CHAPTER V

GEOMORPHOLOGY

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INTRODUCTION

Since the beginning of Quaternary period, the arid and semi-arid terrains of the Thar Desert has witnessed drastic modifications in geomorphology. These geomorphic changes have imparted manifold variations in the physiography and the landform patterns therein. Geomorphologically, the study area and its surroundings display a complex mosaic of landform features. These complexities in terrain characteristics are attributed to the combinations of surficial processes that have changed periodically and can be ascribed to the fluctuations in the climatic conditions and/or Neotectonism. The study of geomorphic aspects of the present area has become a challenging task for the author due to following reasons:

(i) high order heterogeneity in the physiography, landform features, etc.,
(ii) superimposition of topography and landforms due to periodic and episodic changes in endo and exogenic processes,
(iii) lack of continuity in landforms due to dune building activity as well as aeolian sand cover, and
(iv) inaccessibility to the interior areas due to adverse terrain conditions and poor road network.

To overcome the above factors, the author has first studied the area on S.O.I. topographic maps and available literature. These have been further substantiated by the study of satellite imageries from LANDSAT, IRS (LISS-1) and SPOT. The use of remote sensing techniques in geomorphological mapping has become an important tool. The satellite data apart from providing synoptic view of the terrain and spatial distribution of various landform features, are also helpful in delineating concealed signatures as well as in monitoring the dynamics of various surface processes.

The applicability of remote sensing techniques and their interpretation in the geomorphological investigations of Thar Desert and its environs have been endorsed by the magnificent findings, unearthed by the vast scientific community. Few noteworthy contributions are Ghose and Singh (1965), Ghose *et al.*(1966, 1977a & b, 1982), Ghose (1982), Singh and Ghose (1977, 1982), Singh and Kaith (1971), Singh (1977, 1982, 1983, 1992a, b & c), Singh and Shankarnarayan (1982), Singh *et al.*(1982, 1990), Kar (1983a & b, 1986, 1988a, 1989a & b, 1990, 1991), Sahai (1992), Bakliwal and Grover (1988), Ramasamy and Bakliwal (1983), Ramasamy *et al.* (1991), Sharma (1987), Raghav(1992), Yashpal *et al* (1980) etc.

The study area which constitutes the northeastern extension of Thar Desert, illustrates a crucial morpho-tectonic setting. The northern and northeastern boundaries are demarcated by a major tectonic lineament i.e., south Indo-Gangetic foreland basin fault, in the southern and southwestern parts there is the Aravalli Mountain Range and the western sides fall within the influence of Rajasthan Shelf Zone. All the three fringing morpho-tectonic provinces display distinct evolutionary history ranging from Precambrian to Recent. The study area and its various geomorphic attributes demonstrate mixed characteristics of all the three bordering provinces.

In order to describe geomorphological characteristics of the study area, the author has divided the area into two blocks. This zonation has been made on the watershed basis, *viz.*,Upper Luni and Kantli. The demarcation of watershed boundary in alluvium filled areas based on altitude and slope has become a difficult task for the author. This is due to (i) thick dunal sand cover prone to modify landscape frequently and (ii) very poor drainage density and network. For these reasons, the author has considered the Sambhar lake as a line of divide, separating Luni and

Kantli blocks. However, various landform features as well as morpho-stratigraphic aspects have been dealt for the total study area.

PHYSIOGRAPHIC CHARACTERISTICS

It has already been discussed in the preceding chapter that the author's present study incorporates two watershed basins *viz.*, the Upper Luni and the Kantli; stretching from Luni in the southwest to Rajgarh in the northeast. Physiographically, the area exhibits large scale variations in altitude, relief, slope and maturity. These variations in physiographic elements can be assigned to the diversity in geologic environment, influence of tectonism and the magnitude and intensity of various surficial processes.

Physiographically, the study area has been divided into five distinct units, *viz.*,

(i) Rocky Highlands,
(ii) Pediment Zone,
(iii) Rocky Peneplain,
(iv) Alluvial Plains, and
(v) Aeolian Plains.

Block wise description on the geomorphic aspects is discussed below:

UPPER LUNI BLOCK

The Luni block (N 26° 00' - 28° 00' ; E 73° 00' - 75° 00'), is characterised by varied physiographic features. However, the area exhibits a general rise in elevation towards south, attributed to the NE-SW trending Aravalli Mountain Range. The average ground elevation ranges between 300 - 700 m amsl. The general slope of the area is southwesterly.

(i) Rocky Highlands

The NE-SW trending Aravalli Mountain Range forms the most conspicuous landmark feature that falls in this physiographic unit. The rocky highlands consist of chains of mountain ridges running nearly parallel to each other. The intermontane depressions represent elongated U-shaped and V-shaped valleys. The hills rise to heights of more than 350 m from the surrounding plains and are characterised by moderate to steep slopes. Butia Dungar is the highest peak in this region, with an altitude of 970.3 m. Other prominent hills are Rajgarh Pahar (797 m), Kalapahar Dungar (676 m), Taragarh (855 m), Nag Pahar (886 m), Padampura Dungar (820 m) and Bhinai Pahar (724 m). Most of these hills extend unbroken for nearly 5 to 10 km or more. The rocky highlands are characterised by dendritic-subtrellis drainage patterns, however the intermontane valley depressions show the development of an internal drainage system with ephemeral gullies and nalas.

The intermontane valleys are ranging in width from less than a kilometer to more than 10 kilometers. The Sagarmati (a tributary of the Luni) valley lying between Rajgarh Pahar and Taragarh hill is the largest. Other valleys, *viz.*, those of Saraswati, Ana Sagar, Pushkar and Bhaonta are relatively small. The valleys and valley flanks comprise thick accumulations of aeolian sands of stabilised as well as active nature.

(ii) Pediment Zone

The pediment zone is confined to a narrow strip running parallel to the mountain chain as well as the intermontane parts. This zone is characterised by moderate to low slopes and comprises varied materials derived from the denudational activity of various surface agencies. These colluvial materials are deposited in the form of fans. The numerous small streams running through the pediment tract have created extensive gully erosion along them, especially where the sand dunes abutt against the hills.

The pediments in the Pushkar and Sagarmati valleys are comparatively wider than the other areas. Majority of the rivers *viz.*, the Saraswati and Sagarmati and the minor ephemeral streams

Lilri, Raipur Luni, Jojri Nadi, Reria Nadi and Guhiya Nadi have their origin in the pediment zones.

(iii) **Rocky Peneplain**

This physiographic unit displays flat to undulatory peneplanation surface with a thin veneer of soils. Rocky peneplains predominantly occupy the central parts of the area and gradually merge with the pediment zones. The rocky peneplains also comprise scanty isolated hills, especially in the areas around Kuchaman, Parbatsar, Khatu-Kalan, Rian, Nagaur, Alniyawas, Luni, Jodhpur etc.

(iv) **Alluvial Plains**

Spreading all along the river courses, this physiographic unit comprises predominantly of fluviatile floodplain deposits. The most prominent are the alluvial plains of Sagarmati, Saraswati, Luni main channel, Lilri, Jojri and Raipur Luni. These alluvial plains display two different planation surfaces (Ghosh, 1977; Ghose, 1982), attributed to the rejuvenation history of the river valleys. The right bank of the Luni river between Alniyawas-Lambiya (about 35 km long strip) is the most illustrious example of this unit. The overall gradient displayed by the alluvial plains, falls within the range of 1:100 and 1:250.

(v) **Aeolian Plains**

Aeolian plains cover the most extensive tract of the study area. This unit is dominantly confined to the northern and northeastern parts of the area. On account of intensive dune building activity, these plains are characterised by hummocky and occasionally rugged topography. The dune fields around Sujangarh, Sardarshahar, Tivri and Degana are the typical examples.

Vast sand sheets occurring in the area around Didwana, Nagaur, Khimsar, etc. have imparted monotonously flat planation surfaces. These aeolian plains harbour innumerable playas and lakes. Sambhar, Didwana, Kuchaman, Sujangarh, Talchhapar are the major pluvial lakes.

KANTLI BLOCK

The Kantli block encompasses predominantly northeastern parts of the study area, sprawling between the latitudes N 26° 30' - 28° 30' and longitudes E 75° 00' - 76° 00'. This block exhibits two directional slopes. Large part of the area which falls under the influence of Sambhar depression has southwesterly slopes and the area falling within the limits of the Kantli watershed display northerly slopes. The altitudinal variation of the area is in the range of 250 - 1050 meters.

Physiographically, the Kantli block also shows the development of all the five physiographic units.

(i) Rocky Highlands

This physiographic unit is represented by the discontinuous hills and ridges belonging to the Aravalli Mountain Chain. The hills in this part of the study area are more than 500 m in height, the Raghunathgarh hill (1050 m amsl) being the highest peak. The other peaks are Amer (636 m), Danta Ramgarh (692 m), Ganwari hill (846 m), Dokan hill (798 m), Khetri hill (790 m), Kankriya hill (978 m), etc. The rocky highland area is characterised by narrow to wide V-shaped valleys, numerous small streams and rivulets.

(ii) Pediment Zone

The pediment zones are restricted to a narrow belt running along the hill trends. This zone is characterised by moderate to steep slopes and comprise of colluvials as well as dunal sands. Intensive tectonism and erosional activity by water action has developed innumerable deep gullies. These gullies are more pronounced in the areas where aeolian materials predominate. Pediment zones are best exemplified in the areas around Nim ka Thana, Madhogarh, Jharli, Surani, Hanumansagar, Mankri, Amarsar, Bagar, Guhala, etc.

(iii) Rocky Peneplain

The rocky peneplains show more or less similar characteristics as observed in the Upper Luni block. The areas around Nawalgarh, Udaipurwati, Sikar, Danta Ramgarh, etc., fall within the rocky peneplains. Stray occurrences of hilly outcrops of Delhi Supergroup rocks have imparted hummocky and rugged configuration to this physiographic unit.

(iv) Alluvial Plains

The alluvial plains have got limited extent. The older alluvial plains which cover vast tracts of the Kantli block are seen concealed beneath the dunal sands. The younger alluvium is restricted to the intermontane gaps and the river valleys, forming a part of flood plain deposits. The Kantli, Mendha, Sahibi (Sabi), Chandrawati, Sukh Nadi, Sota Nadi, Udaipur-Lohargarh ki Nadi, etc., are few important locales of their occurrence.

(v) Aeolian Plains

This physiographic unit is predominantly confined to the northern parts of the block. Sardarshahar, Rajgarh, Pilani, Jhunjhunun, Churu and parts of Sikar etc., fall within the limits of the aeolian plains. These dunal plains are characterised by a large variety of dunal patterns, *viz.*, longitudinal, barchan, star, transverse, compound dunes, etc. Interdunal depressions are extensive and harbour number of gypseous playas.

LANDFORM CHARACTERISTICS

The study area exhibits a variety of landform features manifested by the various endogenic and exogenic processes. Study of various landform features have been carried out with the help of satellite imageries and subsequent field checks. The study area represents a complex geomorphological setting covered with colluvial, alluvial, aeolian and lacustrine sediments of different generations. The aeolian landforms predominate over the other landforms. In fact, the landscape scenario of the region exhibits complex interplay of multiple dynamic processes reflected in terms of sedimentation history, tectonism and climatic fluctuations.

In order to study the various landforms, the author has classified the landform features on the basis of their process controlled environs and present day physiographic distribution. The adopted approach of classifying various landform features has helped the author greatly in describing the present day aggradational and degradational characters of the terrain and also in establishing the chronology of morpho-tectonic evolution in space and time.

Based on their genesis, the different landforms are broadly divided into four groups, *viz.*, fluvial, aeolian, lacustrine and eluvial, with corresponding erosional and depositional subdivisions. Due to overlapping and repetitive nature of these processes, the correlation of various erosional and depositional landforms is quite a difficult task. However, a general classification of such landforms on the basis of physiographic units and the depositional and aggradational nature has been attempted for the study area, to show the predominance of one process over the other. An overall distribution of various landforms in the study area is shown in the geomorphic map (Fig. 5.1). The detailed landform classification for the study area is given in Table 5.1. A brief account on the landforms in each physiographic unit of the study area is given as under:

ALLUVIAL PLAINS

The landscape typical of the fluvial processes in the desertic and semi desertic environments of the study area comprises flat to undulating older alluvial plains dissected by the present day drainage system. The ephemeral Luni and Kantli rivers, their tributaries, as well as the other minor streams have produced characteristic landforms attributed to periodic flooding and alluviation. The rivers have shifted their courses and overflown their banks during floods, leaving large chunks of sediments on their banks as flood plain deposits.

Fig. 5.1 GEOMORPHOLOGICAL MAP OF THE UPPER LUNI AND KANTLI BLOCKS

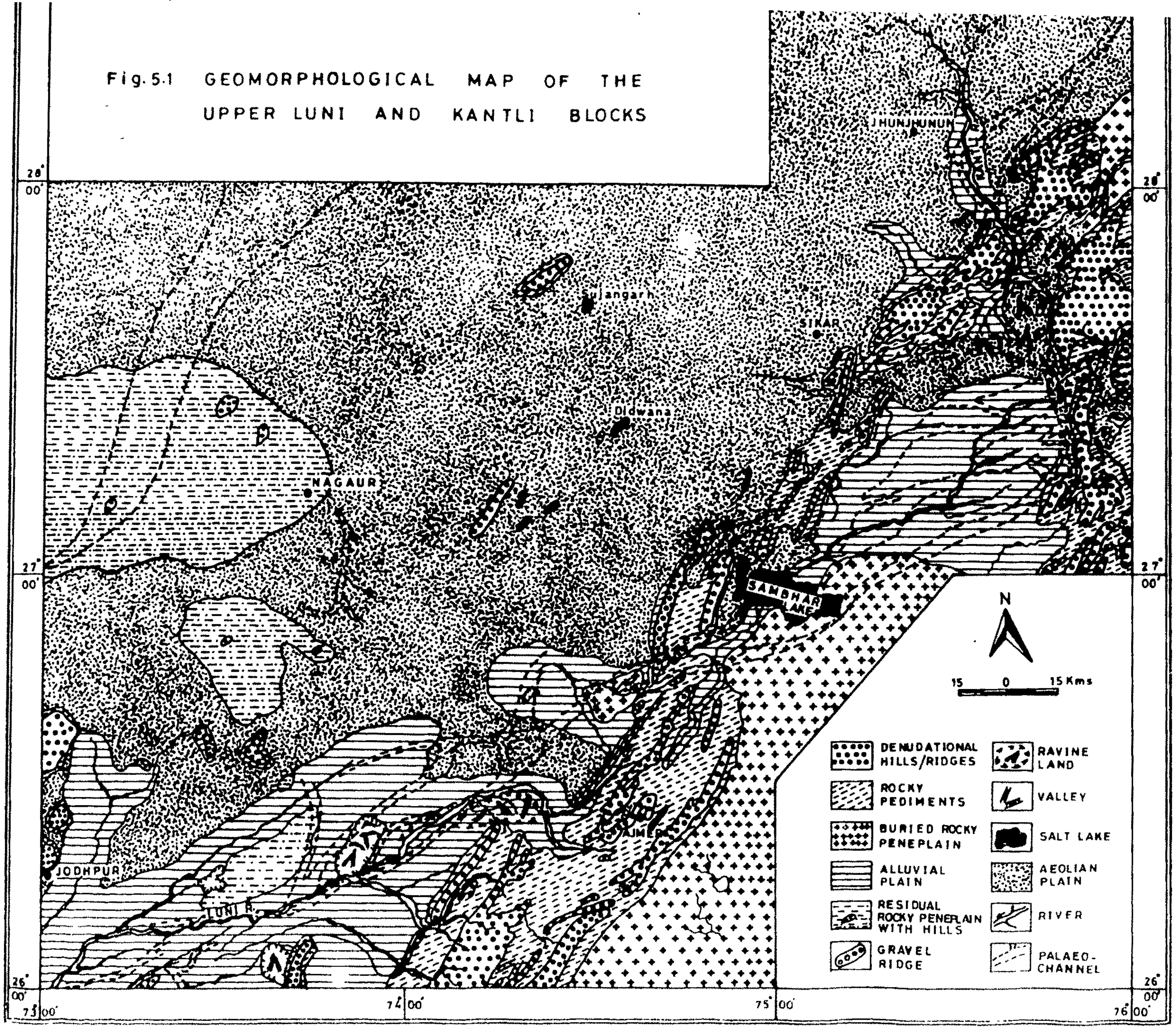

Table 5.1. Landform classification of study area

Physiographic Units	Landform Types		Environment of Genesis
	Depositional	Aggradation	
Alluvial Plains	Flood Plain, Natural levees, Point bars and channel bars, meanders, present day channels, river terraces, gravel ridges, buried/palaeo-channels, playas and fresh water lakes.	Rills and Gullies, Cliffs, scarps, cascades, present day channels, peneplain etc.	Fluvial and Lacustrine
Aeolian Plains	Sand sheets, sand heaps and mounds, present day active dunes of different types, stabilised dunes, playas, etc.	Inselbergs, Yardangs, desert pavements, deflation hollows, etc.	Mainly aeolian but some lacustrine and fluvial also.
Rocky Peneplains	Thin cover of aeolian and fluvial sediments alongwith coarse colluvial fragments.	Residual bedrock surfaces, low-lying isolated hills and hillocks, rocky outcrops, inselbergs, rills and gullies	Subaerial to aerial denudational, fluvial and aeolian.
Pediment Zone	Colluvial fan deposits, coarse gravelly and rocky pediments, talus cones, obstacle dune sand deposits.	Rills and gullies, residual rocky outcrops, etc.	Aerial to subaerial denudational fluvial and aeolian.
Rocky Highlands	Colluvial-mounds and fans talus cones, rocky and gravelly pediments.	Resistant/denuded hills and rocky ridges, cliffs, cascades, V shaped valleys, tors, mesas and buttes	Aerial to subaerial denudational, fluvial.

Some important depositional landforms produced by the river action are flood plains, levees, river channel bars, buried-/palaeo-channels, etc. The erosional landforms mainly include rills and gullies, scarps, river cliffs, cascades etc.

(a) Older Alluvial Plains

The flat older alluvial plains are the most extensive and are covered with alluvium of varying texture and thickness. The sediments comprise of loamy sand, sandy loams, loams and silty clay loam, characterised by well developed soil profile. The older alluvial plains occur farther away from the present day river channels on either side of their banks. The light to medium and medium to heavy textured flat older alluvial plains appear in grey to dark grey and dark tones on LANDSAT imageries. The area downstream of Alniyawas in the Luni basin and the area downstream of Chirawa in the Kantli basin are characteristic examples of older alluvial plains. Although vast track of the study area is occupied by the alluvial plains, intensive aeolian activity has concealed these plains beneath the dunal sands.

(b) Younger Alluvial Plains

The present day younger alluvial plains occur as narrow strips along the Luni and Kantli rivers and other minor stream courses. These plains consist of thick alluvial sediments of recent origin varying from sand to loamy sand and sandy loam. The river beds comprise admixtures of gravels, pebbles and coarse sands (Plate V.1). The dunal sand mounds lying above the alluvial sediments have imparted an undulating topography to this unit. These younger alluvial plains, occurring along the river channels are clearly visible in light grey to white tones on the satellite imageries, due to their location and linear pattern (Plate V.2).

(c) Natural Levees

The natural levees form characteristic ridge like elevations along the river banks, mainly in their middle reaches. The outer flanks of the levees have very gentle slopes and gradually merge into the alluvial flood plains. The levee materials mainly comprise of the sediments deposited by the

Plate V.1 A view of the Luni river cliff section showing admixture of angular to subangular alluvial sediments of recent origin and aeolian sediments of a younger alluvial plain. Location: Alniyawas

Plate V.2 IRS (LISS - I) view of the younger alluvial plains of Luni river.

rivers at the time when they overflowed their banks during periods of flood. Typical levee occurrences along the Kantli river channel have been witnessed at Keharpura, Bharunda Khurd, Bharunda Kalan, Hansalsar, Chhaawshri and Mainpura. Levees along the Luni river course have been observed at Badayali, Kekindra, Kharchiya, Anandpur Kalu, Nimbol, Jhak, Dhigana and Luni Junction (Chawan).

(d) River Channel Bars

Channel bars are located along the river and stream courses and are most characteristic of the braided portions of the Luni and Kantli rivers. They are formed when the excessive load carried by the river is deposited or dumped within the channel and the river diverts or braids. Point bars or meander bars are found on the convex sides of the meanders and grow by individual increments outward into the meander curve (Thornbury, 1984). Point bars and channel bars are observed at Ladpura, Alniyawas, Kekindra, Kharchiya, Anandpur Kalu, Jhak and Kaneo along Luni channel and at Chaawashri, Hansalsar, etc. along the Kantli river channel.

(e) Buried Channels/Palaeochannels

The study area displays ample occurrences of palaeo-river courses and cut-off meanders. These palaeochannels distinctly stand out on the satellite imageries due to their tonal differences from the surrounding areas attributed to the colour of sediments and differential cover of vegetation and landuse (Plate V.3). These units occur in dark and white to dark grey and reddish brown tones in the imageries. The details on the buried palaeochannels of the study area are given separately in the chapter on 'Drainage and Playas'.

(f) Intermontane Alluvial Plains

The alluvial plains lying within the intermontane valley depressions are characterised by elongated alluvium filled planation surfaces comprising 3-5 m thick admixtures of gravelly-sandy sediments, deposited by the rivers/rivulets during flash floods as well as by the process of illuviation. At places these plains are covered by the dunal sands. In the study area, the

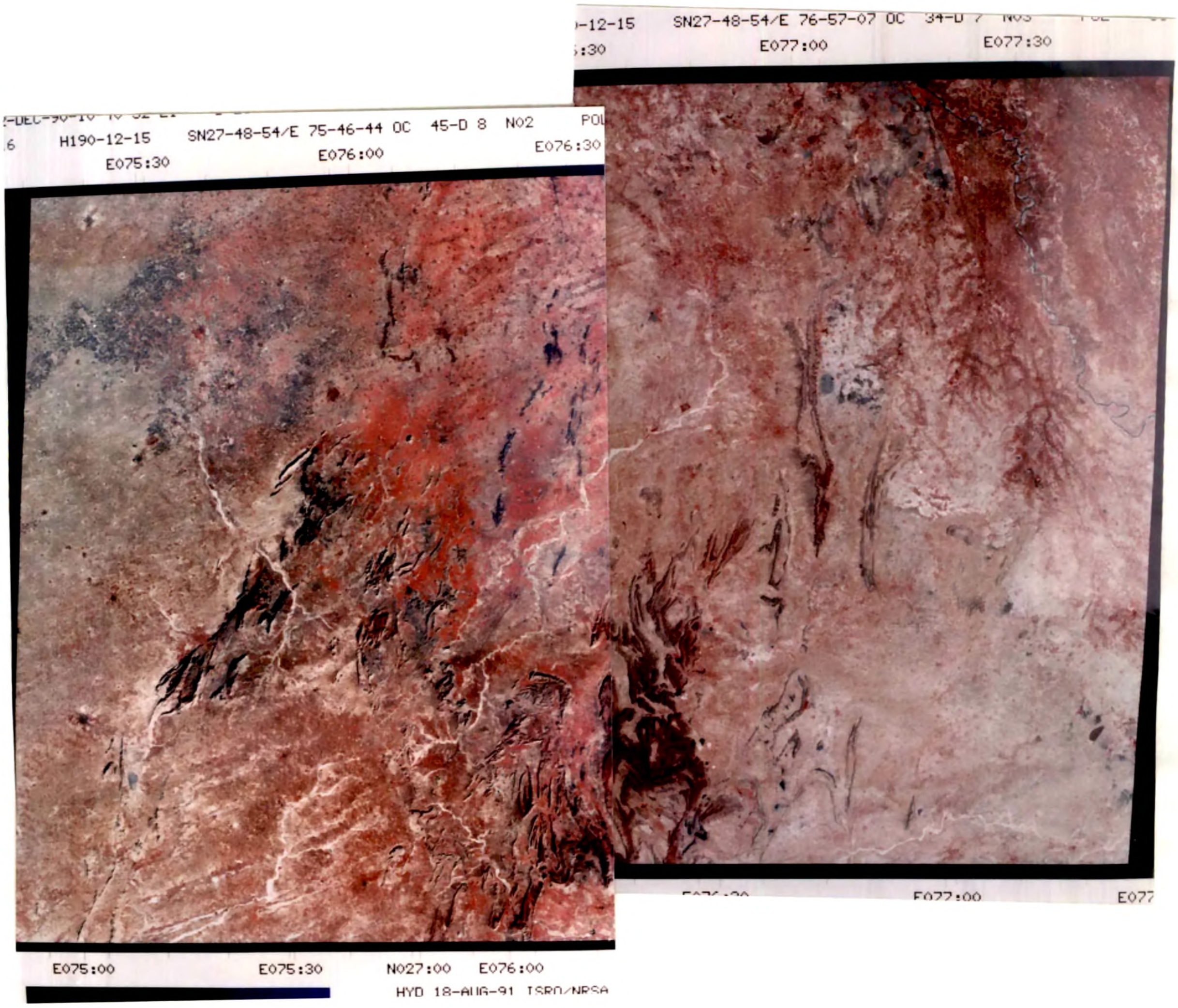

Plate V.3 IRS (LISS -I) view of palaeochannels in the northeastern parts of the study area.

intermontane alluvial plains occur mostly in the southeastern parts around Ajmer, Pisangan, Beawar, Nagelav, Madhogarh, west of Kishangarh, etc. Further NE, these plains are seen at Danta Ramgarh, Udaipurwati, etc.

(g) Rills and Gullies

Any area exhibiting the development of rills and gullies is generally characterised by the badland topography. These badland terrains have been ascribed to,

(i) aggradational phase of fluvial system, and
(ii) tectonism causing upliftment.

In the study area the occurrence of badland terrain is attributed to headward erosion of the streams in the pre-existing alluvium, thereby causing river capturing and deep incisions in the stream channels. The most illustrious examples of stream erosional carved badland areas are the flat alluvial plains and flat buried pediments in Jodhpur and Nagaur districts which have been dissected by recent fluvial activities resulting in shallow rills and gullies (Singh and Ghose, 1977). The aeolian landforms like low dunes have also been dissected by recent flüvial activities producing gullies. The areas around Lambiya, Raipur, Udaipurwati and Sikar are the typical cases of gully formation within the dunal terrain.

The formation of ravine-land topography has also been correlated with the reactivation of pre-existing crustal lineaments, causing upliftment (Thornbury, 1984). The northeastern parts of the study area particularly Mankri, Amarsar, Surani, Jharli, Hathide, Bishangarh, Guhala, Nangal, Nim ka Thana, Madhogarh, Jodhpura, etc. in the Kantli basin show the development of badland terrains attributed to tectonism (Plate V.4).

(h) Cliffs and Terraces

These are the erosional features in the alluvial plains developed along the river courses. The cliffs are almost vertical or high angled cuts along the river banks produced due to the high fluvial activities during the floods. The cliffs along the Luni channel are of 5 - 6 m heights and seen occurring at Jhak, Nimbla, etc., but those along the Kantli course are generally less than 5 m. At Pachlagi, the Kantli river has cut across the aeolian sands producing cliffs of more than 10 m height (Plate V.5). The cliffs and scarps usually occur along the meandering courses of the rivers, especially on their concave side.

AEOLIAN PLAINS

It has already been alluded that the study area constitutes the central and northeastern parts of the Thar desert. The aeolians account for a large portion of the area, predominantly occupying the northern side of the Luni river and stretching from Jodhpur in the southwest to Rajgarh (Taranagar) in the northeast. In spite of hostile conditions, the aeolian terrains of the Thar has remained a centre of attraction to the Pleistocene scientists. Varied landform features, dune patterns, sequential chronology of dune development, past aridity events, etc.,are some of the vital aspects that have fascinated the scientists. It is also significant that amongst all the deserts distributed globally, the Thar desert is the most thickly populated arid region, thereby the desert development aspects have attained very high momentum.

The aeolian plains of the study area in particular have been studied in detail by large number of workers. Some noteworthy contributors are La Touche (1902), Pandey *et al.* (1964), Verstappen (1970), Allchin and Goudie (1971), Vats *et al.*(1976), Ghose *et al.* (1977a & b), Singh (1977, 1982, 1992a, b & c), Wasson *et al.* (1983), Misra *et al.* (1988), Kar (1987, 1990, 1992), Raghav (1992), Wadhawan (1992), Dhir *et al.* (1994) etc.

The complexities in exploring aeolian terrains are manifold. Multiplicity in arid and humid (aggradational) phases, high sand mobility and tectonism that has drastically modified the terrain, etc., are few such factors. This has resulted in a net decrease in the spatial extent of the fluvial landforms, superimposition of one landform over others in a very short span of time covering a few tens of thousands of years.

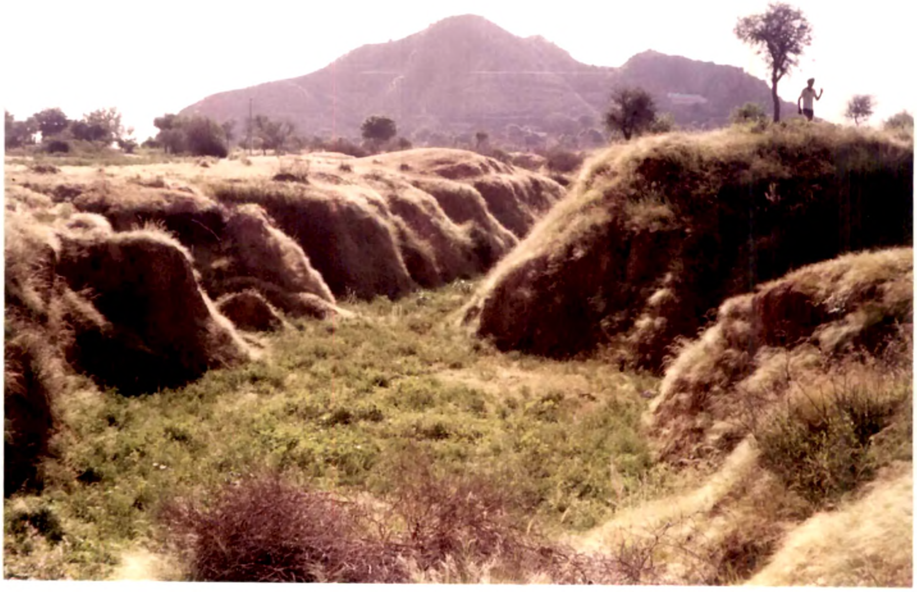

Plate V.4 A view of ravine land depicting typical rill/gully erosion observed in the badland topography. Location: Mankri

Plate V.5 A view of the Kantli river cliff cut across the aeolian sands. Location: Pachlagi village.

Aeolian Landform Features

Based on the study of satellite imageries (IRS), available literature and the ground truths, the major aeolian landforms can be grouped as depositional and erosional ones, the sand mounds and heaps (Plate V.6), sand sheets, different types of dunes (present day active dunes as well as stabilized older dunes), interdunal plains, etc., comprising depositional landforms, whereas the erosional landforms constitute the inselbergs, yardangs, etc., (Plate V.7). The shallow saline depressions, *viz.*, the salt playas, interdunal playas and inland drainage basins constitute characteristic inland lacustrine depressions/landforms within the aeolian plains. The satellite imageries of the area (Plate V.8) show distinct aeolian landforms characterised by various dune patterns.

Sand Dunes

The study area illustrates a large variety of dune patterns. These spectacular features cover almost 58% area of the Thar desert (Singh, 1977). The aspects related to dune morphology, sediment dynamics, etc., have been studied in detail by Thomas (1989), Mckee (1979a & b), etc. The salient features of individual dune pattern category is given in Figure 5.2. These wind borne depositional landform features have been classified on the basis of different criteria, *viz.*, (i) induration and mobility, (ii) dune pattern and morphology, and (iii) wind dynamics. However, for classifying these landforms, the author has adopted the dune pattern and morphology criterion. The study of satellite imageries, topographic maps and ground checks have revealed the following dune types in the study area. The areal distribution of these dune types in the study area is shown in Figure 5.3.

a) *Parabolic and Coalesced Parabolic Dunes*

The parabolic dunes which form a major component of the Thar dune field (Singh, 1982; Wasson *et al.*, 1983), occur in the form of clusters, i.e., each parabolic dune is linked to an adjacent dune so that they seem to share the arms. The cluster of about 20-25 such individual parabolic dunes gives the appearance of a 'rake'. It is observed that the simple parabolic dunes

Plate V.6 A view of extensive active sand sheets typical of the dune field in the northern parts of the study area. Location: Rajgarh

Plate V.7 Wind faceted bouldery rhyolite ridge depicting the intensity of wind erosion in the study area. Location: Luni area

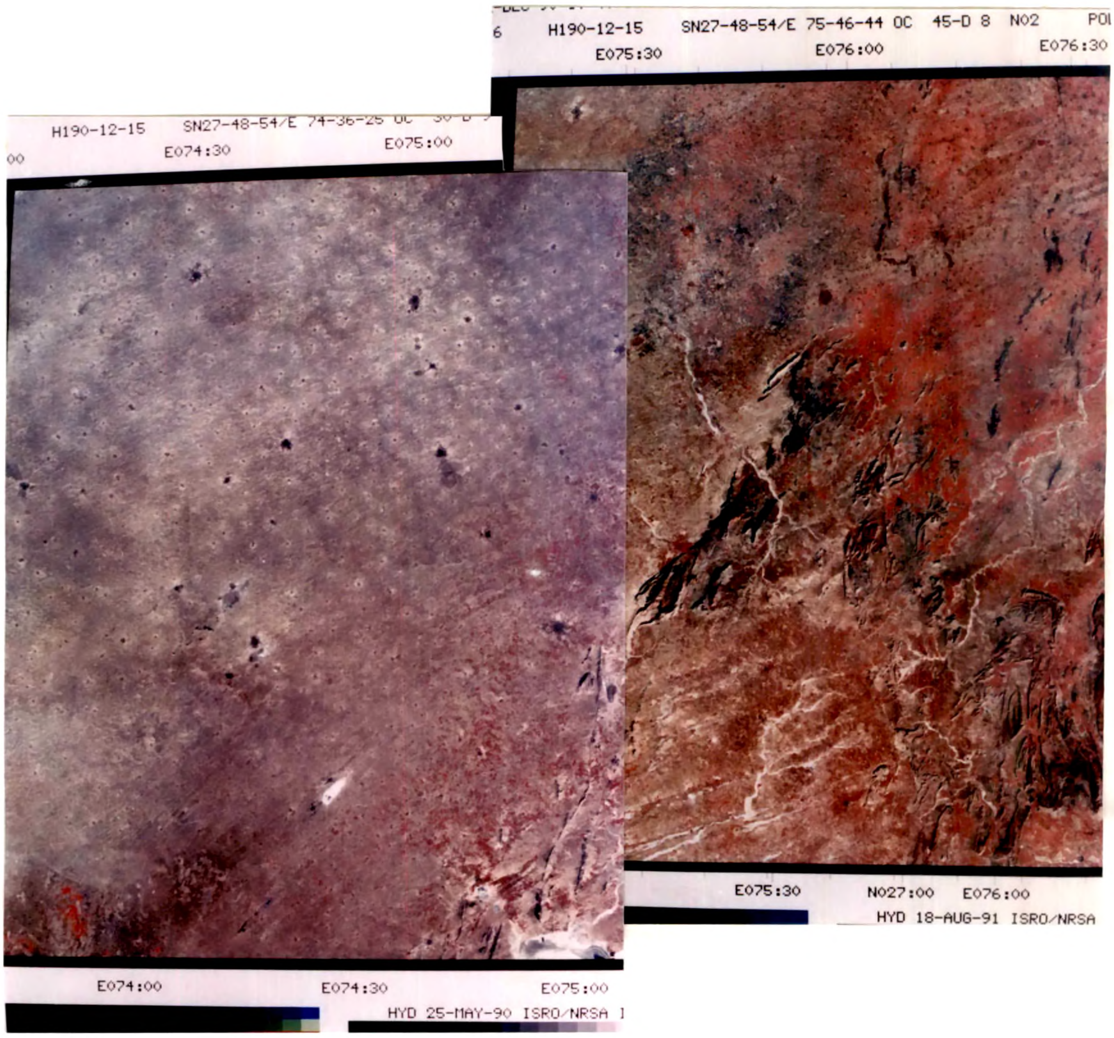

Plate V.8 Satellite imagery mosaic of northeastern Thar dune fields showing complex dunes (star dunes), sand mounds, longitudinal dunes and transverse dunes.

DUNE TYPE	ILLUSTRATION	NUMBER OF SLIP FACES	MAJOR CONTROL ON FORM	FORMATIVE WIND REGIME	NATURE OF MOVEMENT
DOME DUNE		0	Coarse Sand	Various	Limited
BLOW OUT		0	Disrupted vegetation cover	"	May extend downwind
PARABOLIC DUNE		1	"	Transverse Unimodal	Slow nose migration
TRANSVERSE DUNES					
BARCHAN DUNE		1	Wind regime and sand supply	"	Forward migratory
BARCHA-NOID RIDGE		1	"	"	"
TRANSVE-RSE RIDGE		1	"	More directional variability than for barchans	"
LINEAR DUNES					
LINER RIDGE		1 2	"	Bimodal wide uni modal	Extending
SEIF DUNE		2	"	Bimodal	"
REVERSING DUNE		2	"	Opposing Bimodal	May migrate if one mode dominant
STAR DUNE		3+	"	Complex Multimodal	Vertical accretion

Fig. 5.2. CLASSIFICATION OF BASIC DUNE TYPES (After Thomas, 1989)

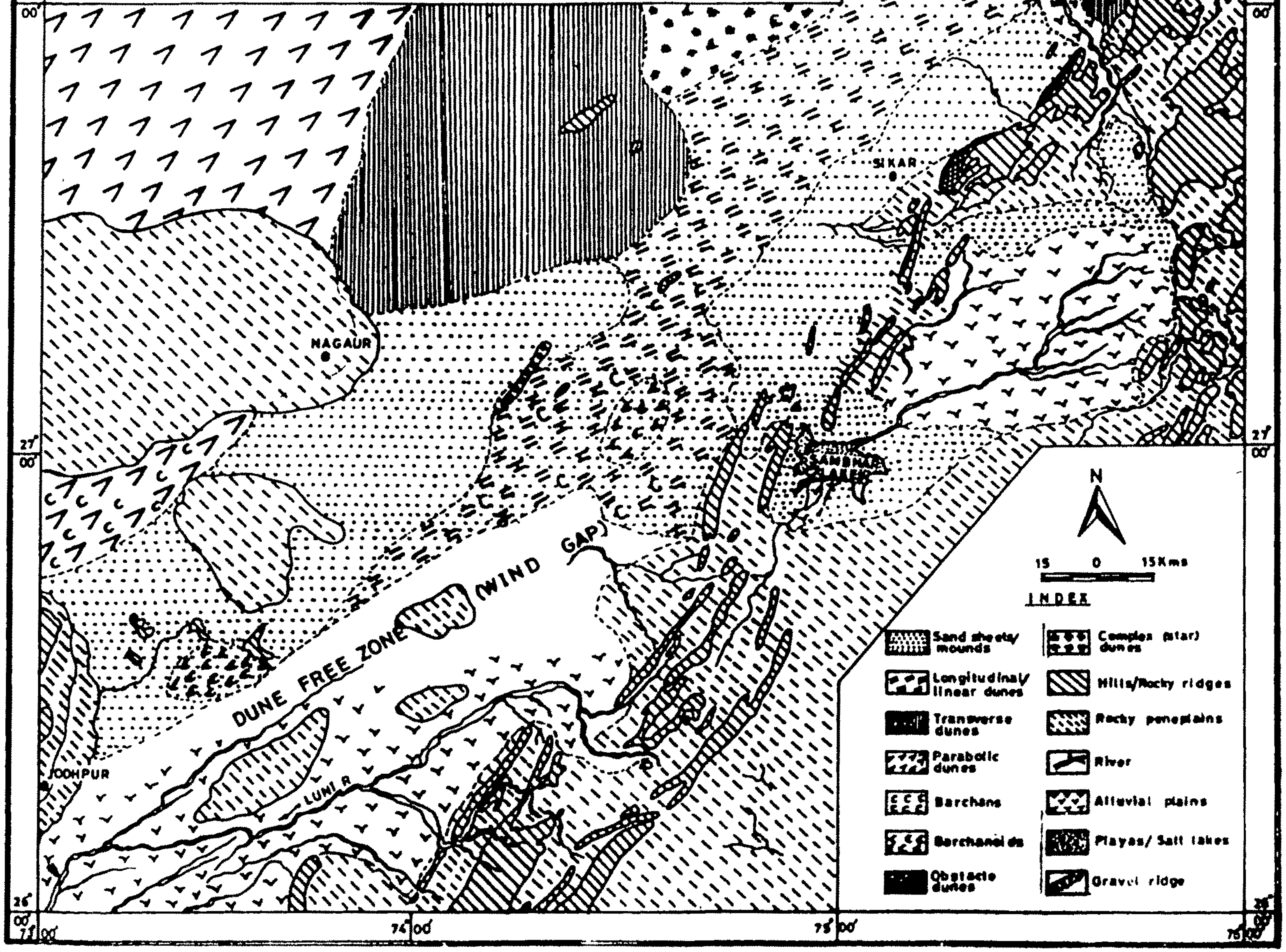

Fig. 5.3. AREAL DISTRIBUTION OF DUNE TYPES IN THE UPPER LUNI AND KANTLI BLOCKS

are generally produced by the prevailing SW wind and ultimately coalesced with transverse ridges to form compound coalesced parabolics. The parabolic dunes are products of erosional and depositional processes that prevailed during long periods of arid phase. The sands were scooped away by the erosional processes creating hollows or parabolics with flanks tapering for several kilometers towards the gentle windward slopes. The sands were then redeposited on the lee side of the parabolas by depositional processes creating the steep leeward slopes, thereby forming the parabolic dune. At places these parabolic dunes over ride one another, which is attributed to the time gap in the development of riding dunes or differential rate of movement (Wasson *et al.*, 1983). The parabolic dunes display heights ranging from 10 m to 30 m and at places they are well stabilized and vegetated.

The parabolic dunes occur mainly in the northwestern and western parts of the study area, eg., Nokha Mandi, Napasar, Gajner in the northwestern side and Khimsar, Birloka, Panchla, Papasni, Kapariya villages in the western parts of Nagaur district and northeastern parts of Jodhpur district. A gradual change in the dune shape has been observed from northeast (coalesced-compound type) to southwest (hair-pin type).

(b) *Longitudinal Sand Dunes*

The longitudinal or linear sand dunes occur as linear, parallel sand ridges and are possibly developed due to the strong prevailing winds during the past arid phase in the region. These dunes were thought to have originated from the parabolics (Verstappen, 1968, 1970; Singh, 1977, 1982; Wasson *et al.*, 1983). However, Kar (1987) suggested that these dunes are formed from the barchans and barchanoids. Kar (1990 a) also viewed that the dunes in their early stages of formation were linked to the elliptical fields of barchanoids. He further opined that the formation of these longitudinal dunes is attributed to gradual decrease in the wind energy resulting in gradual change in the shape of the longitudinal. The longitudinal dunes are also formed due to the funneling effects along the major stream valleys and also on the lee vortices across major obstructions like isolated hills (seif type) [Plate V.9].

Plate V.9 A view of seif dune forming a hair pin pattern due to the funnelling effect of wind on the lee vortices across isolated hills. Location: Belwa

The axis of elongation of these dunes is generally sub-parallel to the mean wind direction in the area. The dunes have heights ranging between 5 m and 50 m, and their orientation varies from N 30° E to N 45° E. These dunes have predominantly attained stabilization and are characterised by moderate to good vegetal cover and the development of soil horizon. In some parts of the dune field the renewed aeolian activity has affected the crests of these dunes causing fresh sediments (sands) to pile up on the leeward sides and crests. Sometimes barchan dunes are also seen superimposed on the flanks of these dunes. The longitudinal dunes are dominantly distributed in the central and northeastern parts of the study area (Plate V.10), which is a region of poorly organised dunefields. Some illustrative localities are around Phalodi, Degana, Chosli, Sanju, north of Didwana, etc.,in the Luni block and Sikar, Nawalgarh, Mukundgarh, Mandawa, Jhunjhunun, Malsisar, Alsisar, Mandrela , etc.,in the Kantli block.

(c) *Barchan Dunes*

The active barchan dunes are formed by unidirectional, uniform winds on the hard surfaces with scanty vegetation and limited sand supply (Singh, 1977). The deposition of sand by the prevailing winds takes place in the form of crescent shaped barchan dunes with steep concave leeward side and gentle convex windward side with two elongated ridges or arms on either side of the steep face. Several such barchans formed in the same path and clustered together gradually resulted in the coalesced barchan dunes. In the dunefields, barchans have collided and linked to form compound barchanoid ridges (Plate V.11). Megabarchans, which are compound forms consisting of superimposed barchans of different sizes, occur in the field less frequently. Megabarchanoids are larger compound barchanoids where the windward slope is covered with at least three tiers of nested barchans roughly from the lower mid-slope to the crestal segment (Kar, 1990a). The leeward slope is mostly composed of long slip face at the angle of repose and a foot slope with a declivity of 10 to 12. But in some cases the long profile of the megabarchanoids shows a gentle convex outline with nested barchans draping the surface from the windward lower mid slope to the leeward foot slope.

Plate V.10 A view of longitudinal/linear dunes with depressions on the crest. Viewer looking NW. Location: Hotala

Plate V.11 A view of barchanoid ridge developed by the collision and linking together of barchans, thus forming step like terraces. Location: Nimbala

Isolated as well as coalesced barchan dunes are scatteringly distributed in the western, central and northeastern parts of the study area. In the western parts, the barchans and related dunes are seen to occur around Panchla, Khimsar, Pipar road, etc.; in the central parts around Didwana, Chandarun, Sanju, Kuchetia, Tosina, Budsu, etc.; and in the northeastern parts around Sikar, Mukundgarh, Gokulpura, Khur, etc. (Plate V.11).

(d) *Transverse Dunes*

The transverse dunes occur at right angles to the direction of the prevailing winds. The formation of transverse dunes has been a matter of debate. Singh (1977) has ascribed this to the prodigious sand cover, abundance of sand supply, absence of vegetation and persistent and widespread wind action. Wavy ridges separated by trough like furrows at right angles to the prevailing wind are mainly created by the dune-building winds.

The transverse dunes show a scattered distribution and occur as patches in the study area. The occurrences are confined mainly to the northern and northeastern parts (Plate V.12), *viz.*, Bidasar, Sujangarh, Ladnun, Surpalia, etc. In the western parts, scanty occurrences of transverse dunes have been observed around Rohina in Jodhpur district. The transverse dunes display heights ranging between 5 m and 40 m and orientation generally varying between N 30° W and N 50° W.

(e) *Obstacle Dunes*

This dune pattern is developed due to the obstruction caused to the sand laden winds by the isolated and continuous chains of hills. The windward obstacle dunes are formed when the prevailing southwest winds are obstructed by the hills and the sands are deposited on the windward slopes due to the sudden decrease in the wind velocity. The leeward obstacle dunes are formed when the prevailing southwest winds sweep the sand over the hills and deposit it on the leeward side right from the slopes of the obstructing hills up to a few kilometers in the direction of the upwind. The obstacle dunes are highly dissected by rills and gullies, and at places are well cemented and vegetated. The major obstacle dunes mostly found on the western

Plate V.12 A view of transverse dune field in the arid aeolian plains of northern parts of study area around Sujangarh. Viewer looking towards SW.

flanks of the chains of hills lying in the areas of Barr, Pushkar, Nawa, Sambhar and further northeast along the slopes of the hills of Danta Ramgarh, Udaipurwati, Khetri and Sikar (Plate V.13). In the western parts of the study area windward obstacle dunes occur abutting against the isolated hills of rhyolite, granite and sandstones. The obstacle dunes have heights ranging between 8 m and 40 m. Phytoreclamation methods are utilized for the stabilization of these obstacle dunes in many parts of the study area (Plate V.14).

(f) *Shrub-Coppice Dunes*

Shrub-coppice or minor obstacle dunes are formed on the windward and leeward sides of minor obstacles like shrubs, bushes and grasses. The sand carried by the winds are blocked and caught by the low lying shrubs and grasses and develop the shrub-coppice pattern in the form of sand mounds, hummocks, etc. These dunes are of different shapes, sizes and orientations, ranging in heights from less than a meter to about 3 meters, the longitudinal and transverse ridges rising upto even 4 - 5 meters. The shrub-coppice dunes are widely distributed in almost all parts of the study area, but concentrated mainly in the western, northwestern, northern and northeastern parts falling within the desertic to semi-desertic tracts (Plate V.15).

(g) *Compound Dunes*

The study area, particularly between Sujangarh and Sardarshahar display rather complex patterns of dunes. The most spectacular types are the 'star dunes' (Plate V.16), 'sand domes' and other complex patterns produced by the intermixing and superimposition of more than one dune types. Such compound patterns are generally attributed to the frequently changing wind directions and energy conditions.

Dunal History

The history of these non-indurated to semi-indurated aeolianites of Thar desert has been a matter of debate. These have been categorised as older and newer dune systems, predominantly based on induration and soil formation criteria. The Thar desert has witnessed two major aeolian

Plate V.13 A view of obstacle dunes or protected dunes developed on the western flanks of the rhyolite hills near Jodhpur.

Plate V.14 A view of stabilization of obstacle dunes by phytoreclamation methods. Location: Mangla village

Plate V.15 A view of shrub-coppice dune developed in shrubby vegetational area.
Location: Gogasar

Plate V.16 A view of partially stabilized star dunes in a complex dune field. Location: Ranadisar-Sardarshaher activities, (i) Lower to Middle Pleistocene and (ii) terminal Pleistocene (Goudie *et al.* 1973; Wasson *et al.* 1983; Ghose *et al.*, 1977 b; Singh, 1977, 1982; Pandey *et al.*, 1964; Singh *et al.* 1972, 1973, Misra *et al.*, 1988).

The geochronological studies of the dunal sands have indicated two aeolian phases during late Quaternary to mid-Holocene, wherein the transverse dunes were formed around 17,000 years B.P. and the longitudinal dunes evolved from the older dunes and developed during the second aridity phase which prevailed sometime during 5300 years B.P. Misra *et al.* (1988) and Allchin *et al.* (1978) based on archaeological evidences, have postulated a major arid phase that prevailed during the lower Palaeolithic cultures.

ROCKY PENEPLAINS

The landscape of the undulating terrain is characterised by a rolling topography with isolated hills and hillocks. It includes mixed landforms of erosional and depositional characters of which the denudational landforms predominate. The erosional landforms include residual bedrock surfaces, isolated hills and hillocks, inselbergs (Plate V.17), rills and gullies, cliffs, etc. The sediments in this terrain are generally assorted coarse grained material of sand, gravel and rock fragments of fluvial and colluvial origin.

PEDIMENT ZONE

This zone is typical of the mountain terrain of the study area and comprise the delluvial (colluvial) fans which occur at the base of hills and mountain ridges (Plate V.18). The slope of these landform features varies from 3 to 8 in the upper part, 1 to 3 in the middle part and less than 1 in the lower part (Singh *et al.*, 1990). In the satellite imageries, this unit is clearly distinguishable from the hills and the buried pediments/pediplain by its light brown to dark grey tone. The colluvial fan materials consist of rocky/gravelly sediments. The surfaces of the pediment zone are rugged due to the presence of these rocky blocks and gravelly sediments. Strewn all over the pediment zone along the hill slopes of the NE-SW trending Aravalli Mountain Range, these colluvial fans are well developed in the areas around Khetri, Singhana,

Plate V.17 A view of erosional, domal hill of Nagaur sandstone amidst residual aeolian plane. Location: Khatu

Plate V.18 A view of an erosional ridge (Delhi Quartzites) amidst residual peneplain depicting steep facets, gently sloping pediments, riddled with colluvial fans (CF) produced under illuvial action.

Udaipurwati, Danta Ramgarh, etc., in the Kantli block and Ajmer, Kishangarh, Beawar, etc.,in the Luni block.

ROCKY HIGHLANDS

The rocky highlands are characterised by the NE-SW trending Aravalli Mountain Range composed of the rocks of the Delhi Supergroup, such as calc-schist, calc-gneiss, biotite-schist, phyllite, crystalline limestone, quartzite, amphibolite, etc. The most resistant hills with higher relief are those formed of quartzite. The hilly terrain is characterised by parallel series of hills, with U-shaped and V-shaped valleys. The hill slopes are generally debris covered and support good vegetation. Colluvial fans, talus cones. etc. are typical of the foot hills, forming the pediment zone. The length of the talus slopes increases towards the east, and the summits of the hills become rounded (Kar, 1983 b). But the granite hills of the region show different characters, with barren hill slopes, lesser amount of debris cover, increased chemical weathering producing cavernous features and spheroidal boulders.

The depositional landforms in the hilly terrain are the colluvial mounds, fans, rocky-gravelly pediments, etc., whereas cliffs, cascades, valleys and the denuded hills, ridges, tors, mesa, butte, etc., are the erosional landforms. Some of the west flowing streams show sudden break in their long profile across scarps producing waterfalls, rapids, cascades, etc. This is characteristic of the Pushkar hills, while in the Raghunathgarh hills and Kankriya hills cascades do occur. The presence of rapids and waterfalls in the hilly terrain bear testimony in support of the neotectonic movements in the region (Sen and Sen, 1983).

MORPHOSTRATIGRAPHY

The study area displays large varieties of landform features attributed to the erosional and depositional activities of the different surficial processes that prevailed from time to time. The sequential events of terrain modifications and generated landform features present a complex scenario of an overall geomorphic history of the study area and its neighbourhood.

The overall morphostratigraphy of the study area, modified after the morphostratigraphy of northeastern Thar proposed by Ghose, 1982 is given in Table 5.2.

Table 5.2 Generalized chronological sequence of geomorphic units in the Upper Luni and Kantli Blocks, correlated with Geology (after Ghose, 1982)

Period	Geology	Geomorphic Unit (Landform)	Climate
3rd PENEPLANTATION IN PROGRESS (Under Aeolian Environment)			
Recent	Younger Aeolian Sediments	15. Sand heap, Sand ripple	Present arid to semi-arid
		14. Playa	
		13. Wadi	
Sub-Recent to Recent	Younger Alluvium	12. Present (Active) dune	Warm sub-humid
		11. Present river channel and braid	
Sub-Recent (Early Holocene)	Older Aeolian sediments	10. Present flood plain	
		09. Backswamp	
		08. Stable dune	
		07. Pediplain	
		06. Pediment	Arid
		05. Bornhardt (Comprising of basement rocks)	
2nd PENEPLANTATION (Under Aeolian Environment)			
Upper Pleistocene to Early Holocene	Older Alluvium	04. Left out channel	Humid and Cold
		03. Older flood plain	
		02. Terrace	
Pleistocene (?)	Sandstone/Siltstone, Conglomerate (Indicate the ancient river bed, but do not form any land forms)		
1st PENEPLANTATION (Under Fluviatile Environment)			
Precambrian	Delhi Supergroup of rocks and post-Delhi intrusives	01. Hill ranges, discontinuous hills, outcrops	