) The older **Alwar Group** incorporating metamorphosed, ferrugenous arenaceous clastics (conglomerates, arkosic quartzites, feldspathic quartzites, quartzites) with subordinate

phyllites,calc gneisses, schists and marbles. (iii) The oldest **Rayanhala Group** overlying the rocks of pre Aravalli age (banded, siliceous marbles, quartzites, phyllites, schists, and conglomerates) The metasedimentaries of these Super Group are exposed in the eastern extremities of the study area around Pushkar, Sambhar, Kishangarh etc The rocks of this Supergroup have been affected by repeated episodes of folding (Naha et al.,1984,1987) and polyphased metamorphism.The sedimentaries and volcanics of the Delhi Supergroup bears the testimony of regional metamorphism and superimposed contact metamorphic signatures caused due to several phases of acid and mafic volcanic intrusions, such as Erinpura granites, Kishangarh syenites, Ambaji granites and Sendra granites.

The Malani Igneous Suite

They represent a widespread acid volcanism at the waning phase of Proterozoic in the western parts of Rajasthan. Malani Igneous Suite includes extrusive volcanic outpourings as well as plutonic intrusions that took place in several phases.They overlie the Proterozoic metamorphics of the Delhi Supergroup and underlie the Jodhpur Group of rocks of Marwar Super Group.The extrusive phase (745 m.y) comprise of tuffs, welded tuffs, rhyolites, rhyolite porphyry, and mafics; while the intrusives (600 m y) are represented by Siwana and Jhalore granites with associated dykes. In the study area these igneous rocks are best exposed in the southern and south western parts around Jodhpur, Barmer, Balotra, Jhalore and Siwana as hills and inselbergs. Chawade and Chandrasekaran (1996) reported a pre -Malani (post Delhi) anorthositic phase. The Proterozoic geological succession of the study area is presented in Table 2.1.

Era	Supergroup	Group	Lithology
Post Delhi Intrusives			Malani rnyolites, Erinpura granites, migmatites, pegmatites
Precambrian	Delhi	Ajabgarh	Quartzites, Biotite schists, calc schists, calc gneisses, phyllites, marbles, conglomerates
		Alwar	Quartzites, phyllites, schists, marbles
		Rayanhala	Banded siliceous marbles, quartzites, phyllites, schists, conglomerates
Archaean	Pre - Aravalli (BGC)		Gneisses, granites, schists, marbles, amphibolites, migmatites.

After Gupta et al., (1992)

TABLE 2.1 PROTEROZOIC STRATIGRAPHY OF THE STUDY AREA

PALAEOZOICS

Since the Aravalli and Delhi Super group of rocks and Malani Igneous Suite have acted as barriers in eastern and sourther parts respectively, the western part of the Rajasthan had proved to be an ideal and extensive basin of deposition from Cambrian till Tertiary periods This regional basins includes number of sedimentary sub-basins viz Marwar basin (Cambrian), Bap-Badhura basin (Permian), Lathi basin (lower Jurassic), Jaisalmer basin (Mesozoic, Tertiary), Barmer basin (Mesozoic, Tertiary) and Palana-Ganganagar shelf (Tertiary), all collectively responsible for the thick accumulation of sedimentary sequences of shelf - deltaic facies (Pareek, 1981)

MARWAR SUPERGROUP

On account of the wide aerial extent and thick accumulation of sedimentaries, Marwar basin have been assigned the Supergroup status. These sedimentaries overlie the Malani's and comprise three distinct groups viz. Jodhpur Group, Bilara Group, and Nagaur Group (Khan and Sogani,1973). **The Jodhpur Group** of rocks predominantly comprise gritty / pebbly sandstones, occasionally shales, claystones, siltstones, and boulder beds (Pareek op cit.) The dolomites and limestones of **Bilaria Group** form a narrow fringe of exposures around Nagaur. The sandstones of **Nagaur Group** are best exposed around Nagaur, Nohra, Bap etc.The Marwar Super Group of rocks are best exposed in the north eastern and central parts of the study area around Jodhpur, Pokran, Phalodi, Ladnun, Nagaur, etc.

The Birmania basin, i.e. the southeastern extremity of Rajasthan shelf consists of a thick sedimentary sequence of an old arenaceous member (Randha sandstone) and younger calcareous member (Birmania limestone) lying unconformably over the Malani igneous rocks These sedimentaries have been correlated with that of Jodhpur and Bilara groups of Marwar Super Group (Muktinath, 1969).

BAP - BADHURA REMNANTS

A narrow stretch of NE - SW trending (between Nokhra and Bap) glacially striated, bouldary, cobbly sedimentaries - the Bap Boulder Bed, a solitary outcrop of marine sedimentaries - the Badhura sandstone represent the Permian sedimentary sequence of the western Rajasthan. The Bap boulder bed comprise gravels and pebbles, derived from Pre-Cambrians (rhyolites, slates, quartzites, granites, tuffs, amphibolites) and Marwar (limestones, dolomites) Supergroup domains (Pareek 1979). The Badhura remnants exposed in northwest of Badhura, comprise an intercalated sequence of variegated sandstones, shales and siltstones with varieties of Permian fossil assemblages.

MESOZOICS

The sedimentary sequences of Mesozoic era in Rajasthan are confined to Lathi, Jaisalmer, Barmer basins and Ganganagar shelf (Narayanan, 1964; Dasgupta, 1975). These sedimentaries overlie the Malani's, Marwar's and Bap-Badhura remnants. They cover a tract extending from Barmer in the south to Mohangarh in the north; Jaisalmer in the west to Lathi in the east. Surface outcrops of Mesozoics include sedimentaries belonging to Jurassic and Cretaceous periods, however Triassic sequences are established at depth.

JURASSIC ROCKS

The Jurassic sedimentaries of this area designated as **Lathi Formation** embraces a sequence of arkoses, lithic arenites, siltstones and shales with ferrugenous bands and haematitic nodules. They attain a thickness of about 400m and also have NNE - SSW strike with horizontal or gentle undulating dip and are endowed with dicot fossil woods. They are exposed as inselbergs and hillocks around Lathi, Devikot, Javandah, Kaladongar areas in the western parts of the study area (Pandey, 1992). On the basis of palaeontological evidences, Dave and Chatterjee, (1996) recognized five marine transgressive sedimentary sequences.

CRETACEOUS ROCKS

The Cretaceous rocks of western Rajasthan are represented by marine sedimentary sequences comprising well developed limestones, shales and sandstones which are restricted to Barmer and Jaisalmer basins. In Jaisalmer basin, they include **Jaisalmer limestones, Baisakhi shales, Bedasar sandstones, Parihar sandstones and Habur limestones** occurring as inselbergs, mesas and buttes. They attain a thickness of more than 900 m with diverse fossil assemblages

In Barmer basin, the oval shaped elongated synclinal depression with north - south axis preserves a sequence of sandstones, conglomerates, phosphatic sandstones and mudstones designated as **Fategarh Sandstone**.

CENOZOICS

The Cenozoic era is represented by sedimentaries belonging to Palaeocene and Eocene periods of deltaic and marine transgressive facies (Singh, 1984). In Jaisalmer basin, the Tertiary sequence comprise :

(i) Sanu sandstones - fresh water, unfossiliferous, current bedded, gluconitic sandstones with interbedded clayey and ferrugenous shales.

(ii) Khuiala Limestone - marine fossiliferous sequence comprising sandstones, orthoquartzites, siliceous limestones, chalky limestones, fragmented bouldary and algal limestones.

(iii) Bandah Limestone - consisting of bentonitic clays, pyrite nodules, carbonaceous shales, and foraminiferal limestones.

In the Barmer basin, the Tertiary sediments comprises sandstones, conglomerates, fullers earth, bentonite which have an aggregate thickness of approximately 400m and are represented by (i) **Akli Bentonite** (ii) **Mandai Sandstone** and (iii) **Kapurdi Fuller's Earth** well exposed around Mandai, Sheo, Akli etc. in the southern parts. The Marh sandstone and Jogira fullers earth represent the Tertiaries of Palana - Ganganagar shelf. The pre Quaternary geology of the study area constructed on the basis of the earlier works are presented in Table 2.2 and Figure 2.1.

QUATERNARIES

The Quaternary geology of the western Rajasthan comprise a rich assemblage of sediments bestowed by the different surfacial processes such as aeolian, fluvial, lacustral and residual that have been operating for the past 1.6 millennia under differing climatic

Period	Jaisalmer Basin	Barmer Basin	Ganganagar Shelf
Palaeocene	--------	-------	-------
Miocene	-------	-------	-------
Oligocene	-------	-------	-------
Eocene Palaeocene	Bandah Fm. (75 m.) [Limestone, Clays, Shale] Khuyala Fm. (100 m.) [Sandstone, Limestone] Sanu Fm. (75 m.) [Sandstone, Shale]	Kapurdi Fm. (30 m.) [Fullers earth] Mandal Fm (100m) [Sandstone] Akli Fm. (265 m.) [Bentonoite]	
Cretaceous	Parh Fm Goru Fm. Habur Fm. (200 m.) Pariwar Fm. [Sandstones and Limestones]	Fategarh Fm. (50 m.) [Sandstone, Conglomerate, Mudstone]	-------
Jurassic	Bedasar Fm. (65 m.) Baisakhi Fm. (165 m.) Jaisalmer Fm. (150m.) Lathi Fm. (450 m.) [Sandstones, Shales, Limestone, Grit, Conglomerate]	Lathi Fm . (330 m) [Conglomerate, Sandstone, Grit, Shale]	--------
Triassic	---------	----------	---------
Permian	Badhura Fm. (30-250m.) [Sandstone] Bap boulder bed [Pebbles, cobbles, Boulders of rhyolite, granite, sandstone etc.]	---------- ---------	Badhura Fm. [Sandstone] ----------
Devonian	----------	--------	---------
Silurian	----------	--------	---------
Ordovician	---------	--------	---------
Cambrian	Nagaur Group (75-410m) [Sandstone, Conglomerate, Dolomite, Limestone, Shale] Bilara Group (100-300 m) [Dolomite, Limestone] Jodhpur Group (125 - 240 m) [Sandstone, Conglomerate, Shale]	Birmania Fm. (307 m) [Limestone] Randa Fm. (214 m.) [Sandstone]	--------- ---------
Pre-Cambrian	Rhyolitic and granitic Intrusives		

After Pareek (1981)

TABLE 2.2 PALAEOZOIC AND TERTIARY GEOLOGY OF THE STUDY AREA

vicissitudes Since the Quaternaries of 'Thar' have a vast lateral and vertical extent, they conceal most of the pre Quaternary geology to a greater extent.

REVIEW OF LITERATURE

Besides the geology, the geomorphic, environmental and palaeoclimatic aspects of the study area have attracted a wide spectrum of scientific workers. The century old literature on the Quaternaries of this area includes the work of Blanford (1877); La Touche (1902); Holland and Christie (1909), Auden (1952), Ghosh (1952) and Krishnan (1952). However, for the past two decades, the arid and semi-arid tracts of Rajasthan have become the loci of palaeoclimatic, geomorphic, archaeological and neotectonic studies, which resulted in the generation of voluminous data on the multifacets of the Quaternary period. Though, the thick accumulation of sediments in the Thar can be attributable to numerous factors, the salient among them include the pre Quaternary topography, neotectonism and palaeoclimatic fluctuations (Wadhawan and Sural, 1991).

Owing to the fact that, a complete succession of the entire Quaternary period (a maximum thickness of 300 m.) is yet to be recorded, an attempt has been made in the present work to construct the Quaternary stratigraphy on the basis of relative order of superposition of different litho types from dunes, interdunal plains, playas, and alluvial plains Singh et al (1974) proposed the litho-stratigraphy and palyno-stratigraphy of core sediments from Sambar, Lunkaransar, Didwana, and Pushkar lakes. His studies revealed five phases of vegetation and associated climatic regimes for the past 12000 yrs B.P in the Thar, which are :

Phase I (10,000 yrs B.P) An extremely arid period responsible for the formation of sand dunes which were instrumental in creating the lake basins viz. Sambar, Lunkaransar, and Didwana (Verstappen, 1970).

Phase II (10000 - 9500 yrs B.P) Prevalance of fresh water conditions in the lakes as evidenced by the presence of *Typha angustata* pollen assemblage.

Phase III (5000-3000 yrs B.P) a period of relatively high rainfall as indicated by the presence of pollen assemblages such *as Artemisia, Oldenlandia* that are characteristic of wet - humid climate.

Phase IV (5000 - 3500 yrs B.P) This period commenced with a moist climate as evidenced by the grassy savannah-steppe type of vegetation, which subsequently gave way to a later dry phase. The drier period is exemplified by the gradual decline in the frequencies of *Typha* pollen assemblages and this condition seemed to have prevailed uptil 1500 yrs B.P.

Phase V (3500 yrs B.P - Present) a period with the prevailing climatic and vegetational conditions. Allchin et al (1978) using dune pattern and archaeological evidences sequenced the climatic history of the Thar into four different phases viz.

(i) A major dry Phase (Pre - Middle Stone Age > 40 Ka. B.P)

(ii) Major wet phase (Middle Stone Age 40 - 20 Ka. B.P.)

(iii) Major dry phase (Upper Palaeolithic 20 - 10 Ka B.P)

(iv) A moist phase (Mesolithic 10 - 9.5 Ka. B.P)

Ghose (1965), on the basis of palaeogeomorphic studies, postulated an integrated drainage in the central Luni basin prior to recent dune building activity with wetter climatic conditions during the middle Palaeolithic period. Interestingly, the archaeological (Acheulian - Middle Palaeolithic) evidences in the central Luni basin suggest an intermittent humid phase within a general aridity trend (Misra, 1961,1968).

Agrawal et al., (1980), opined that Quaternary formations of western Rajasthan are of fluvial, lacustrine and aeolian in origin. They also concluded that the gravel ridges of Jayal area are of early Pleistocene age. On the basis of C^{14} dates of the Malhar lake sediments, they have proposed alternate wet and dry phases which can be related to 7000 $\pm$ 500 , 15,000 $\pm$ 2000 and 40,000 yrs B.P.

Wasson et al., (1983), in their detailed account on the geomorphology, late Quaternary stratigraphy and palaeoclimatology of the Thar dune field, opined that the dune sands are

derived from local provenance. The dune building activities had started at least 20,000 yrs B P and stabilized by the middle to late Holocene.

Raghavan (1987), constructed the Quaternary stratigraphy and geomorphic evolution of Nagaur district and had opined that the presence of five distinct calcic bands in dunal sections between 2 5 -4 6 m depth are suggestive of increased moisture availability for the dissolution and formation of $CaCO_3$ and assigned a time frame of 11 4 , 12 73,24.43, 29.0 and >31 Ka periods

Misra et al., (1988), worked out the Quaternary stratigraphy of the Thar by dividing into three formations, ranging in age from early Pleistocene to Holocene (Table 2.3) viz **Jayal Formation** - a bouldary, cobbly calcretised gravel, **Amarpura Formation** - Calcified fluvio-lacustral and fluvio-aeolian sediments; **Didwana Formation** - well pedogenised aeolian sands and playa sediments However, recent work of Gangadhar and Tiwari (1995), opined that the Jayal gravels are lag deposits of Khichan conglomerate of Nagaur group belonging to Cambrian age.

Wadhawan (1991), suggested that the Quaternary deposition of the Thar confines to four major sub basins as under

Shahgarh-Kishangarh sub basin comprising fluviatile basal Quaternary sequence, designated as "**Shumar Formation**" which is buried under a thick multi layer of aeolian cover

Sanchor- Shergarh - Dechu sub basin mostly incorporates clusters of multi layered parabolic dunes. Three distinct aeolian episodes have been inferred in this tract. The upper Quaternary aeolian sediments rest disconformably over the aggradational fluvio-aeolian deposits (early Quaternary /Neogene age) which inturn lie unconformably over the Proterozoics.

Merta-Degana-Jayal-Didwana sub basin incorporates early Quaternary/Neogene deposits of fluvio-lacustral, fluvio - aeolian origin. The oldest aeolian sediments with clay

illuviation and calcretization rest with a sharp contact over these fluvial- lacustral-aeolian sediments (Wadhawan,1990)

Ganganagar sub basin comprises drowned Quaternary fluviatile and fluvio-aeolian deposits of the lost river Saraswati The fluviatile deposits comprise gravels, sands, siltstones, and are confined to the palaeochannels Calcretization and formation of gypsum are also widely prevalent. The second phase of aeolian activity is indicated by the complex, superimposed linear / parabolics and star dunes. The general stratigraphy of these basins are shown in Figure 2 2.

Besides the four major sub basins of Wadhawan (1991), Tiwari and Ramakrishnan,(1995) established the fluvio-lacustral sedimentary sequence of early Pleistocene age in the Luni sub basin Dhir et al , (1992) on the basis of nature of sediments and geochronology proposed a stratigraphic framework for Quaternary and Neogene sediments, as elucidated in the Table 2 4

Chawla et al , (1992), has provided thermoluminescence chronology of dune profiles indicating a peak in sand accretion rate at 14 Ka and a period of dormancy during 13 - 6 Ka B P They also suggested that the aeolian sand mobilization in the Thar desert dates back to 36 - 40 Ka B P

PRESENT STUDIES

As it has been alluded in the previous pages, the Quaternary geology of the study area is a function of aeolian, fluvial, lacustrine sedimentary facies and associated residual deposits. The aeolian sediments have very wide distribution (vertical and lateral) in the study area and in particular the area south of Barmer and along the Pakistan border in Jaisalmer and Bikaner districts The central part of the study area i e Luni, Jaisalmer, Nagaur and Barmer plains have very thin mantle of aeolian cover

The fluviatiles are confined to the present and past river courses, which again are concealed by the aeolian cover The lacustral sediments are associated with the present

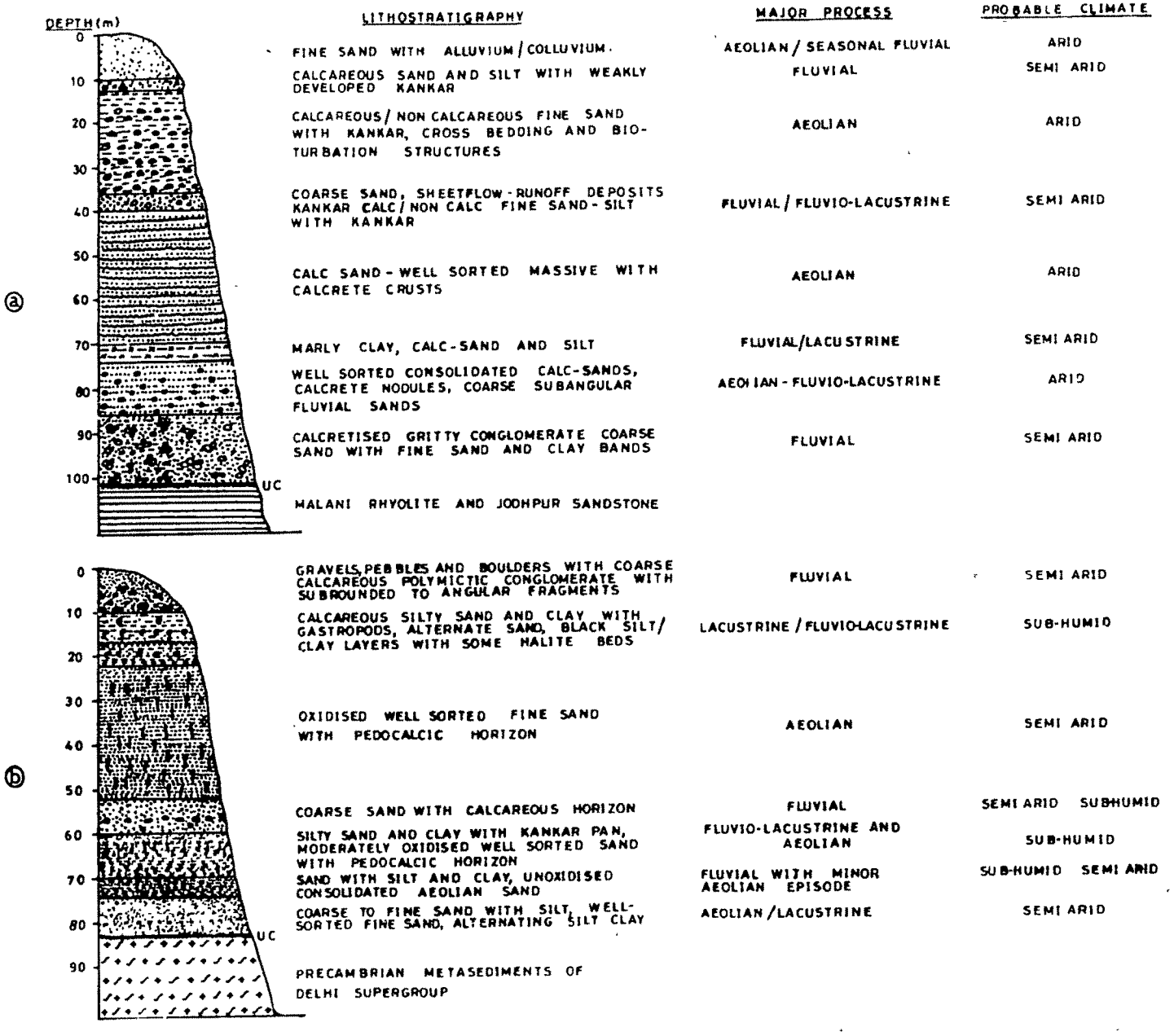


Fig 22 Quaternary Lithostratigraphy in (a) Southwestern Thar and (b) Northeastern margin of Thar

(After Wadhawan 1988)

Formation	Lithology	Culture	Chronology
Didwana	Fluvio - lacustral aeolian sand, clay and silt	Lower Palaeolithic to Mesolithic	Early Holocene - to late middle Pleistocene
Amarpura	Fluvio - lacustral clay, sand and silt	Lower and middle Palaeolithic	Middle to early phase of late Pleistocene
Unconformity			
Jayal	Ferricretised and calcretized bouldary - cobbly conglomerate.	Lower to middle Palaeolithic	Neogene

After Misra et al (1989)

TABLE 2.3 QUATERNARY STRATIGRAPHY OF THE EASTERN THAR

Lithology	Geological period	Approximate chronology
Aeolian sands and salines	Late Quaternary (late Pleistocene - early Holocene)	4 - 50 Ka B. P
Alluvial sediments, calcpans, calcrete bands, calcretized gravels and aeolian sand.	Middle Quaternary (late middle - early phase of late Pleistocene)	50 - 200 Ka B.P.
Disconformity		
Lithic calcrete, bouldary, cobbly gravel beds	Early Quaternary (early - middle Pleistocene)	> 200 Ka. B P
Ferricretes, fluvial sands and gravel	Neogene (miocene - Pliocene)	
Unconformity		
Bedrock	Pre-Cambrian - Palaeogene	

After Dhir et al. (1992)

TABLE 2.4 LITHOSTRATIGRAPHY OF NEOGENE-QUATERNARY SEDIMENTS IN THAR

day playas (Sambar, Didwana, Lunkaransar) and older dried up salines covered by aeolian sediments Among the surfacial deposits, calcrete is the most conspicuous and widely distributed in the entire study area The other residual deposit, ferricretes are confined to a linear stretch in the NW - W parts i e Mohangarh-Ramgarh-Shumarvali Talai-Savanta - Girab localities of the area investigated Though the outcome of the earlier works overwhelm several mysteries in the evolution of the Thar, the difficulties still prevail in observing continuity of various litho-stratigraphic units

AEOLIAN STRATIGRAPHY

This encompasses predominantly windblown sands, but occasionally fluvio-aeolian/ colluvial sediments are also encountered. The windblown sands are nonstratified, subangular to subrounded Compositionally, quartz and feldspar dominates with subordinate proportions of amphiboles, pyroxenes, micas depending upon the provenance of the sediments Wasson et al (1983), Raghavan (1987a) proved beyond doubt that the aeolian sediments are derived and recycled from the local provenance.

Reddening of active dune sands in some localities (Tiwri, Osiyan, Nagaur, Didwana, in the eastern part and Girab in western part), ascribed to warm - humid climate of the past (Raghavan, 1987a). However, the author's observation clearly suggest that the iron rich provenance (Jodhpur sandstones, Lathi sandstones) is the prime cause for the reddening of dunes On the contrary,the stabilized dunes on account of pedogenesis exhibit distinct layering and the colour of the soils range from grey (5YR 6/1) to red (2.5 YR 6/8).

Dhir (1994) recognized a sequence of three aeolian formations of aeolian sequence around Jodhpur area, in ascending order as follows :

(i) ***The Pal series*** - comprising a reddish brown, non-calcareous, pedogenised sands.

(ii) ***The Khatawas Formation*** - comprising a yellowish brown, pedogenised sand.

(iii) Recently activated sands covering patches at surface

Dasgupta et al , (1983), observed a sequence of four aeolian and three fluvial morphostratigraphic units in the Quaternary sequence near Jaipur area, each of them can

be identifiable by their morphology, colour, nature of iron oxides, calcareous contents Compilation of Quaternary sedimentation record (Wadhawan and Sural, 1991) shows presence of four aeolian stratigraphic units.The first and the oldest unit comprises sand sheets and buried dunes

Sundaram et al , (1996), compiled and correlated the Quaternaries of Kantli-Ghaggar basin, Luni basin, Sambhar lake and Jaipur area and classified the Quaternaries into four formation viz (i) **Bikaner Formation**, (ii) **Churu Formation**, (iii) **Sambhar Formation**, (iv) **Luni Formation;** each comprising one or more units of the different facies (aeolian, fluvial and lacustral). The general lithostratigraphic sequence proposed by them for the Kantli - Ghaggar basins is as under

Fluvial sand, silt and clay without soil formation

Yellowish brown aeolian sand without soil formation

Brown or grey loamy fluvial soil underlain by grit-gravel-sand and clay

Oxidized, pedogenised aeolian sand

Calcrete, gypsite pans underlain by gritty gravel, sand and clay

Yellowish brown, fine, pedogenised dunal sand

Gypsum deposit

Gritty granular pebbly deposit, reworked ferricrete and rock fragments.

To evaluate precisely the aeolian stratigraphy of the study area, some of the aeolian sections available from the previous work are provided below.

16 R (N 27° 24' ; E 74° 33')

This is a 20 m thick excavated dune section near Didwana that incorporates the aeolian facies of Didwana Formation (Misra et al , 1988) This profile (Figure 2.3) can be divided in to three major lithological units as

Top unit I comprising yellowish brown, well sorted, structureless fine sand (4 9m) with a non calcified upper part (0 80 m from top) and a calcified (powdery calcrete) lower part

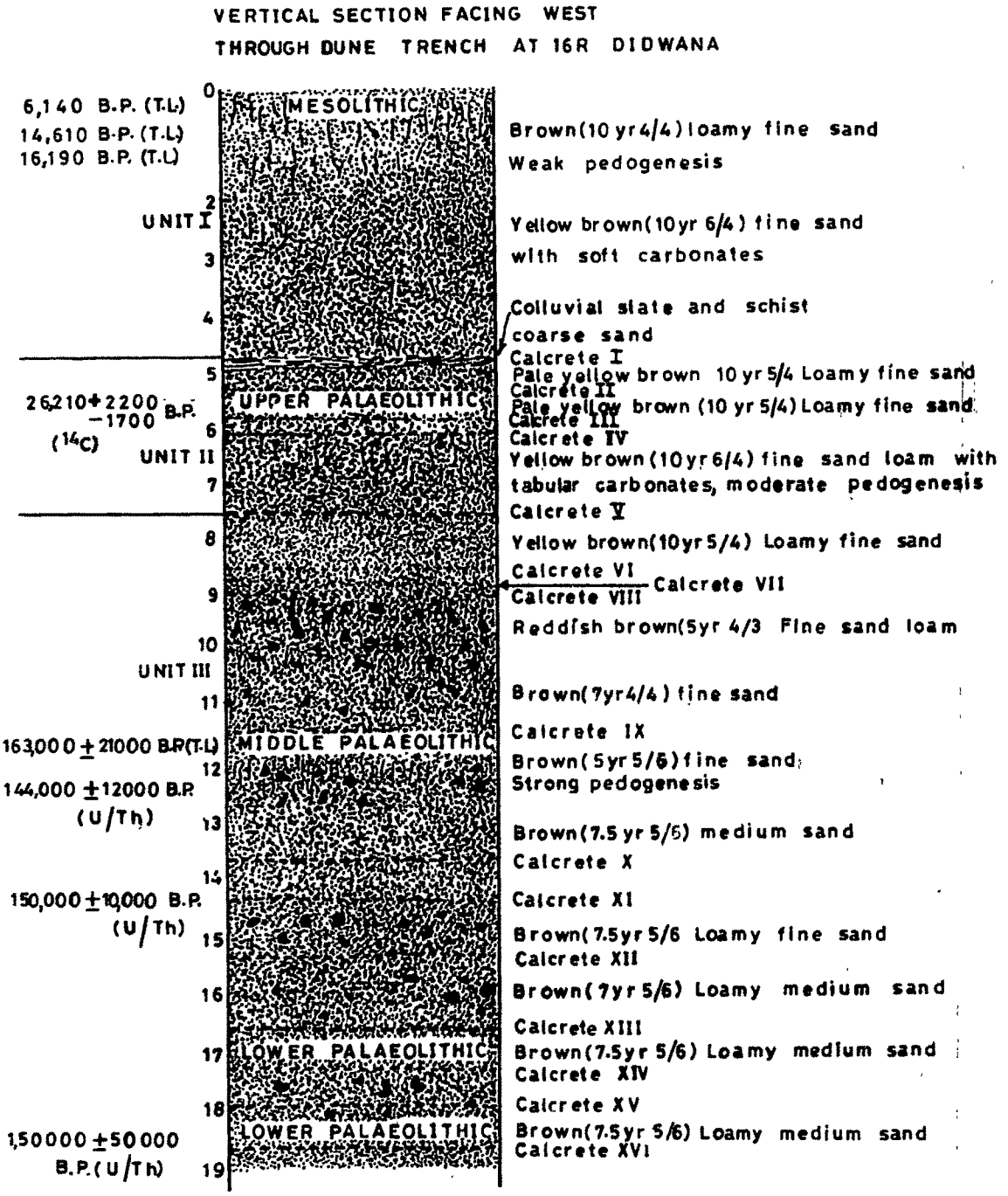


Fig. 2·3 The 16R Dune profile at Didwana

(After Misra and Rajaguru, 1986)

Middle unit II This unit is about 3m thick, comprising predominantly calcretic nodules in a well sorted, calcareous sandy matrix with intercalated calcretic bands and is separated from the unit I by a colluvial layer of phyllite, quartzite, slate etc

Bottom unit III is 10 m thick brown to pale red, medium sand with strong development of calcrete nodules These nodules are concentrated near the unit II & III boundary and are randomly dispersed in the lower part The intensity of calcretization designate this horizon as petrocalcic horizon

Upper Palaeolithic tools occur at a depth of 5.4 and 6 1 m (in unit II) and middle Palaeolithic implements at a depth of 9 and 13 (in unit III). Lower Palaeolithic tools are also encountered at a depth of 17.2 and 18.40 m. The TL dates available on this sands indicate a time span of 160 Ka - 5 Ka B P. (Singhvi et al., 1994). The 160 Ka age for the basal parts also suggests the onset of aeolian activity, since the middle Pleistocene Synthesis of TL dates further suggests a sharp sand accretion rate around 14 Ka

Amarpura (N 27° 23' ; E 74 °35')

Exposed aeolian section occur midst a gently undulating aeolian plain in the eastern extremities of the Thar. The succession depicts that the weakly pedogenised aeolian sediments are laid over a calcretised alluvium The age determination attempted through the type and degree of pedogenesis aided by TL dates for the sand samples suggest the sand accumulation during late Pleistocene and Holocene which has been ceased by late Holocene (Wasson et al., 1983).

Shergarh Tri Junction (N 26° 26' ; E 72° 25')

Exposure of an aeolian - colluvial sequence of 4 m thickness is observed at this site In total there are four colluvial layers (10- 40 cm thick) with the intervening aeolian sands (Figure 2 4 [a]) The colluvium is predominantly rhyolitic with lime coatings. The aeolian sands are calcareous, with nodules of calcrete and signatures of lime redistribution.

Uncorrected C^{14} dates on the carbonates point to a time frame of 22 5 Ka to 37.4 Ka B P for the entire sequence.

Awai (N 27° 30' ; E 71° 50')

This section (Figure 2 4 [b]) lies amidst a dune free sandy plain. The top 3 m are homogenous, weakly calcified aeolian sands up to 2.5 which grades to 0.05 m thick well calcified (soft nodular calcrete) part The aeolian sequence from 3.0 to 5 5 m is distinguished by the presence of sharply defined calcretic bands. The contacts of these bands with the aeolian sediments are sharp with very little evidence for lime redistribution. Both TL and C^{14} dates (Dhir, 1994) of these calcretic bands assign an age of 30-40 Ka B P

Sataya (N 27°21' ; E 71°22')

This aeolian sequence comprises pale brown, slightly calcareous fine sand with weak pedogenic signatures of about 20m thickness. While the top 10m is structureless fine sand, the middle portion (10-16m) exhibits weakly developed bedding planes (Figure 2.4 [d]) The TL ages for the section range from 13.3 - 14.5 - 14.9 Ka at a depth of 8 - 13 7 - 18 3 m respectively These dates suggest an enhanced but, short lived sand accumulation around 13-14 Ka (Chawla et al., 1992) Author's observation of well pedogenised, illuviated, dissected aeolian profiles with palaeosol horizons at ***Dhanola tri junction*** (25°25' N; 71°10' E) (Figure 2 4[c]) and ***Tilwara*** (72°5' N; 25° 50 E) (Plate 2.1 a & b) areas around Barmer comprise three well developed, distinct, lithounits (Ramakrishnan and Tiwari, 1996a) viz lithounit I, yellowish brown, non calcareous, weakly pedogenised, feebly laminated fine sands without any illuvial or calcification features Lithounit II underlie lithounit I with a sharp boundary and marked by very well pedogenised, blocky, illuviated, greyish loamy sand layer with incipient calcretic nodules. At Tilwara this lithounit is well developed and encompasses a rubified palaeosol horizon

The Lithounit III is a reddish brown well pedogenised, granular, non calcareous coarse to fine sand with features of 'insitu' weathering.

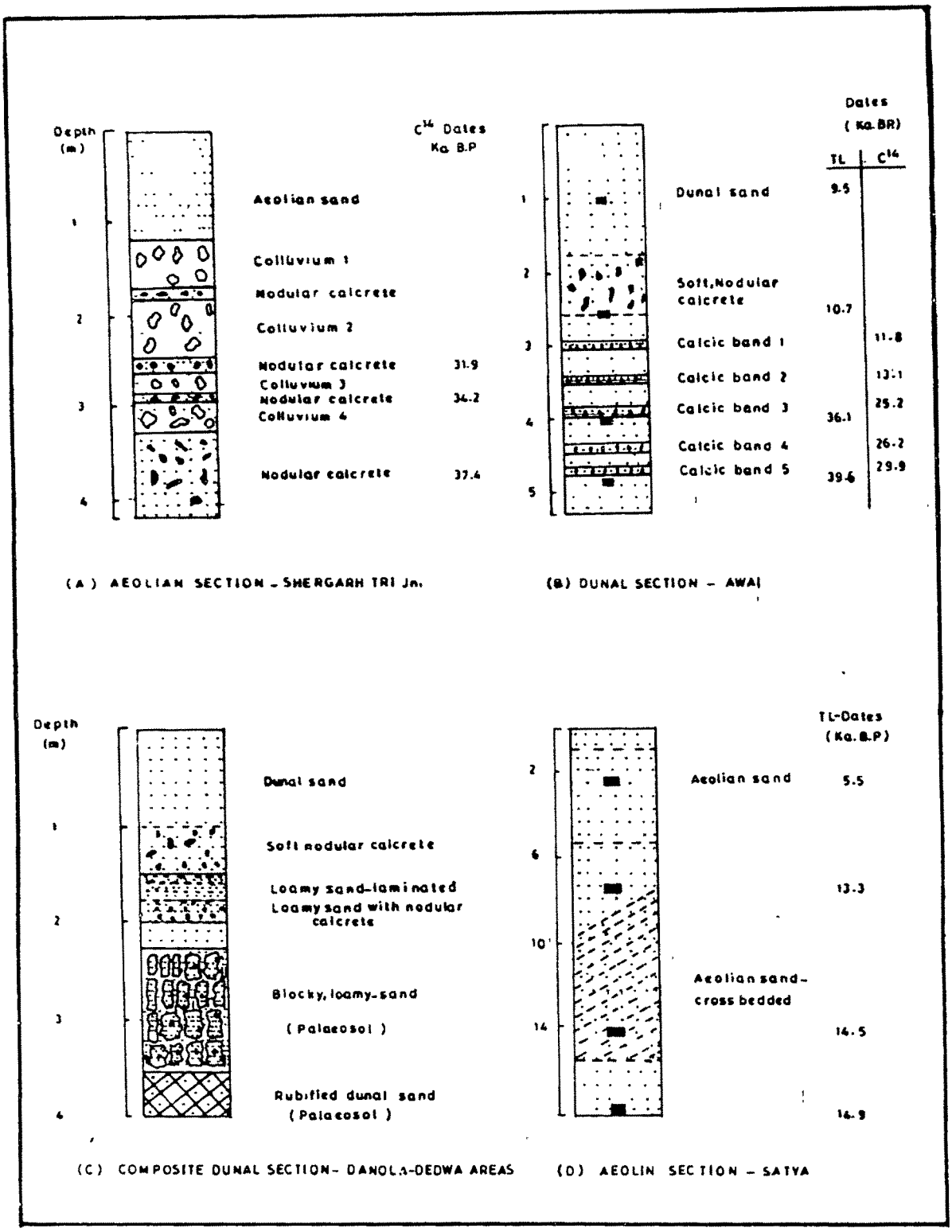


Fig. 2.4 - Aeolian sequences of study area.

Plate 2 1

(A) Field photograph showing stabilized parabolic dunes with palaeosols Loc. Luni river bank, Tilwara.

(B) A close up view of the above section containing char coal and bone remains.

A

B

Plate 2.1

The degree and type of pedogenic features observed in these profiles exemplifies clearly their antiquity Further, the oldest aeolian sediment so far reported (50-100 Ka. B P) around Dhorimanna, (Misra et al , 1988) proximal to the above area supports their antiquity comparing to the other areas

ALLUVIAL STRATIGRAPHY

Unfortunately the Quaternary alluvial sediments are not as ubiquitous as that of aeolian counterparts However, presence of a rich assemblage of fluvial sediments (besides the present day riverines designated as the younger alluvium) over a wide stretch in the northern and southern parts has been astonishing the researchers for a long time. These alluvial materials designated as the older alluvium are a mixture of gravel/pebble, sand, silt and clay Distinctions can easily be made between the younger alluvium from the well cemented, oxidized, calcretised older alluvial materials.

Raghav and Grover (1991) divided the fluvial sediments of the Kantli river (adjoining the study area in the east) in to three lithounits viz

(i) The sandy younger fluvial unit (F_0) confined to the banks /floodplains of present river courses
(ii) Older fluvial unit (F_1) comprising pedogenised coarse to fine grained sands and silty sands with occasional gravels and pebbles.
(iii) The oldest fluvial unit (F_2) comprising calcretised conglomerates, sands and silty sands.

For the better understanding of the alluvial stratigraphy, some of the sections worked out by other workers as well as by the author are presented below

Sindari (N 25°20' ; E 72° 00')

This location in the lower reaches of Luni valley exhibits an exemplary cyclic, freshwater fining upward sequence (20 m thick) of grits - sandstones - siltstones resting over a conglomeratic base and overlain by Recent windblown sands (Figure 2 5 [a], Plate 2.2). The

basal conglomerate is polymictic, incorporating clasts from Pre-Cambrian (rhyolites) to the Tertiary period (siltstones) The geological, petrological and absence of any archaeological evidences point to early Pleistocene age for these sedimentaries (Tiwari and Ramakrishnan, 1995)

Silari (N 26° 17' ; E 73° 31')

This section is located in a granitic terrain overlain by a moderately thick alluvium. The 20 m thick alluvial sequence (Figure 2 5 [b]) is made up of loamy, calcareous, materials with appreciable content of rounded to subrounded pebbles A lithic calcretic band comprising coalesced nodules is also evident. The entire alluvial sequence rest over a weathered granitic mantle The transitional phase in sedimentation history from fluvial aggradational phase to aeolian phase is indicated by intercalated deposits as evidenced at Raneri.

Raneri (N 27°40' ; E 72° 40')

This section exhibits an interplay of aeolian and fluvial sequences in a interdunal plain. The general sequence of the exposed profile (2 5m) include calcretized, oxidized gritty sand in the lower part overlain by pinkish pedogenised aeolian sand. The aeolian layer is followed by a band of gravels and nodular calcretes that do not show any sign of lime redistribution within the profile This band has sharp boundary with the overlying non pedogenised, weakly calcified layer Further details of this profile are discussed in the chapter 4, Duricrusts

Besides the exposed alluvial sections, the subsurface geology of these sediments were also constructed with the help of bore hole records (Gangadhar, 1996) Some representative, important sections are furnished as under :

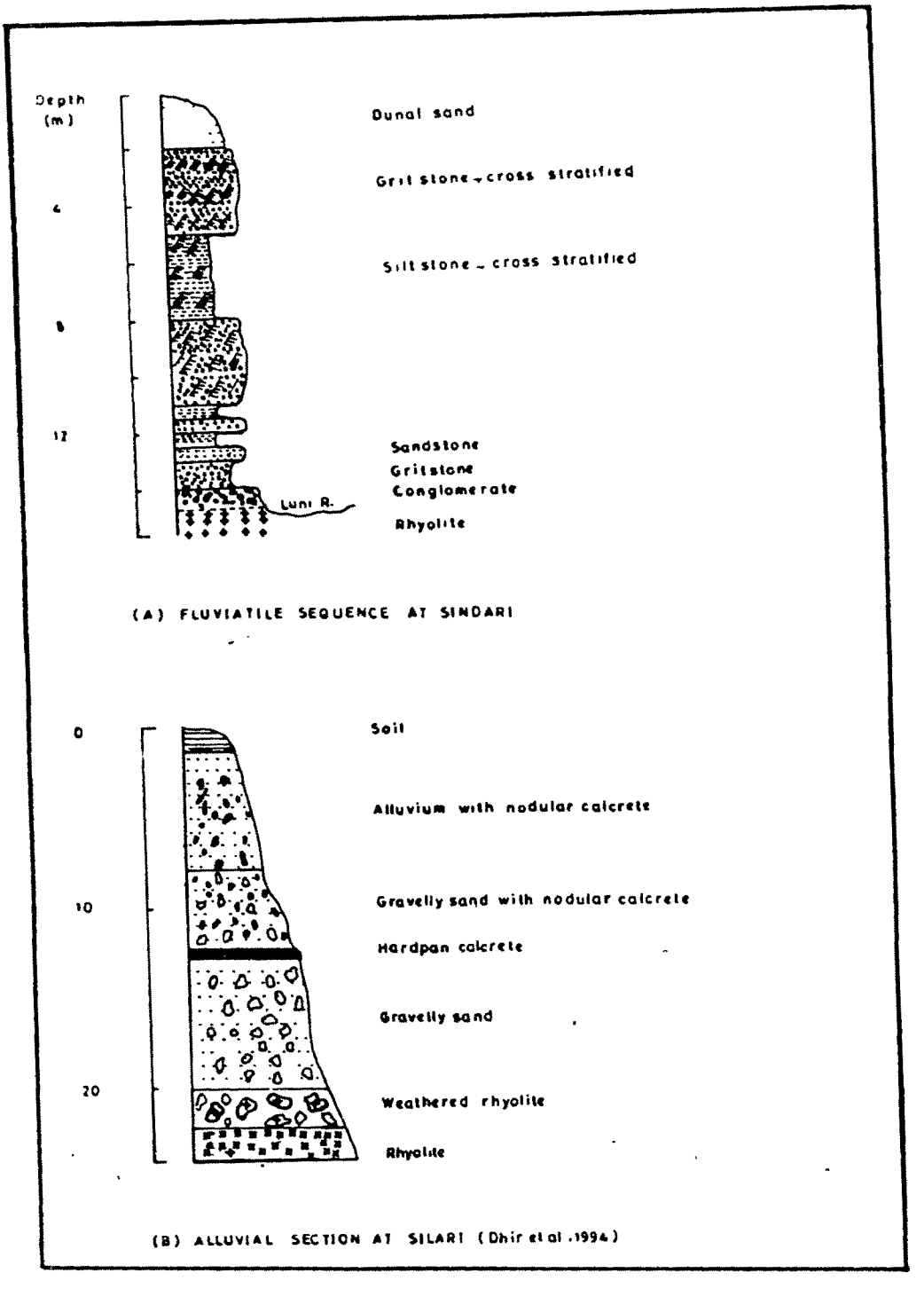


Fig. 2.5-Alluvial sequences of study area

Plate 2.2

A view of Luni river cliff showing early Pleistocene fluvio - lacustral sequences Loc. Sindari

Plate 2.2

(i) Subsurface geological section across Kantli at Chanora

This E-W trending section divulge an alluvium filled, buried palaeo Kantli channel of about 2.5 km width The total thickness of the alluvium is about 50 m and include admixtures of sands, gravels/pebbles calcretised sands, clays and silts (Figure 2.6). The pebbles with a sandy matrix form the basal unit, which is overlain by a clayey layer with silt admixtures. The topmost layer include a 10-15m thick sandy horizon

(ii) Subsurface geological section across Kantli river at Jodhpura :

This section is akin to the above mentioned with a difference in that the thickness of the gravelly/pebbly layer is comparatively thinner than that of Chanora. Overlying this is a 20-25 m thick horizon of sands and silts with lenses of clays.

On the basis of the detailed study by the author as well as by other workers (Ghose, 1982; Raghav and Grover, 1991; Gangadhar, 1996) a tentative classification of the Alluvial Formation is proposed as below :

Chronology		**Lithotype**
Younger Alluvium (F_0)	-	Gravels, sands, silts of present river courses and flood plains.
Older Alluvium (F_1)	-	Calcretized, pedogenised grits, sands (fluvial), and silty sands (aeolian)
Oldest Alluvium (F_2)	-	Oxidized, weakly cemented, siltstones, grits, gravelly sands, calcretized, indurated conglomerates, silts, sands etc.

LACUSTRINE STRATIGRAPHY

The study area incorporates copious playas, saline depressions with a internal drainage characteristic of a desertic terrain. The important among the playas are Lunkaransar (in the north of the study area), Mitha rann, Jaisalmer rann, Tanotwala rann (in the west) Thob rann (in the south) and Sambhar, Didwana, Talchapar etc. (in the east) The lacustrine sedimentary records of Lunkaransar, Sambhar, Didwana, Talchapar lakes were

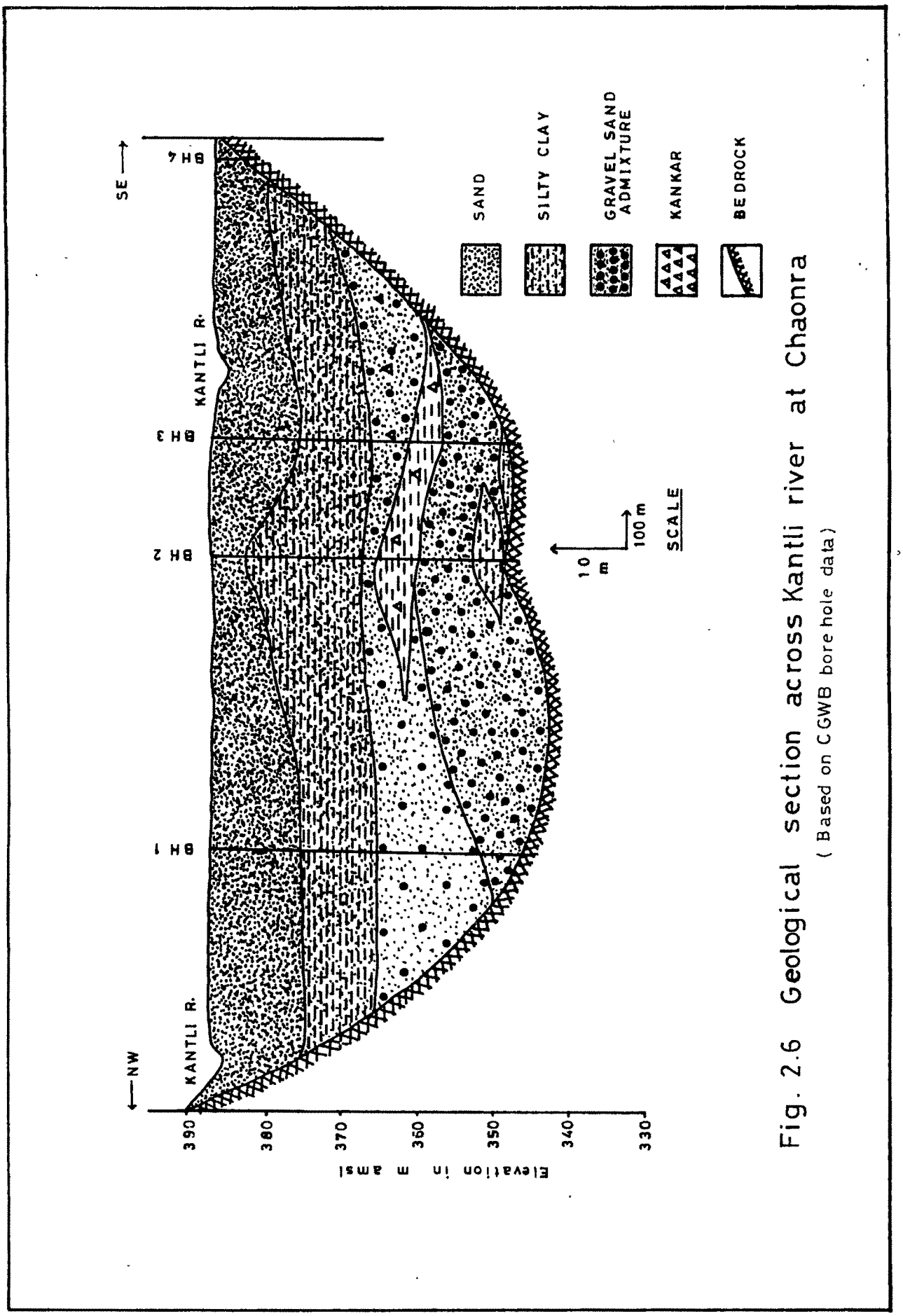


Fig. 2.6 Geological section across Kantli river at Chaonra

(Based on CGWB bore hole data)

studied by number of workers (Singh et al 1974, Swain et al., 1983; Wasson et al , 1983; Rai, 1989. Rai and Sinha,1990). The litho-stratigraphy of some of the playas as worked out by others are discussed as under

Sambhar Lake (N 27° 00' ; E 75°00')

The detailed stratigraphy of Sambhar lake through bore hole records reveal a basal micaceous schist overlain by a bed of alluvial, valley fills. The alluvial deposit is covered by aeolian sands which merges laterally with the sand ridges of the surrounding area (Figure 2 7). Several thin bands of calcretes are intercalated in the sand bed. Overlying the aeolian sand is a thick bed of lacustrine, laminated clays and silts having remains of wood and pollens (Singh et al., 1974).

Lunkaransar Lake (N 28 °30' ; E 73 ° 45')

The composite stratigraphy of this lake includes a basal bed of loose sand overlain by a sequence of laminated clay, selenite, granular gypsum, clays and silts. The gypsum layer becomes progressively thinner towards margins and the sequence is dominated by sandy material intercalated with thin bands of silts and clays. The stratigraphy of the Lunkaransar lake is illustrated in Figure 2.8 .

Didwana Lake (N 27°22' ; E 74 ° 35 ')

The composite stratigraphy of the Didwana lake includes a basal lining of calcretic pan overlain by sands on lake margins. The sands as well as calcrete pan inside the basin are overlain by a sequence of laminated clays, non laminated silts and fine sands. Since the lake sediments, away from the lake margin lie directly over the calcrete pan, it is likely that sands originally overlying the pan were eroded out in the initial stages, while the early sediments were being laid down The details of the stratigraphy of this lake is provided in Figure 2 9

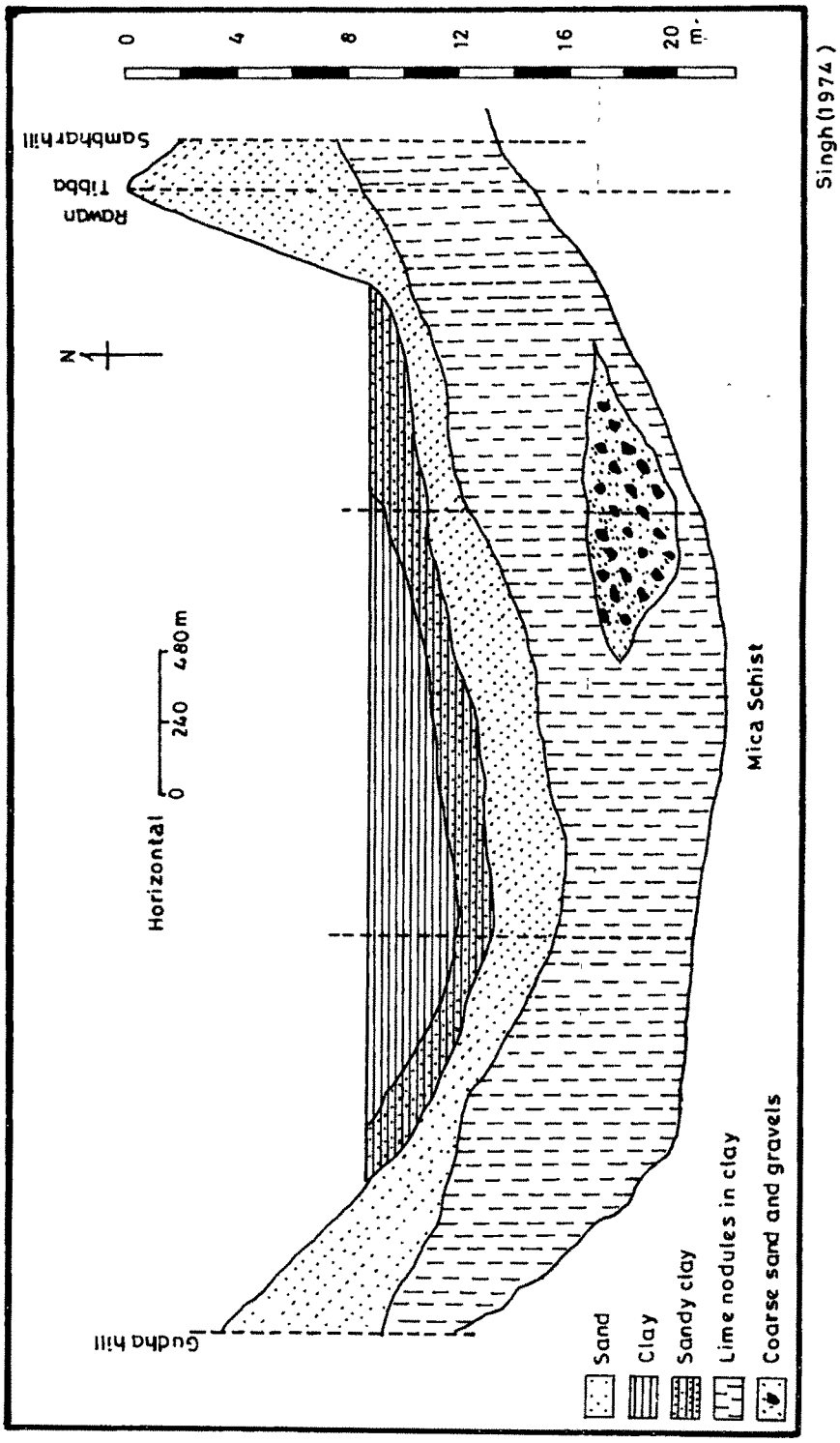


Fig. 2.7. Stratigraphy of Sambhar lake.

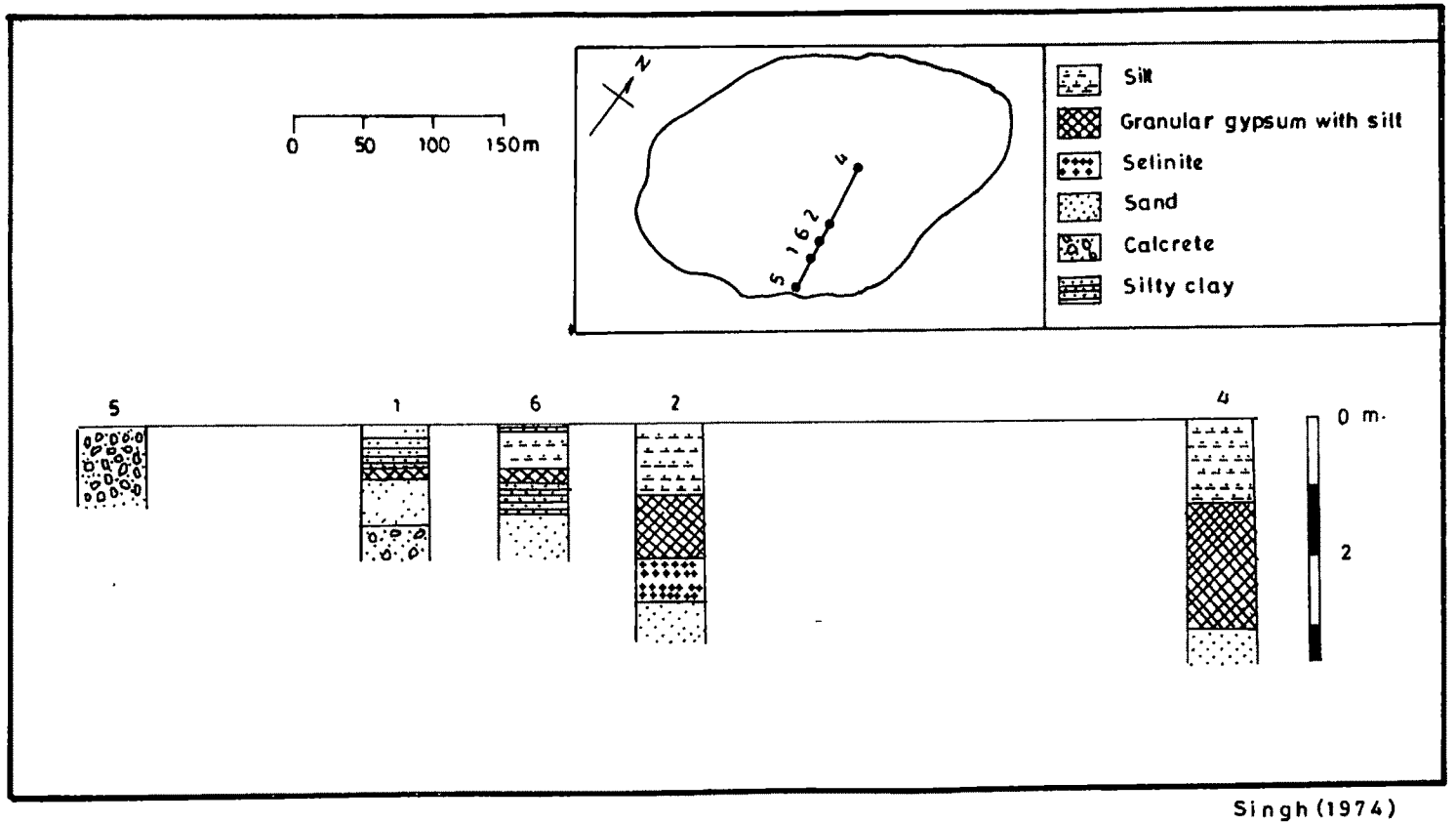


Fig. 2.8. Stratigraphy of Lunkaransar lake

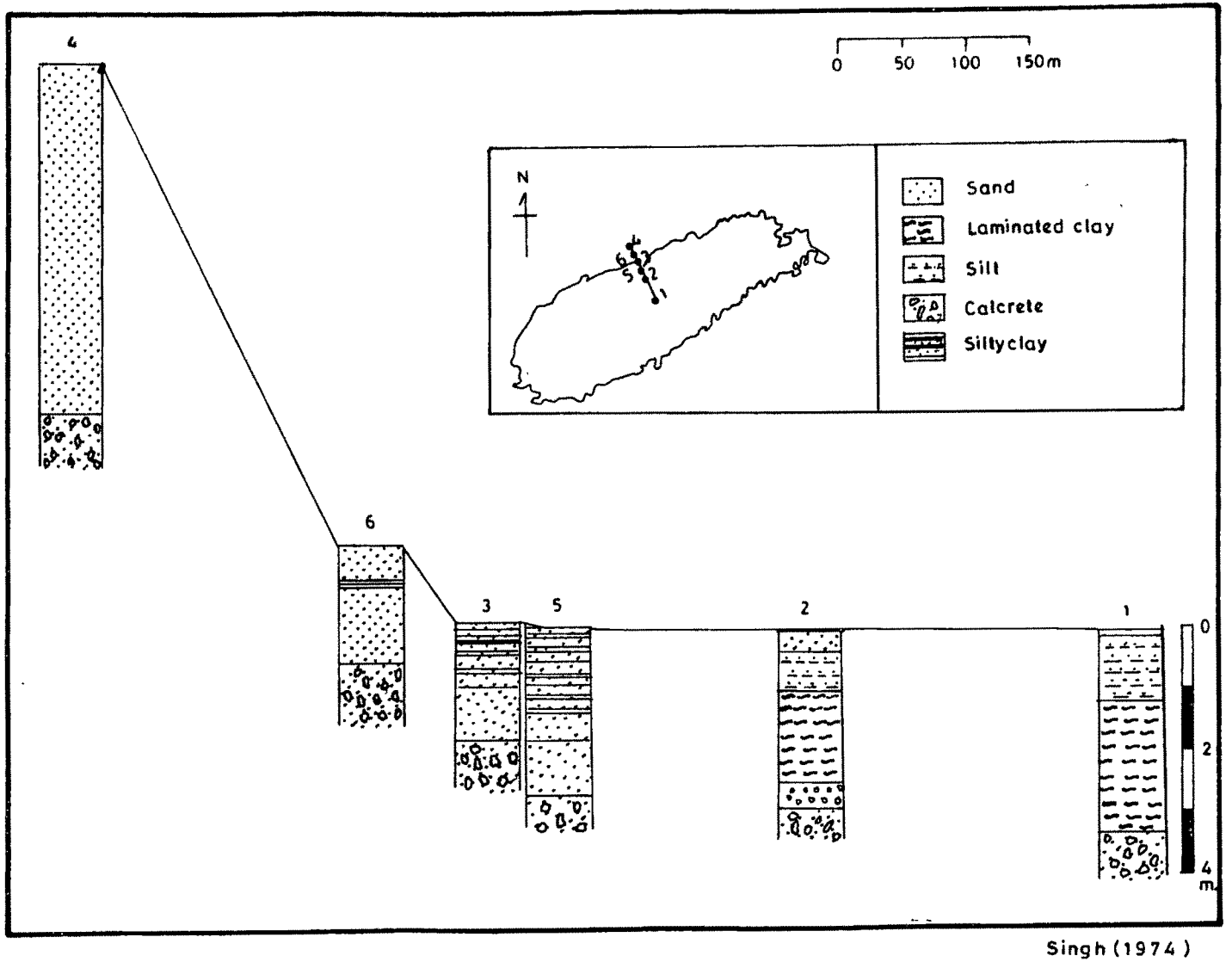


Fig. 2.9. Stratigraphy of Didwana lake.

Wasson et al., (1983), on the basis of variation of textures of clasic sediments, mineralogy of evaporites and precipitates inferred a hypersaline condition during LGM followed by a widely fluctuating lake levels between 13,000 yrs B P and 6000 yrs B.P with a high water level between 6000 - 4000 yrs B.P. (Figure 2 10).

Rai (1989) on the basis of comparative study on the subsurface lithologs of Sambhar, Didwana and Kuchaman lakes envisaged the following facts

(i) Calcretization marks the beginning of sedimentation in Sambhar and Kuchaman lakes.
(ii) Sedimentation in the lakes is dominanted by clays / silts rather than sands.
(iii) Sedimentation in the playas are not consistent.

The lacustral sedimentation history and associated pollen assemblages thus spells clearly the ameliorating climatic conditions that have been prevailing over the study area.

DURICRUSTS

Associated with the Quaternary sediments are the latter formed residual deposits viz. calcretes, gypsicretes etc. Genesis, chemistry and palaeoclimatic significance of these duricrusts are discussed in detail under the chapters Calcretes and Ferricretes.

TECTONIC SETUP

Tectonic fabric of Rajasthan has deep roots in the geological history beginning from Pre-Cambrian to the Sub - Recent times The NE-SW trending fold belts of Aravallis and Delhi's, and emplacement of granites represent the tectonic events during Pre-Cambrian period. Initiation of horsts and grabens, polyphase metamorphism and folding, forms the tectonism of Delhi phase Creation of Rajasthan shelf zone, emplacement of Jhalore and Siwana granites, formation of Barmer basin, are the tectonic features representing the Palaeozoic and Mesozoic periods (Srivastava,1988). However, Ahmad and Ahmad (1980) recognized the Great Boundary Fault as Tertiary phenomena. Terrain characteristics (disruption of stream channels, pull apart basins, lakes) of the present Rajasthan owes to

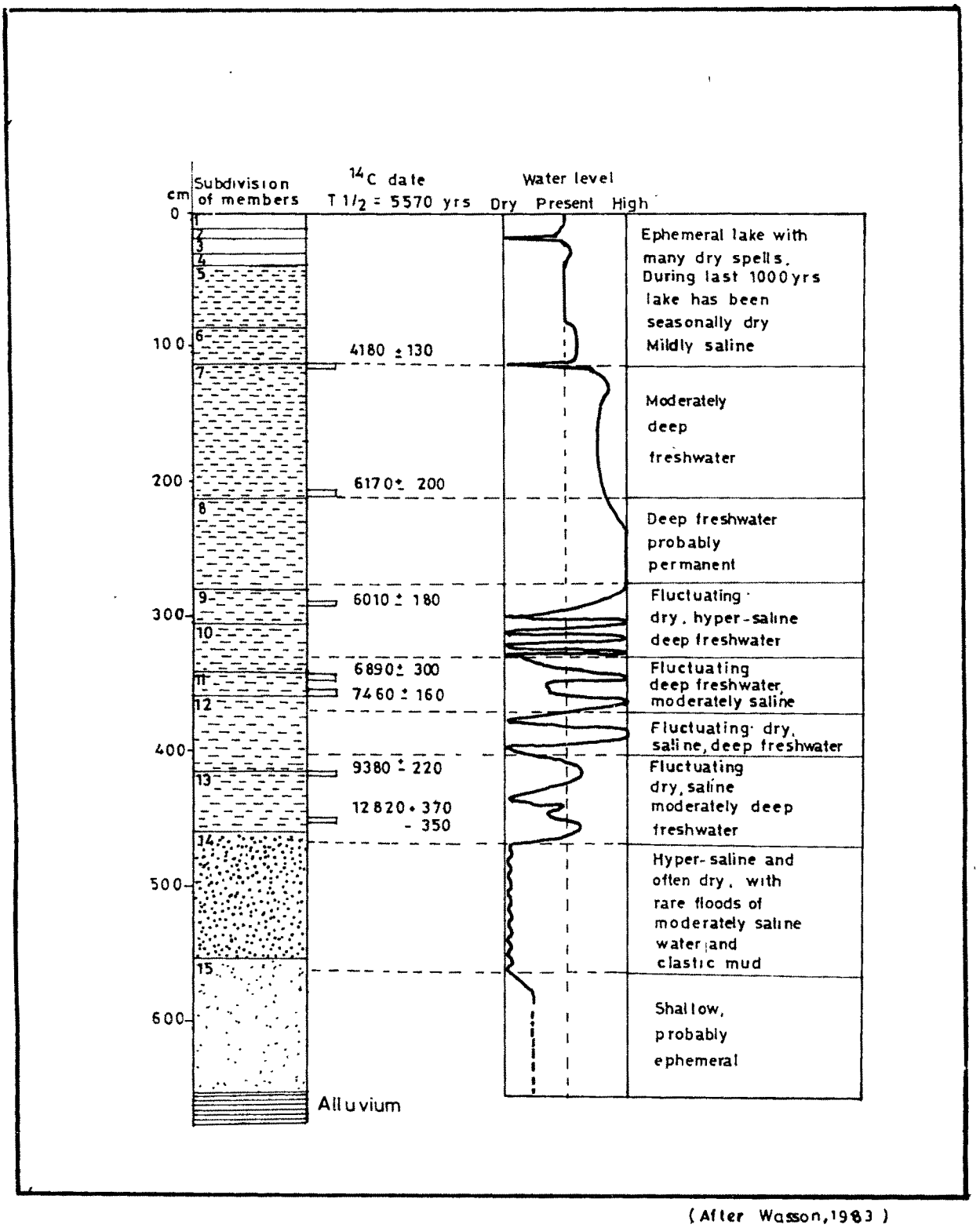


Fig. 2.10. Chrnostratigraphy and water level fluctuations of Didwana lake.

great extent the Neotectonic activities caused due to the reactivation of basement faults. (Kar 1988b)

Some of the regional tectonic features represented as lineaments (Figure 2.10) are ·

(a) West coast lineament : A NW - SE trending linear extension from Bulsar to Kalner is instrumental in the architecture of Jaisalmer, Barmer and Sanchor basins.

(b) Jaisalmer - Barmer lineament · This lineament is parallel to west coast lineament In the southern parts of the study area, these lineaments delimits the Tertiary basin and extends as a fault in Mesozoics of Jaisalmer basin.

(c) Luni-Sukri lineament : This NE - SW trending lineament aligned along the Luni and Sukri rivers with a linear or curvilinear exposition extends from Sambhar lake in the NE to the Great Rann of Kachchh This linear system of parallel faults gave rise to a graben that controls the courses of Luni and Sukri rivers. Emplacement of Malani igneous rocks and culmination of Delhi orogeny associated with the reactivation of this fault system (Bakliwal and Ramasamy, 1983a). Neotectonic activities of these lineaments are also widely advocated by several workers.

(d) Lathi-Rajkot lineament : This N-S trending lineament begins from the trappean terrain of Rajkot, through the Jurassics of Kachchh, traverse the Barmer and finally cuts across the Mesozoics of the Jaisalmer basin.

Bakliwal and Ramasamy (1987) opined that this lineament could have been Mesozoic in age and possible have been activated during Tertiary times. Besides the fore said major lineaments, there are several minor lineaments that cris-cross the study area representing sympathetic fractures as major lineaments, lithological contacts, axial planes, local faults, dyke swarms etc.

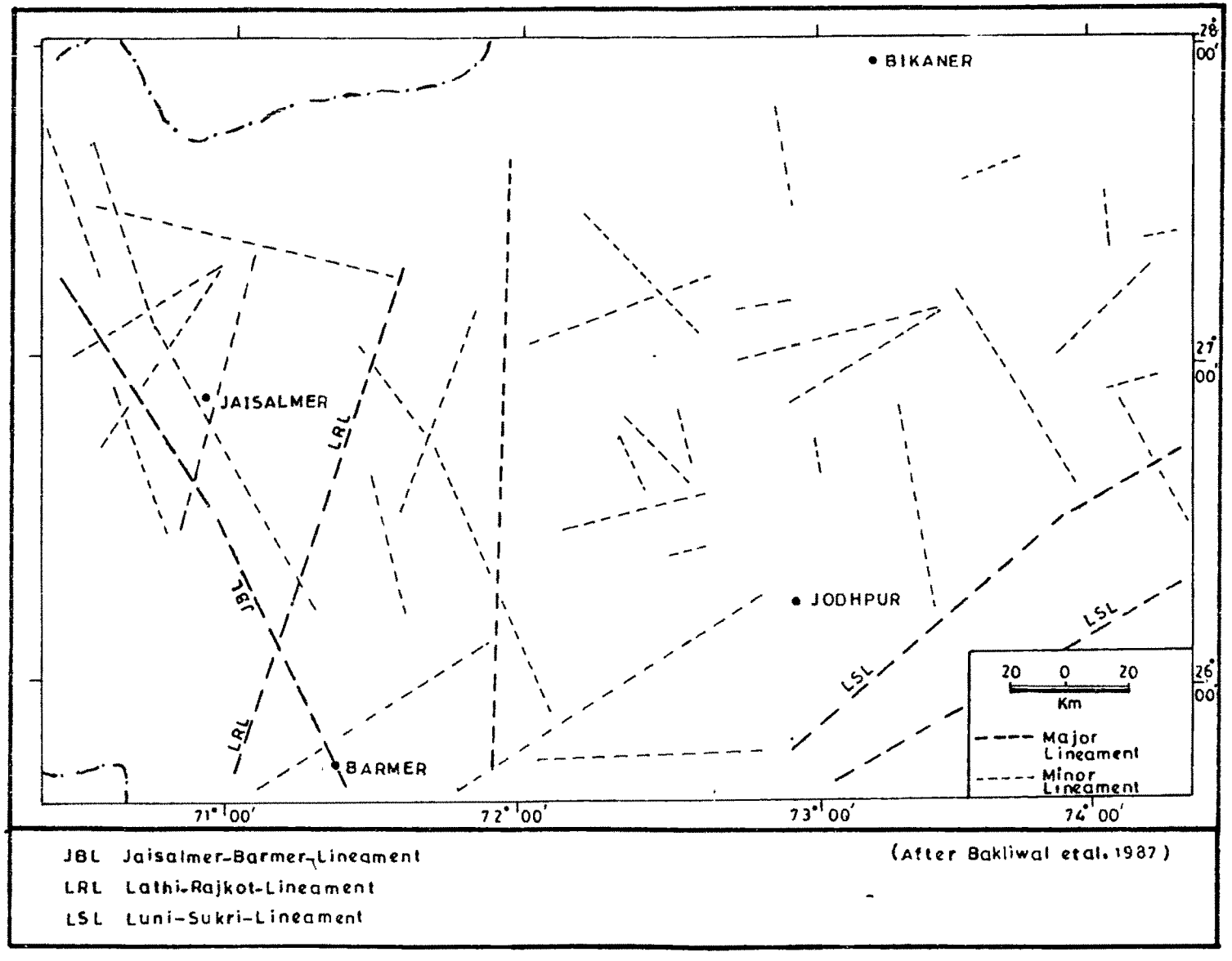


Fig .2.11 – Lineament fabric of study area