CHAPTER - 3

GEOMORPHOLOGY

GEOMORPHOLOGY

INTRODUCTION

The landform characteristics of the study area which constitutes an integral part of the Thar desert is highly perplexing and heterogeneous. Hence, geomorphological investigations of the study area were carried out through the available literatures, along with author's input from S.O.I topographic maps and satellite imageries where ever the data are lacking.

The noteworthy contribution made by various workers on the geomorphic aspects of the study area can be obtained from Ghose and Singh (1965), Ghose et al., (1966, 1977a & b, 1982), Ghose (1982), Singh and Ghose (1977, 1982), Singh (1977, 1982, 1983, 1992 a, b & c), Singh et al., (1982,1990), Kar (1983 a & b, 1986, 1987, 1988 a & b, 1990, 1991), Sahai (1992), Raghav (1992), Wasson et al., (1983), Pal (1991), Pal and Pal (1990), Sharma (1991), Chatterji et al., (1978), Rakshit and Sundaram (1990), Wadhawan (1988, 1990, 1991).

The striking geomorphological peculiarities, within the study area is broadly attributed to the surfacial processes, governed by the water and wind agents (Figure 3.1 & 3.2). Based on the predominance of these agents and spatial manifestations, the author has divided the geomorphical studies into two domains viz. **Fluvial and Aeolian domains**.

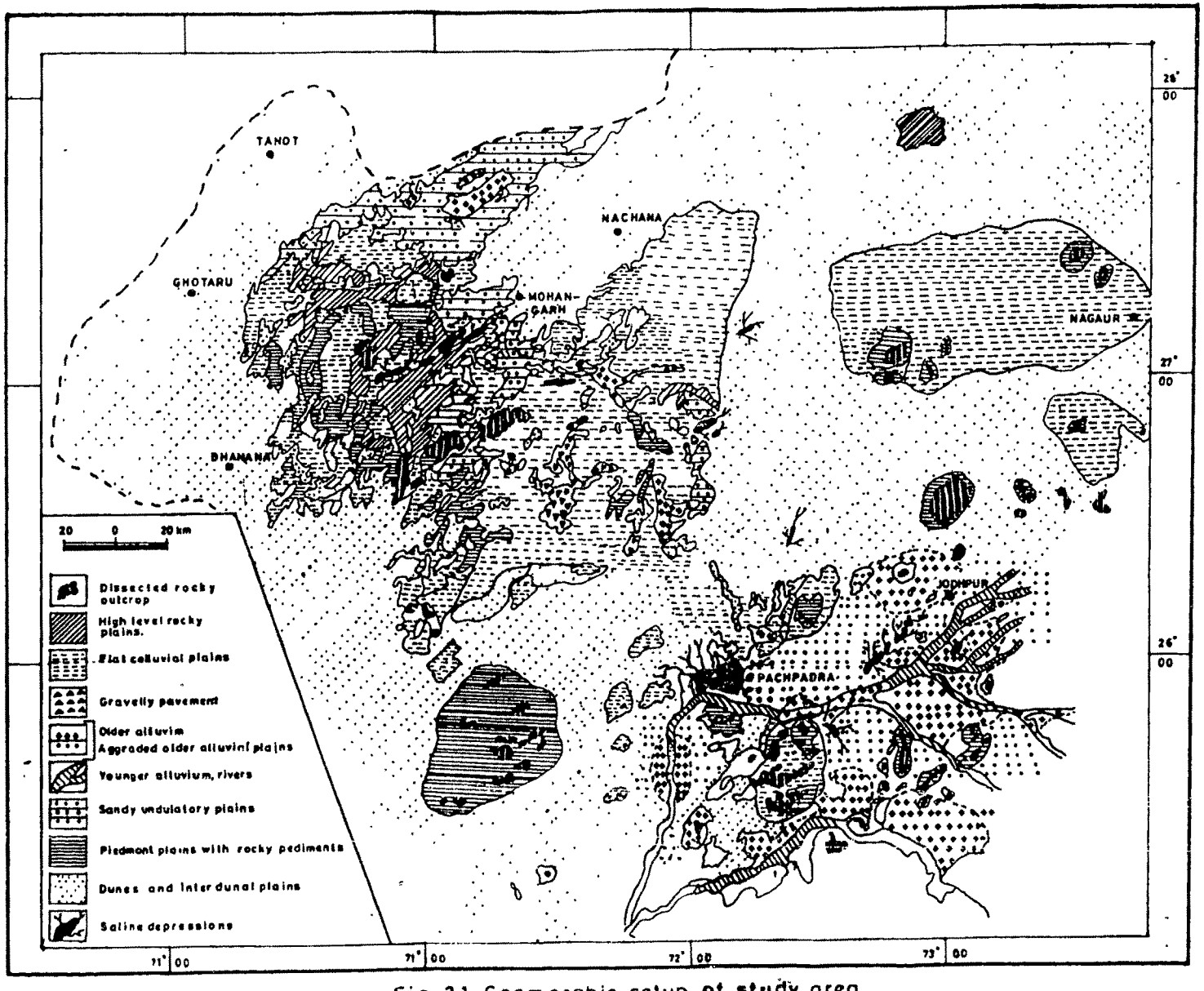

Fig. 3.1 Geomorphic setup of study area.

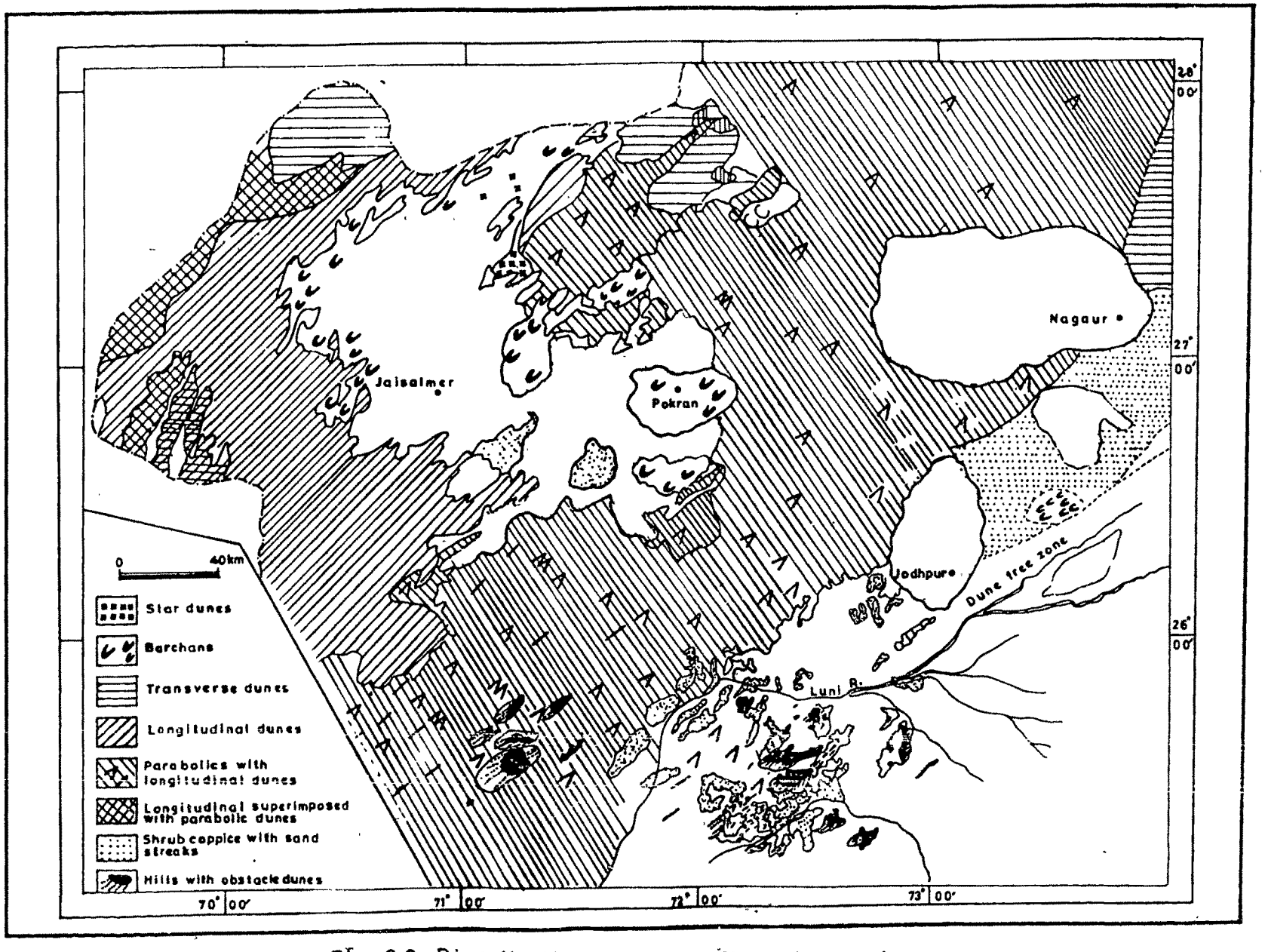

Fig. 3.2 Distribution of dune types in study area

FLUVIAL DOMAIN (LUNI BLOCK)

The geomorphic expressions of this domain are the manifestation of the present and proto Luni drainage system, as well as the contribution from aeolian and other aggradational / degradational processes. The various landform features observed in this block are discussed as under

DISSECTED ROCKY OUTCROPS

This geomorphic unit comprises low and high hills, ridges belonging to Delhi Mountain Range and latter litho-stratigraphic groups These dissected rocky outcrops are dominantly scattered in the central, southern and south eastern parts of the Luni block. These hills occurring mostly in Sumerpur and Pali areas are in the range of 307 to 579 m height and have narrow ridges, conical shape and relatively of high relief. The hills are generally rectilinear in form with 25° to 30° slopes, and are covered in their lower parts with thick colluvial debris. All the hill slopes are highly dissected by numerous streams draining in to Luni.

The hills of 300 to 972 m height comprising intrusive and extrusive igneous rocks are scatterdly distributed in the southern, central and western parts of the study area (Rhyolitic - around Osian, Shergarh, Sar, Mogra, Bar, Barmer, Balotraand. Granitic-around Salawas, Jhalamand, Nandwan, Ritleasni and Bilara) as domes and inselbergs (Plate 3.1A). The chief constituents of these hills are Jalor and the Siwana granites and rhyolites (Plate 3.1B). All the granitic hills are of domal shape with convex summit and concave basal slope The slope generally vary from 15° to 35°. The extrusive hard and massive rhyolitic masses are more resistant to weathering and are standing as rugged inselbergs and domed inselbergs

The hills composed of Vindhyan sandstones occur in extreme northeastern and central parts of the Luni block near Jhanwar, Osian, Shergarh, Belwa, Balesar, Jodhpur, Bilara, Phalodi areas The slopes of these hills vary from 20° to 35° The common landforms

Plate 3 1

(A) A view of wind faceted granitic yardang Loc. north of Pali.

(B) A view of rhyolitic ridge showing intensely developed joints due to arid climate and wind deflation Loc. Dhorimanna.

A

B

Plate 3.1

developed are mesas and buttes. The height of these hills vary from 28 to 88 m above ground level

PIEDMONT PLAINS

In the central Luni basin around Jalor, Siwana, Bujawar, etc the hills are flanked at their bases by piedmont plains (Ghose et al., 1966) and are composed of thick colluvial debris derived from adjoining hills. The total thickness of the sediments vary from 10 to 25 m in upper part and 3 to 5 m in the lower part In the upper part, large boulders and angular rock fragments of 2 to 3 m diameter are covered with small pebbles, gravels and gritty sands The piedmont slope varies from 3° to 5° At certain places, obstacle dunes and whalebacks are seen developed on the colluvial sediments. The colluvial deposits are deeply dissected by gullies The drainage pattern in this unit vary from dendritic to sub parallel

ROCKY /GRAVELLY PEDIMENTS

This geomorphic unit is developed at the base of rhyolitic, granitic, quartzitic and sandstone hills, distributed around Bilara, eastern parts of Osian, Kailana, Mandor, Lordi, Balesar, Phalodi, Thob, Nagarmewa, Bhadrajan, etc. and are characterized by gentler slopes These pediments all along their base have three distinct slope categories viz 3°to 8° in the upper part, 1° to 3° in the middle part and less than 1° in the lower part. In most cases, the pediments are covered with rock fragments of various size and shiny desert varnish on their surface. Occasional granitic outcrops of 1 to 2 m height as domes are also commonly prevalent

FLAT BURIED PEDIMENTS

This unit is akin to rocky gravelly pediments with colluvial or aeolian or alluvial cover. The principal areas of occurrence are around Bilara, Osian, Tiwri, Mokalsar, Ramania, Kundal, and northwest of Phalodi. They are covered with 1 to 3 m deep alluvial sediments which are mainly transported by stream channels from the adjoining hills and pediment surfaces and are partly developed insitu. The slope in these plains is less than 1° with a few

drainage channels. Number of the channels originating from the hills and pediments have lost their courses in these buried pediments

SANDY UNDULATING BURIED PEDIMENTS

The mode of formation of this unit is similar to that of the flat buried pediments, but later, intense aeolian activities that created sand sheets (5 to 2m thick) and sand dunes of 2 to 10 m height, at certain places even of 20 to 40 m height. Slope of this unit is irregular and varies between 1° and 3° Major areas of this geomorphic feature are located in the eastern parts of Osian around Danwara, Kasti, Jaintra, Balesar, Shekhala and northwest of Phalodi

FLAT AGGRADED OLDER ALLUVIAL PLAINS

This geomorphic unit represents the most extensive and characteristic coverage of this block The alluvial sediments of these plains comprising rounded to sub rounded clasts of varied size and provenance (Tiwari and Ramakrishnan, 1995). At certain places the sediments are also formed by insitu weathering. Calcretization is also widely prevalent and it varies from simple $CaCO_3$ coating to well developed pan types. The nature of the surface sediments vary from loamy sand to sandy loam and in certain pockets silty clay to clay The overall slope of this unit is less than 1° and devoid of drainage channels. These aggraded plains on account of drainage impediment at times become hyper saline. This is observed at Rupawas and Gondoch, Peswas, Nimbla, Pachpadra and Pataeu. The older aggraded alluvial plains on account of intense aeolian activities generated a sandy undulating aggraded plains with sand sheets, longitudinal and transverse dunes, sandy hummocks and ridges.

GRADED RIVER BEDS AND YOUNGER ALLUVIAL PLAINS

The Luni river and its major tributary river courses displays varied longitudinal gradients viz 1:600 (Sukri river); 1:500 (Jawai river) and 1:550 (Khari river) Singh and Ghosh, (1977) has worked out that the gradient of Luni river i e 1 500 in the upper reaches and 1.1000 in the lower reaches This geomorphic unit is characterized by wide, flat sand bars

and sandy beds of different size. The younger plains occur as narrow strips and have been formed along the banks of the Luni river and its major tributaries Their developement is attributed to occasional flooding and consequent deposition as flood plains and natural levees The width of the plains vary from 100 to 6000m and it is widest along the middle and lower segments of the Luni. In some parts of these plains, especially near the banks, sandy hummocks and low longitudinal and transverse dunes are formed due to the reworking of riverine sediments. Excluding the above parts, the alluvium plain is nearly level with less than 1° slope. Narrow gorges with steep slopes along present day stream courses also encountered near Sindari (Tiwari and Ramakrishnan, 1995).

SAND DUNES AND INTERDUNAL PLAINS

The vast dunal tracks occur predominantly in the north and north western parts of the region (Figure 3.2) In this region six type of dunes viz. obstacle, parabolic, coalesced parabolic, longitudinal, transverse, barchan and shrub coppice are recognised. Among these, the parabolic dunes (simple or coalesced) are by far the most widely distributed followed by longitudinal, and transverse dunes. Obstacle dunes (Plate 3 3A - both falling and climbing) are confined to southern and south western parts of this block (viz. Jalore, Barmer, Balotra, Jodhpur etc.). Barchans and barchanoids occur in patches and seen superimposed over parabolics dunes in the northwestern parts of the block around Pokran, Shergarh as well as in the eastern parts around Pipar road, Rathkurya, etc..

The first four types of dunes are showing different stages of stabilization from simple consolidation to well developed layers with or without $CaCO_3$ concretions. The height of these dunes vary from 10 to 80m. However, the Barchans are active and comprise non calcareous sands with an average height of 3 to 10m The shrub coppice dunes (Plate 3.3B) are generally 0.5 to 3 m height and occur in the form of sand mounds, hummocks and low longitudinal and transverse ridges.

The **Flat inter dunal plains** mostly occur within the interdunal areas of stabilized, coalesced parabolic (Plate 3.4A), longitudinal and transverse dunes (Plate 3.5A) located in the western part of this block The slope is less than 1° The sediments are sandy loam in nature with lime concretions at depth (around 2 m). The Sandy undulating interdunal plains is more wide spread and occur between stabilized dunes around Bautra, Padru, Dakhan, Dudwa areas. Intense aeolian activities resulted in imparting the undulations on alluvial surfaces, resulting in the formation of sand sheets, sand hummocks, low longitudinal and transverse dunes. The slope is irregular and varies form 1° to 3°

SHALLOW SALINE DEPRESSIONS

The saline depressions of different shapes and sizes are distributed in this block The salient among them are that occurring in Thob, Pachpadra, Chanaud, Sanwara, Samuja and Bhadrajan. Among these, the Pachpadra saline depression covers the largest area The surface of these depressions is nearly leveled with a slope less than 1 °.

PRESENT AND PALAEODRAINAGE

The southwesterly flowing ephemeral Luni constitutes a major and the only active drainage system with its tributary systems (viz. Bandi, Sukri, Jawai etc.) originating within the pediment plains of Aravalli Mountain Range. Besides the active Luni drainage system, this block is characterized by wide buried valleys, vast alluvial plains and linearly distributed saline depressions representing the remnants of a well integrated drainage that existed in the past (Ghose and Singh,1972)

The visual studies of satellite imageries of the lower parts of this block is characterized by a network of palaeo-drainage system, salt playas, flood plains, levees, two sets of river terraces The linear segment of Luni channel between Tilwara and Gandhav, deep gorge (15 - 20m) between Bhukan and Sindari (Plate 3.2B), compressed meanders in the present day Luni course, its palaeochannel configuration as well as over all geomorphic setup of Lower Luni valley display ramifications of the past powerful activity of fluvial

activity in this block (Figure 3.3). The Luni - Sukri lineament seems to have grossly influenced the drainage network of Luni and its tributaries

AEOLIAN DOMAIN (JAISALMER BLOCK)

By virtue of its location in the extremely arid part of the Thar desert, this block has landform features typical of any arid terrains They comprise areas of either dominantly sandy forms or barren rocky - gravely forms, punctuated with areas of shallow insitu or transported depositional forms Among the land forming processes aeolian process are the most conspicuous and important. In contrast to the Luni Block, the effects of fluvial process is almost negligible The most notable among the ephemeral streams are the Lik, originating at Bhaniyana and flowing southwards, the Sukri, originating near Sankra and flowing north west, the Vikharan nadi, originating near Khuiyala The area between Pokhran-Mohangarh-Ramgarh-Sam-FategarhRajmathai-Lawan is dominantly rocky / gravelly in contrast to extensive dunal tracks riddled with different dunes types.

DISSECTED ROCKY OUTCROPS

Scattered all around Pokhran and Bhaniyana (Rhyolitic), Randha and Lakhan (granitic), Ramgarh-Joga, Kanod, Sam-Shipal-Rama-Rasla [Sandstone (Plate 3.2A) and limestone] these dissected rocky outcrops have developed a variety of landform features in the form of mesas and buttes (especially on sandstones), while the limestone hills provide a low rounded profile The occurrence of rhyolite and granitic bornhardts, yardangs is a common sight in the Barmer ares. The hills around Thayat, Kanod, Mohangarh, Danwar are developed in the form of custae and hogbacks. The hills are barren and almost devoid of any talus

HIGH LEVEL ROCKY STRUCTURAL PLAINS /HAMADAS

Much of the rocky terrains (Tertiaries and pre Tertiaries) with near horizontal or gently dipping strata have been sculpted in to high level rocky, structural plains (hamadas) bounded by steep escarpments In the case of slightly tilted beds, the hamadas appear like

Plate 3 2

(A) A view of sandstone plateau with ferricretic duricrust and the pedimentary slopes merging with aeolian plains.
Loc Khara rann, Chetral

(B) Panoramic view of Luni river showing deep entrenchment
Loc Bhukan

A

B

Plate 3.2

Plate 3 3

(A) A view of falling dunes (obstacle dunes) Loc Chotan.

(B) A view of shrub coppice dunes Loc Bhaniana

A

B

Plate 3.3

Plate 3 4

Panoramic view of a mega parabolic dune developed in the vicinity of sandstone mesa Loc Belwa.

Plate 3.4

Plate 3.5

(A) A view of transverse dunes. Loc. Sujangarh.

(B) A view of dunefield showing coalesced barchans. Loc. Phalsund.

A

B

Plate 3.5

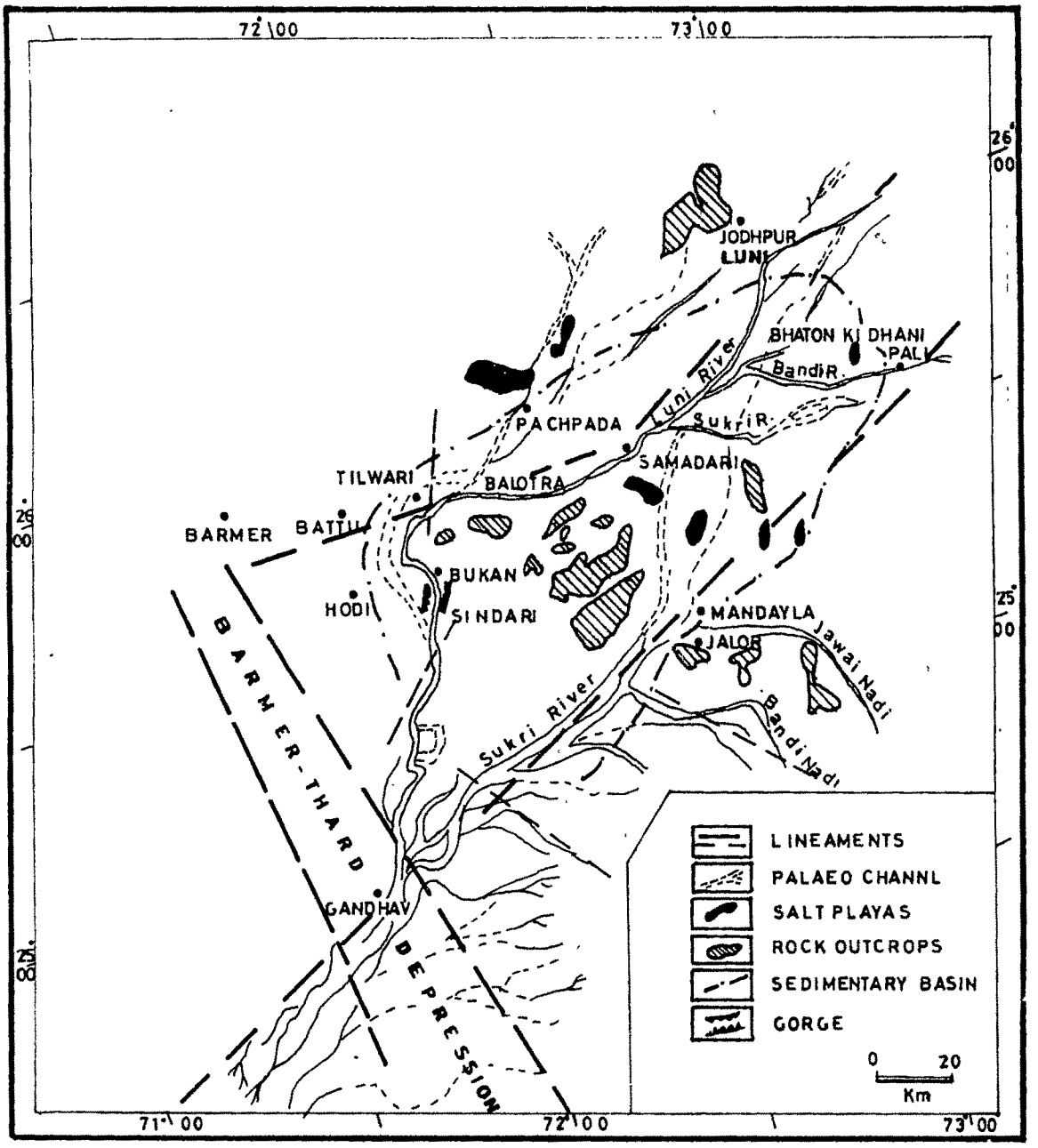

Fig. 3·3 Morphotectonic Map of Luni Block

broad cuestas with steep southeast facing escarpments with northwesterly gentler dip slope (1° - 5°). A number of drainage lines originating from the dip slope and maintain their courses on the rocky hamadas and ultimately die out after a certain distance The Kankni and Masurdi nadi near Jaisalmer and Sam nadi near Khuiyala are the best examples of such kind. The surface of the hamadas is rocky, irrespective of genetic and stratigraphic attributes i.e either over Jodhpur sandstone around Pokran, over Jaisalmer limestone around Jaisalmer or on Badesar sandstone around Mokal However, rough surfaces are evidenced over the Khuiyala limestones (around Khuiyala, Habur, Sanu, etc.). The usual landform sequences from the escarpment towards the dip slope is a cuesta or a hogback, followed by a narrow serir plain and a broadly convex hamada .

ROCKY/GRAVELLY PEDIMENTS

The isolated hills and escarpment sides of some hamada are flanked by rocky/gravelly pediments These pediments are widely distributed in Damodara Kanoi-Habur-Mokal-Chhatrel-Sam-Khuri-Bida areas. In the southern parts of this block around Derasar, Shersingh ki dhani these are formed on rhyolites and granites The gravels are of angular nature and covered by desert varnish and carbonate coatings. The slope seldom exceeds by 1°

GRAVELLY PAVEMENTS

A vast area between Pokran, Chandan, That, Hamira, Devikot, Sankra, Ola, Bandewa, Rajmathai and Nananiyai is occupied by patches of exposures of gravelly surfaces with slightly convex outline. These gravels comprise predominantly well rounded quartz and quartzitic pebbles and cobbles The gravels appear to be released gravels (lag deposits) from the weakly cemented conglomeratic beds, associated with the Lathi sandstone (Kar,1991) The average slope of this unit is between 1° and 3°

FLAT BURIED PEDIMENTS

This unit is having wide distribution in the Jaisalmer block (around Bandah, Ramgarh, Sultana, Khinya, Khimsar, Joga, Habur, Bersi, etc.) and is associated with rocky / gravelly

pediments, pavements and hamadas. The average depth of these colluvial material varies from 0 30 m to as much as 1 m As in the case of pavements, surfacial concentration of coarser fragments, in comparison to finer sub soil is also observed here too In the case of buried pavements, the coarse particles are of the size of cobbles and pebbles followed by sands The slope of these unit vary from 0° to 1° Saline flat buried pediments occur amidst hills and pediments around Modha and Sirwa located west of Devikot.

Sandy undulating buried pediments are observed around the margins of the rocky desert and also within the low, mobile barchans and other small ridges and sandy hummocks. Within the rocky area, these occur mainly along the dry channels and areas of topographical low. Chief occurrences of this unit are around Pokhran, Ujlan, Chachcha, Bhairwa, Sultana, Ramgarh, Bandah areas

FLAT OLDER ALLUVIAL PLAINS

In contrast to the Luni block, this unit is very localised in Jaisalmer block and mainly along the dry bed of Sukri nadi through, Ramdeora, Odhaniya, Chandan; along Lik river to the south of Bhaniyana, in the north between Bahla and Brahmanwala Tibba, between Odhaniya and Nananiyai, Gadada road and Girab. The thickness of this unit varies from 60 cm to 90 cm with a sequence of medium to fine sands followed by pebbles, that inturn followed by the riverine conglomerates at depth

Sandy undulating older alluvial plains are observed around Bahla in the northern part of this block with sandy hummocks and sand sheets that cover the alluvial plains. The over all slope is irregular and is between 1° and 3°

SAND DUNES AND INTERDUNAL PLAINS

Among all the geomorphic units of this block, different types of dunes are by far the most conspicuous and widely distributed They are distributed in the north, west and southwestern parts In total seven major dune types are recognized viz longitudinal, transverse, parabolic, stars and complex (reticulate and longitudinal dunes superimposed

on transverse) Among the dunes, the longitudinal dune covers maximum area (i e around Ramgarh, Tanot, Kishangarh, Longewala, Dhanana) followed by transverse (around Kishangarh, Tanot, north of Nachna, Chotan), parabolic (Shiv, Phalsund, Girab, Phalodi), complex and star (in pockets around Sultana, north of Mohangarh) The longitudinal dunes exhibit changing shape and form, while they are isolated and unbranced in the western parts of Jaisalmer (Dhanana, Kuri, Bersiala) they become progressively branched and transits from longitudinal to parabolic in the south eastern parts of Jaisalmer (viz. Phalsund, Shiv, Girab, Shergarh, Dechchu)

The most active and mobile dunes of the present day are either simple barchanoids (8 to 10 m height), barchans (Plate 3.5B) 2 - 8 m and other minor sand streaks or megabarchanoids (15 -40 m height).

The **interdunal flats** comprises sandy-rocky sub-units The area around Tanot, Kishangarh comprising longitudinal and transverse dunes are characterized by a distinct fine loamy sandy flats The sandy interdunal flats are associated with the dunes around Ghotaru - Shahgarh - Babuwali The northeastern parts of Jaisalmer is characterized by rocky interdunal flats around Mohangarh. Here, the interdunal flats have gypsum crust.

SALINE DEPRESSIONS

The playas or salinas occur scatterdly within the rocky part, particularly at Lawan, Pokran, Ujlan, That, Mohangarh, Kanod, Hadda, Chetral. All these ranns are fed by small rivelutes The origin of these playas is attributed to numerous factors viz tectonism, obstruction of drainage channels by dunal sands, ie. chocking of river channels and climatic changes (Singh, 1972, Kar, 1992)

MORPHOSTRATIGRAPHY

The sequential development of different landform features of the study area primarily owes their origin to two exogenetic processes viz. the fluvial and aeolian, incorporating erosional and depositional activities. Ghose (1982) accounted the morphostratigraphy of

the Luni block principally to fluviatile process with superimposition of subsequent aeolian processes The Morphostratigraphic evolution of Luni block as worked out by him is furnished in Table 3.1

The concept of first Quaternary peneplanation by fluviatile erosion -that was responsible for the generation of pediments. With the advent of early Holocene aridity, the Pleistocene fluviatile landscape was considerably modified by aeolian activity Pronounced and prolonged denudation of the fluviatile landforms lead to the retreat of hills and pediments, production of rock pavements, broadening of pediplains, there by representing second phase of peneplanation. The sediments derived from the erosion of the Pleistocene peneplanation lead to the deposition over older alluvial and eroded peneplains as older dunes.

Following this arid phase of early Holocene, another phase of humid to sub - humid phase gave birth to the Younger alluvium of present day river beds and flood plains The dominant present day aeolian processes resulted in the deposition of sands, derived from earlier geomorphic surfaces that resulted in the disruption of rivers and formation of wadis and playas

However, the authors observation in the field has revealed atleast three generation of playa formation in contrast to two (Rai, 1992) as indicated by the superposition of gypsiferous beds over fluviatile sediments, aeolian sediments and present day saline depressions. The morphostratigraphy of the western extremities of the Luni block, and parts of the Jaisalmer block is worked out by Pal (1991) Singh (1972) accounted the formation of playas by chocking of rivers due to dune building activity during Pleistocene aridity Culmination of arid phase by 10,000 yrs B.P and the onset of humid phase (Singh et al , 1974) resulted in the deposition of younger alluvial plains and stabilization of older dunes. The second phase of aridity (3800 yrs B.P) is represented by barchans and shrub coppice types of dunes and obliterated fluvial landscapes. This aeolian phase was followed by an ameliorating climatic conditions that resulted in the development of colluvial and sheet wash deposits

Domain	Erosional features	Depositional features	Distribution with in study area
Fluvial domain	Dissected rocky outcrops, (hills and ridges), narrow V-shaped deep valleys, gorges, knick point terraces, cut off meanders, active and defunct stream channels	Flood plains (Older & Younger alluvium), alluvial / colluvial fans levees, channel bars.	Southeastern and southern parts abutting Delhi mountain ranges and pediment plains i e LUNI BLOCK
Aeolian domain	Desert peneplain / pediplains, inselbergs, yardangs, gravelly and rocky pavements, hammadas, mesas, buttes, escarpments	Dunes and interdunal plains, colluvial fans, bajadas, pediments, sandsheets, playas and salines.	Vast desertic tracks of the west, central, and northern parts of the study area i e JAISALMER BLOCK

TABLE 3.1 DOMINANT LANDFORMS IN THE STUDY AREA

Period	Geology	Geomorphic units	Climate
III rd peneplanation in progress - under aeolian environment			
Recent	Younger aeolian sediments	15 Sand heaps, sand ripples 14. Playas 13 Wadis	Present arid - semi arid
SubRecent to Recent	Younger alluvium	12 Present active dunes 11. Present river channels & Braid 10. Present flood plain	Warm - subhumid
Sub - Recent (early Holocene)	Older aeolian sediments	9. Backswamps 8. Stable dunes 7. Pediplains 6 Pediments 5 Bornhardt -- Comprising of basement rocks.	Arid
II peneplanation under aeolian environment			
Upper Pleistocene - Early Holocene	Older alluvium	4 Left out channels 3. Older flood plains 2. Terraces	
Pleistocene	Sandstone ,siltstone ,conglomerate	Indicate ancient river bed but do not form any landforms.	Humid and cold
I st peneplanation-- under fluvial environment			
Pre-Cambrian	Delhi Supergroup of rocks and post Delhi intrusives	1 Hills and inselbergs.	

After Ghose , 1982

TABLE 3.2 MORPHOSTRATIGRAPHY OF THE LUNI BLOCK

Dassarma (1983) envisaged the prevalence of a younger fluvial surfaces as linear stretches, both parallel and normal to the present day river courses buried under a veneer of aeolian sediments In the western extremities of the study area, the recession of the Tertiary sea was followed by the generation of a planation surface under wet humid conditions as indicated by the formation of wide spread iron crusts, that are occupying the top of mesas and buttes The fluvial erosion and depositional features of Late Neogene - Quaternary period is also evidenced by the fluviatile, non fossiliferous, ferrugenised sequences of Shumar Formations (Singh, 1982) Rocky pediment, gravel laden, dune free structural plains at different elevations with typical scarps and gullies remain manifestation to the neotectonic activities (Kar 1988 a)

Interludes of amelioration in aeolian activities are also evidenced by the occurrence of colluvial wash materials of different phases (Dhir, 1992) with in the dunal plains.