CHAPTER IV

TECTONIC SETUP

TECTONIC SETUP

GENERAL

The northwestern parts of the Indian subcontinent exhibit one of the most complex evolutionary history since the Pre-Cambrian times. Out of the various factors responsible for drastic modifications in the present-day landscape and the processes, tectonism has played a pivotal role. The basement tectonism related to Aravalli-Delhi orogeny and their subsequent reactivation at various stages have been responsible for the accumulation of thick pile of younger sediments, change in river courses, drainage disruption, formation of playas/salt lakes, etc.

The different sedimentary basins of the entire Rajasthan shelf have been explored in detail by various workers and organisations to study the tectonic and structural configuration, geological evolution and hydrocarbon prospects. These include various scientists of the Oil and Natural Gas Corporation (ONGC), National Geophysical Research Institute (NGRI), Geological Survey of India (GSI), Physical Research Laboratory (PRL) and several other scholars of the Geology departments connected to the Universities and Institutes. Important contributions have been made by various geoscientists on the regional tectonism of the Rajasthan region. Noteworthy among these include Heron (1953), Eremenko *et al.* (1968), Ray (1976), Sen (1981), Sen and Sen

(1983), Roy (1985, 1988, 1994), Roy *et al.* (1984), Roy and Das (1985), Ahmad and Ahmad (1980), Singh (1982, 1988), Sinha-Roy (1984, 1988), Naha and Roy (1983), Sychanthavong and Desai (1977), Sychanthavong and Merh (1985, 1986), Sychanthavong (1990), Srivastava (1988), Sharma (1977, 1983, 1988), Dassarma (1986, 1988), Deb and Sarkar (1990), Powar and Patwardhan (1984), Biswas (1987), Arora (1993), Bakliwal and Ramasamy (1987), Ramasamy *et al.* (1991), Ghosh *et al.* (1991), etc. These studies have provided an impressive picture of the regional tectonic evolution of the northwest Indian basin in general and the Rajasthan region in particular.

REGIONAL TECTONIC FRAMEWORK

The tectonic framework of northwestern India (Fig. 4.1) constitutes three major Precambrian orogenic trends, *viz.*, the NE-SW Aravalli trend, the NNW-SSE Dharwar trend and the ENE-WSW Satpura trend. Biswas (1987), while describing the tectonic framework of Western India based on these major orogenic trends, showed that the major NE-SW Aravalli trend splays into three components at its southwestern extremity. The main NE-SW trend continues across the Cambay graben into Saurashtra as a southwesterly plunging arch The northern components of the Aravalli orogen, *viz.*, the Delhi fold belt trend turns to E-W and continues into the Kachchh region across the Cambay graben. The southern component in turn swings to SE and joins the Satpura trend.

Deb and Sarkar (1990) have identified six tectonic domains in the Rajasthan region based on tectono-lithological characteristics. These are:

1) the Banded Gneissic Complex (B.G.C.) and other older granites,
2) the Bhilwara belt,
3) the Aravalli-Jharol belt,
4) the North Delhi belt,
5) the South Delhi belt, and
6) the Vindhyan basin.

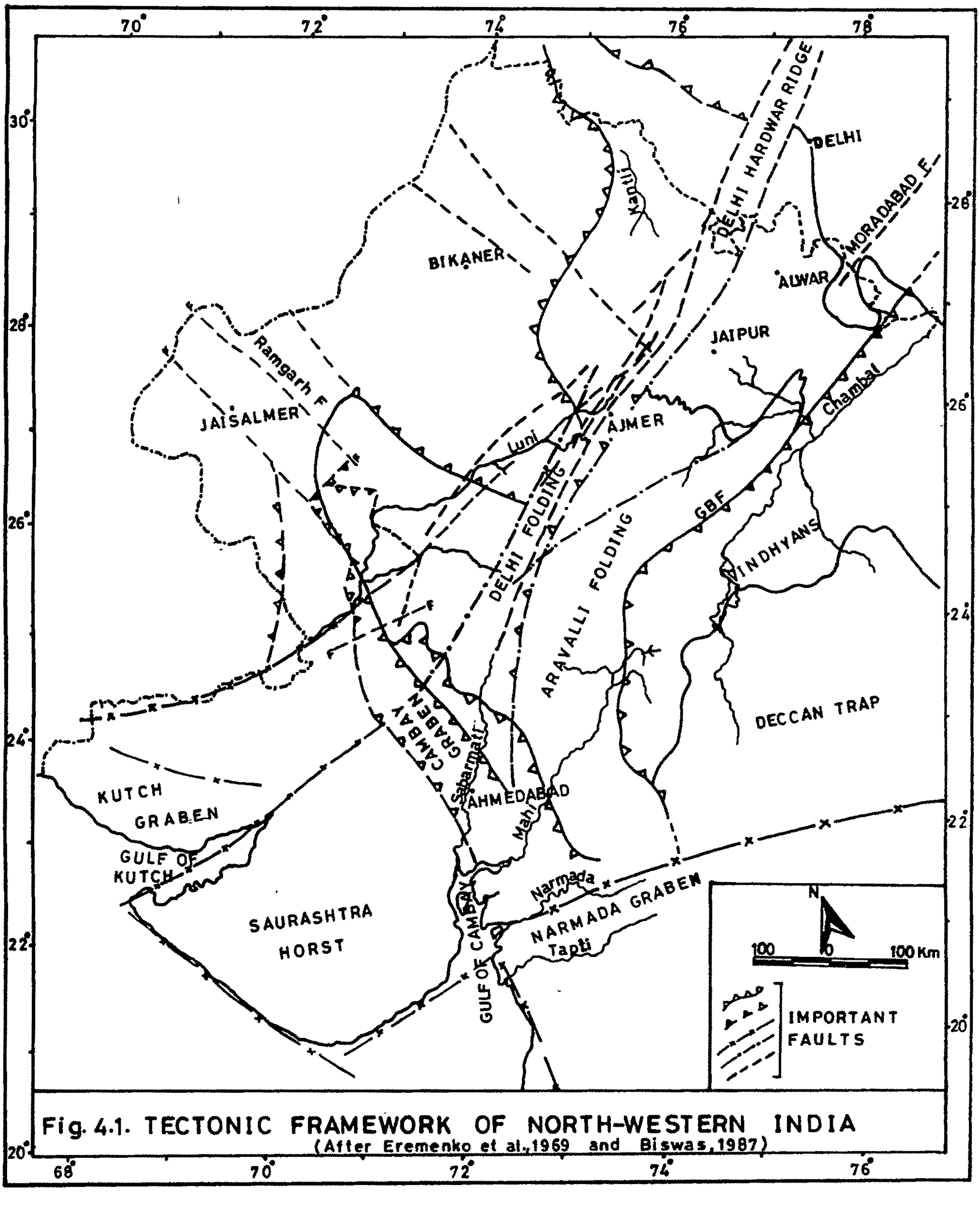

Fig. 4.1. TECTONIC FRAMEWORK OF NORTH-WESTERN INDIA
(After Eremenko et al., 1969 and Biswas, 1987)

BASEMENT/PROTEROZOIC TECTONISM

The NE-SW trending Proterozoic fold belt of the Aravallis and Delhis form an important feature in the Rajasthan region lying to the south/southwest of the Indo-Gangetic plains. The interpretation of the nature of the crust which underlay and delimited the Proterozoic sedimentary-volcanic basins is essential for an understanding of the post-Archaean crustal record of the Aravalli Mountain Range.

Sychanthavong and Merh (1985) emphasised the role of proto-plate movement in the geological evolution of the Precambrian terrain of NW Peninsular India. They envisaged the Aravalli-B.G.C. proto-continent to be part of a primitive Archaean proto-continent which got detached and drifted towards southeast to the Dharwar and Singhbhum proto-continents; the three proto-continents later behaving as one unit since 1600 M.y. The Narmada suture marks the joining line between the Aravalli and the two southern Singhbhum and Dharwar proto-continents. This was accompanied by sea-floor spreading in the northwest, wherein the Delhi group of rocks got deposited, the Ajabgarhs in a leptogeosyncline over the oceanic crust and the Alwars over the continental shelf areas.

ARCHAEAN (B.G.C.) PHASE

The ancient Archaean sialic crust underlying the Proterozoic basins has been assigned an age of 3500 M.y. The earliest magmatic event in this Precambrian crystalline crust occurred during this period when tonalitic to granodioritc suite of rocks were expelled from the mantle along with tholeiitic basalts (Macdaugal *et al.*, 1983), some of which had an oceanic affinity (Roy, 1988). Intrusion of granitic bodies into the earliest formed crustal rocks, *viz.*, the Archaean Mewar gneisses took place at about 3000 M.y. and 2600 M.y. ago (Choudhary *et al.*, 1984), which culminated the Archaean crust building process.

The emplacement of the Berach and related granites at the end of the Archaean (2.6 to 2.5 Ga.) resulted in the arching and doming of the crust (Srivastava, 1988). Intracratonic basins or incipient grabens were created due to the faulting at the crest of the dome. A number of linked or partially detached fault troughs developed over the denuded Archaean crust (Roy, 1988) which formed the basins for the deposition of thick Proterozoic sediments beginning with the Aravalli sedimentation. The Great Boundary Fault (G.B.F.) formed the eastern boundary of this basin.

ARAVALLI PHASE

The various depositional basins formed over the Archaean crust had a seaward connection and have been considered as stable continental margins or interior basins as the Aravalli succession in the type area is characterised by two major litho-facies sequences (Roy and Paliwal, 1981), *viz.*, a deep sea facies and a near shore shelf facies.

An interplay of tectonism, erosion and sedimentation during the period produced changes in the depositional environment. The vertical movements within the Archaean crust were the major tectonic processes at the time which created changes in relief between the basins and the uplifted basement blocks.

By the end of the Aravalli sedimentation a number of ultramafic intrusives had intruded the Aravalli sedimentarysequence. The Aravalli rocks were then intensely folded, four major phases of folding with easterly or westerly plunge having affected them. Several faults and ductile shear zones were formed at the time of this deformation phase (Roy, 1988), most of which were along the basement cover interface. The emplacement of the Darwal and Amet granites and other related granitic bodies at about 2000 Ma. (Choudhary *et al.*, 1984) synkinematically or late synkinematically with the first Aravalli folding marks the culmination of the Aravalli depositional cycle (Roy, 1985).

The period also witnessed intense metamorphism and crustal shortening in the Aravalli depositional basin which resulted in the development of tensional cracks that gave rise to another set of faulted intracratonic basins, parallel to the Aravalli basin with a NE-SW trend. The eastern Aravalli-B.G.C. block was upthrusted in a westward direction. The deposition of the Delhi Supergroup of rocks began in the basin to the west of the upthrusted Aravalli-B.G.C. block.

DELHI PHASE

Sychanthavong and Merh (1985), while describing their alternative plate tectonic model for the geological evolution of the Precambrian terrain of northwestern India viewed that the Delhi rocks were deposited during the period when the drifting of the Aravalli-B.G.C. protocontinent was taking place (2000 M.y. to 1650 M.y.). The Alwar series were deposited on the Aravalli-B.G.C. protocontinental shelf and the Ajabgarh series on the oceanic crust.

The Delhi sedimentary basins opened up first as a system of horsts and grabens (Roy, 1988) which later on extended in a NE-SW direction all along the axial trace of the Aravalli Mountain Range. Volcano-sedimentary rocks of the Delhi Supergroup were laid down in these basins. The Delhi basin of northeastern Rajasthan is characterised by many fossil grabens, horsts and arches which broadly constitute three sedimentational domains (Singh, 1988). These are, from west to east, the Khetri sub-basin, the Alwar sub-basin and the Bayana-Lalsot sub-basin. Deb and Sarkar (1990) grouped these sub-basins under the north Delhi belt (after Sinha Roy, 1988). The south Delhi belt extends from just north of Ajmer to south of the Abu road in the south and conforms to the 'main Delhi synclinorium' of Heron (1953). The Sambhar-Jaipur-Dausa (SJD) transcurrent fault played a dominant role in the opening of the north Delhi pull-apart rift basin whereas in the south Delhi belt it behaved as a transform fault for the ocean opening (Sinha Roy, 1988).

Sychanthavong and Merh (1985), while envisaging the tectonic model of Delhi Mountain range, emphasized on the plate movements. These workers have postulated that at about 1650 M.y. the subduction of the Delhi oceanic plate beneath the Aravalli-B.G.C. protocontinent took place, resulting in underthrusting and squeezing of the Delhi sediments against the Aravalli-B.G.C. protocontinental margin. This subduction began when the Aravalli-B.G.C. protocontinent collided with the Dharwar and Singhbhum protocontinents, the continued sea-floor spreading being the reason for the subduction. The Idar-Deogarh-Ajmer-Khetri fault zone which is the junction line between the Alwars and Ajabgarhs represents the trench and margin of the trailing edge of the Aravalli-B.G.C. protocontinent. The Alwar series of rocks occur to the east of this lineament and the Ajabgarh series to the west of the lineament.

The Delhi Supergroup is characterised by more extensively developed volcanic facies rocks and the deposition of the sedimentary sequences in fluvial and marginal (shallow water) marine environment. The sedimentary-volcanic association of the Delhi basin was affected by multiple folding (Ray, 1976; Naha *et al.*, 1984, 1987) and polyphased metamorphism wherein three phases of folding have been recognized. The continued movement of the Delhi oceanic plate and the subduction process controlled the folding episodes of the Delhi sediments. Due to these folding events a number of low-angled thrusts developed in the Ajabgarhs west of the subduction zone and high-angled faults developed in the Alwars and the underlying Aravalli-B.G.C. basement, east of the subduction zone.

According to Sychanthavong and Merh (1985), the Delhi orogenic upheaval which controlled the F_1 and F_2 Delhi foldings, took place during 1650 M.y. to 1400 M.y. and from 1000 M.y. to 850 M.y. respectively, as evidenced by the age of granitic and other intrusive rock bodies associated with the Delhis. They visualised the intrusion of these igneous rocks along the low-angled thrusts during F_1 folding and along the high-angled faults during the F_2 folding. The intrusives along the high-angled regional faults in the Alwars represent products of anatectic melting of the Aravalli-B.G.C. proto-continental basement rocks.

The F_1 folds in the Ajabgarhs are overturned to the west while those in the Alwars and the underlying Aravalli-B.G.C. basements were upright. In contrast to this, the F_2 folds in the Ajabgarhs are upright, whereas in the Alwars and Aravalli-B.G.C. basement they are overturned to the east. Longitudinal dislocations occurred during the F_1 and F_2 folding episodes and transverse fractures during the F_3 phase of folding of the Delhi Group of rocks. The longitudinal dislocations had a mantle connection causing the emplacement of associated igneous intrusives. Further, squeezing of the proto-continents caused the upliftment of the geanticlines and co-axial refolding of F_1 and F_2 folds. Granulitic rocks were pushed up along some local and regional faults during this uplift (Sychanthavong and Merh, 1985).

During the upheaval period of the Ajabgarhs and Alwars, the subduction zone shifted further northwest and the emplacement of the Erinpura and Malani suite of rocks took place. The waning phase of F_2 Delhi folding also witnessed the collision of the Gondwana continent with the Indian craton (750 M.y. and 650 M.y.) which controlled the F_3 Delhi deformation. The culmination of the Delhi orogeny (1.45 to 1.7 Ga.) is marked by some granitic emplacements in different parts of the Delhi fold belt (Roy and Das, 1985; Srivastava, 1988), especially in the Alwar basin.

The presence of pre-Delhi (Aravalli?) or Delhi sediments at many places in Sirohi, Pali, Jodhpur, Jalore, Nagaur, Jhunjhunun, Churu and Bikaner districts below the Malani rhyolites and the Marwar Supergroup of rocks to the west of the Aravalli ranges indicate that the Indian landmass or continental block may have extended far to the west of the mountain belt (Srivastava, 1988).

The terminal phase of the Proterozoic crustal formation in the northwestern Peninsular Indian shield is marked by the opening of the Champaner and Sirohi basins along the southern and southwestern flanks respectively of the Aravalli Mountain Range. Shallow water sediments and volcanic rocks were deposited in these basins. Emplacement of the Godhra granite (ca. 900 Ma.) cluminated this orogeny involving the Champaner rocks. This was followed by the intrusion of the Erinpura granite and Malani rhyolites in that order. Srivastava (1988) considered the Malani rhyolites and Erinpura granite as marking the close of the Champaner orogeny. After this orogeny there was extensive acid magmatism over large areas in the southern parts of the Delhi fold belt (850 - 750 Ma.)

PALAEOZOIC-MESOZOIC TECTONISM

The late Proterozoic upliftment of the Aravalli Mountain chain created lines of weakness or cracks in the continental block to the west of the ranges along which rhyolitic intrusions took place. From the Cambrian period onwards the Trans-Aravalli sector in Western Rajasthan, popularly known as the Rajasthan Shelf Zone (RSZ), formed an extensive basinal set up for the sedimentary units of the Palaeozoic-Tertiary period. The Aravalli and Delhi Supergroup of rocks formed the easternmost boundary and the Malani Igneous Suite, the southern boundary of these basins, in which the Palaeozoic and Mesozoic rocks were deposited. Dasgupta and Chandra (1978) viewed that the tectonic elements to the west of the Aravalli Mountain belt (i.e., the RSZ) have been shaped before or along with the Delhi orogeny in the Aravalli Mountain region. Subsequent epeirogenic movements have only reactivated the zones of weakness and created new basins and highs by vertical uplift and subsidence along the high angle normal faults genetically related to the Proterozoic basement (Srivastava, 1988).

The later formed younger subvolcanic granitic intrusives, *viz.*, the Jalore and Siwana granites are located in the areas of basement uplift and crustal upwarps related to the Sarnu high and Tharad high along the eastern boundaries of the Barmer graben and the Sanchor basin. A number of peralkaline granitic bodies of the Jalore and Siwana type also occur in the Barmer horst region.

Fermor (1930) had formulated the view that the Aravalli Mountain Range was upfolded, metamorphosed and partially eroded during the pre-Vindhyan times. Subsequent rejuvenation of the Aravalli Mountain Range as a horst took place along roughly parallel boundary faults, one, the Great Boundary Fault in eastern Rajasthan and the other, a hypothetical western fault. Heron (1938) agreeing with Fermor's views also suggested a Mesozoic uplift of the Aravalli Mountain Range.

The Kachchh and Sanchor basins in the south and Jaisalmer basin in the central parts of extreme northwestern part of India, were created by the early Jurassic epeirogenic movements (Srivastava, 1988) which may have continued upto the Upper Cretaceous. From the onset of late Palaeozoic to that of the early Jurassic, parts of Western Rajasthan remained as a stable land (Pareek, 1979), during which extensive erosion took place. During the Jurassic, a large part of this region was covered by the sea. The Barmer graben was developed from the Barmer basin during the Jurassic-Cretaceous period by the phenomena of subsidence and fracturing. Widespread volcanic activity occurred in this region from early to middle Cretaceous.

CENOZOIC TECTONISM

The post-Cretaceous (Cenozoic) tectonic events in northwestern India were related mainly to the collision of the Indian plate with the Tibetan plate, which resulted in the development of

NNW-SSE and E-W fractures or lineaments and reactivation of some Proterozoic fracture and fault systems. The hinging of the Indian plate in the northwest and subsequent counter clockwise rotation of it (58 Ma. to 55 Ma.) was mainly responsible for the development of these Cenozoic fault and fracture systems. The alkaline rocks of Mundwara, Sarnu-Dandali and west of Barmer town are due to these post-Cretaceous tectonic events (Srivastava, 1988).

The Indo-Gangetic plains to the south of the Himalayan fold belt represent a sediment filled foredeep basin, formed due to the flexuring and subsidence of the Indian plate after its collision with the Eurasian plate in Eocene 45-50 Ma. ago (Dewey *et al.*, 1989). The intraplate subduction which took place along the Main Central Thrust (MCT) caused the upliftment of the Himalayas (Thakur, 1995). The heaving up of southern Himalayan province formed the Siwalik fold belt and the subsidence of the northern parts of the Indian plate, creating the Indo-Gangetic basin in which rapid sedimentation took place during the Quaternary period (Tandon, 1991; Shukla *et al.*, 1994). Due to the continued northward drift and pressure of the Indian plate, the Indo-Gangetic plain has been subjected to upheavals and subsidence while the crustal accommodation is taking place along the transcurrent faults of the Indian shield that extend beneath the alluvial sediments of the Indo-Gangetic plain (Thakur, 1995).

Geophysical investigations carried out by various organisations have revealed that the basement of the Indo-Gangetic basin is characterised by a number of troughs, ridges and faults and has a general northward slope with corresponding increase in sediment thickness towards the Himalayan foothills (Arora, 1993; Pant and Sharma, 1993). The crustal movements and the subduction of the Peninsular Indian plate with the Siwalik molasse at its front, occurred along the Main Boundary Thrust (MBT) giving rise to the Siwalik ranges during the early Pleistocene. The Delhi-Hardwar Ridge and the Moradabad Fault are the important sub-basement structures in this part of the Indo-Gangetic basin (Sengupta, 1962). This epeirogenic tectonism related to the collision of the Indian and Eurasian plates continued upto the Neogene times.

Ahmad and Ahmad (1980) categorised the Rajasthan Great Boundary Fault and the Sardarshahar fault into Tertiary faults and postulated that the Aravalli range was uplifted as a horst between these faults.

TECTONIC FRAMEWORK OF STUDY AREA

The distribution of various landforms and their orientations in the study area exhibit strong influence of major tectonic linears which are part and parcel of the Bhilwara, Aravalli and Delhi Supergroup of rocks. In the context of regional tectonic setting, the study area is dissected by a series of NE-SW, NW-SE, N-S and E-W fault/fracture systems crisscrossing each other. In addition to the Precambrian master strike slip faults and other fault/fracture systems, there are many reactivated fault systems in the study area which are neotectonically significant. The important fault systems which are manifested as tectonic linears are:

i) Luni-Sukri or Luni Rupnagar/Rupangarh fault,
ii) Kasganj-Didwana-Dausa fault, and
iii) Sardarshahar fault.

The major tectonic trends related to the Aravalli and Delhi orogenies pass through the study area.

LINEAMENT STUDIES

Study of lineament fabric of the study area constitutes an important aspect owing to the lack of continuity in outcrop and landform features. For this purpose the author has referred numerous satellite data on LANDSAT, SPOT and IRS (LISS-I) at the Space Applications Centre, Ahmedabad.

REGIONAL LINEAMENT FABRIC

The northwestern part of the Indian peninsular shield exhibits a spectacular network of numerous tectonic lineaments (Fig. 4.2). Remote sensing studies of the various lithostratigraphic domains and subsequent geomorphological, geological and geophysical surveys carried out by several organisations and individual researchers from different fields of earth sciences, have revealed the subsurface lithological disposition, basement configuration and the tectonic setup of

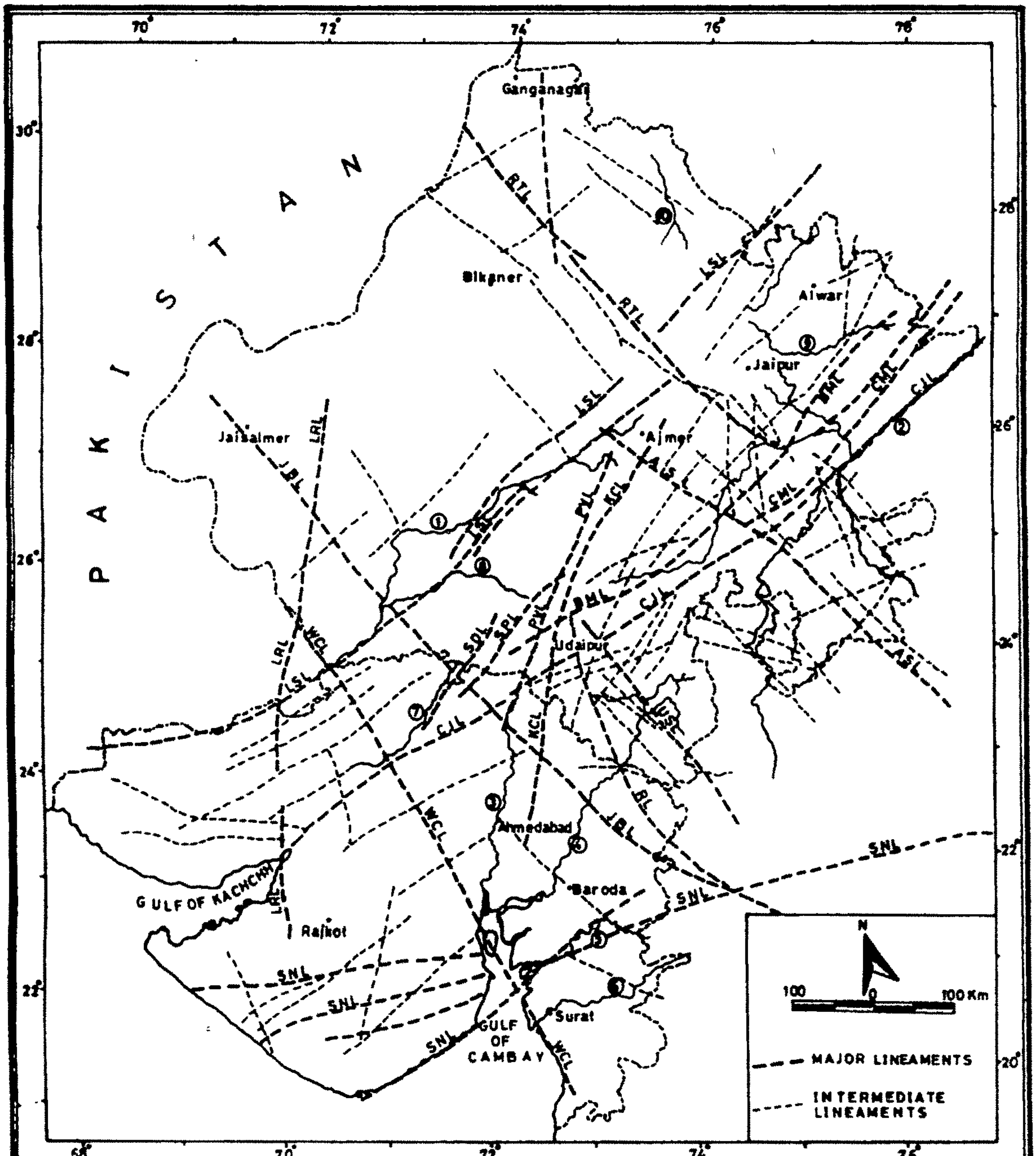

Fig. 4.2. SIGNIFICANT LINEAMENTS OF NORTH WESTERN INDIA

(After Bakliwal et al., 1987)

I	WCL:- WEST COAST LINEAMENT	
II	JBL:- JAISALMER-BARWANI "	
III	ASL.- AJMER - SANDIA LINEAMENT	
IV	RTL:- RAISINGHNAGAR-TONK "	
V	USL.- UDAIPUR - SARDARPUR "	
VI	RL:- RAKHABDEV LINEAMENT	
VII	KCL:- KISHANGARH-CHHIPRI "	
VIII	PVL:- PISANGAN-VADNAGAR "	
IX	SPL:- SADRI - PALANPUR "	
X	SDL:- SIROHI - DISA LINEAMENT	
XI	LSL:- LUNI - SUKRI LINEAMENT	
XII	CML:- CHITTAURGARH-MACHILPUR LINEAMENT	
XIII	BML:- BHARATPUR - MOUNT ABU "	
XIV	CJL:- CHAMBAL - JAMNAGAR LINEAMENT	
XV	LRL:- LATHI - RAJKOT LINEAMENT	
XVI	SGL:- SARDARSHAHR - GANGANAGAR LINEAMENT	
XVII	SNL:- SONE - NARMADA LINEAMENT	

RIVERS

1	LUNI
2	CHAMBAL
3	SABARMATI
4	MAHI
5	NARMADA
6	TAPTI
7	BANAS
8	SUKRI
9	BANGANGA
10	KANTLI

northwestern India as a whole and the Thar Desert of Rajasthan in particular. Bakliwal and Ramasamy (1987) have delineated and classified several lineaments of Western India on the basis of their extent, orientation and density distribution. These lineaments were classified into three categories,

(i) **Major Lineaments (more than 300 km in length)**: These lineaments are less frequent than the intermediate and minor lineaments, and are either the linear and curvilinear expressions of tectonic discontinuity or the surface signatures of the deep seated crustal fractures. They have regional significance in the tectonic evolution of the Palaeozoic, Mesozoic and Cenozoic geology of the Thar Desert (Bakliwal *et al.*, 1983).

(ii) **Intermediate lineaments (300-100 km in length)**: These lineaments are in general related to the tectonic history of the individual sedimentary basins and represent faults/fracture systems which have strongly influenced the drainage disruption, axial traces of regional folds and boundaries of groups or formations.

(iii) **Minor Lineaments (less than 100 km in length)**: These are the most frequent of the lineaments and genetically related to the major and intermediate lineaments and have strongly influenced the evolution of drainage patterns and small scale expressions.

The major and intermediate group of lineaments in Rajasthan generally have NNW-SSE, ENE-WSW, NE-SW, NW-SE, N-S and E-W orientations and crisscross relationships.

Major Lineaments

The important lineaments which have played significant role in the tectonic evolution of northwestern India and western Rajasthan in particular from Proterozoic to Recent are listed in Table 4.1.

I. <u>The West Coast Lineament</u>: This NW-SE trending major lineament from Bulsar (Gujarat) in the south to Kalner in the northwest traverses a considerable part of the Thar desert. It has

Table 4.1. Important lineaments of northwestern parts of Indian Subcontinent

Trend	Lineament	Reference to Fig. 4.2
NW-SE	West Coast Lineament (i.e., Western Cambay basin fault) Jaisalmer-Barwani Lineament Ajmer-Sandia Lineament Raisinghnagar-Tonk Lineament	(I) (II) (III) (IV)
NNW-SSE	Udaipur-Sardarpur Lineament Rakhabdev Lineament	(V) (VI)
NNE-SSW	Kishangarh-Chhipri Lineament Pisangan-Vadnagar Lineament Sadri-Palanpur Lineament Sirohi-Disa Lineament	(VII) (VIII) (IX) (X)
NE-SW	Luni-Sukri Lineament Chittaurgharh-Machilpur Lineament (Great Boundary Fault) Bharatpur-Mount Abu Lineament	(XI) (XII) (XIII)
ENE-WSW	Chambal-Jamnagar Lineament	(XIV)
N-S	Lathi-Rajkot Lineament Sardarshaher-Ganganagar Lineament	(XV) (XVI)

played a significant role in the genesis of the Cambay graben and its northern extension along Sanchor-Barmer-Jaisalmer basins.

II. Jaisalmer-Barwani Lineament: It is a 1000 km long deep seated lineament extending from Barwani in the southeast to Jaisalmer in the northwest. The major segment of this lineament passes through the desertic tracts. In the southwest near Godhra, it delimits the southwestern boundary of the Aravalli basin and in the central part it abruptly cuts the Delhi metasedimentary rocks of the Aravalli hill ranges. Further northwest in the Barmer area, it delimits the Tertiary basin and then extends as a fault into the Mesozoics of Jaisalmer area. Since this lineament traverses the rocks of different ages from Precambrian to Tertiary, it can be concluded that the Jaisalmer-Barwani lineament has been reactivated over the periods (Bakliwal and Ramasamy, 1987). The further northwestern extension of this lineament is traceable upto Afghanistan through Pakistan as the Mari-Jaisalmer arch (Dasgupta, 1975).

III. Ajmer-Sandia lineament: This 550 km long lineament extends between Sandia (Madhya Pradesh) in the southeast and Ajmer in the northwest cutting across the Deccan Trap, the Vindhyan plateau, the pre-Aravalli pediplains and finally the Delhis in the Aravalli hill ranges, perpendicular to the regional trend (Bakliwal and Ramasamy, 1987). It is a well defined fault in the Vindhyans of central India, but its expression is a simple linear feature in the pre-Aravalli granitic and gneissic country between Bundi and Ajmer.

IV. Raisinghnagar-Tonk lineament: This lineament of more than 400 kms length passes mostly through the desertic tracts and hence its geologic and tectonic relevance is unknown. It demarcates the contact between the dune invaded pre-Aravalli pediplain of Jaipur region and the dune free Bhilwara plains (Sinha Roy, 1986).

V. Udaipur-Sardarpur lineament: This NNW-SSE trending lineament of about 300 km length and extending between Udaipur in the NW and Sardarpur in the SE, is expressed as a linear escarpment in the Deccan Trap in the southern part, controls the Mahi river course in its central part, forms the contact between the Debari and Udaipur Groups of rocks and in the northern part forms a well defined boundary fault between the Aravalli basin and the Bhilwara Supergroup of rocks (Bakliwal and Ramasamy, 1987).

VI. Rakhabdev lineament: Extending from Nathdwara in the north to Barwani in the south, for about 350 km, the Rakhabdev lineament is a deep crustal curvilinear lineament whose curvature is in conformity with the western margin of the Bundelkhand massif. This lineament is aligned almost along the axial portion of the Aravalli basin and both the eastern and western margins of the basin are parallel to this lineament. The reactivation of this lineament during the Proterozoic and Cenozoic times is indicated by the fact that the older and younger sequences of the Aravalli Supergroup and also the Deccan Traps are traversed by it. This lineament has also played a significant role in the Aravalli deformation as evidenced by the occurrence of large scale folds with NE-SW trending axial traces to the west and E-W trending axial traces to the east of this lineament in the Lunavada Group of rocks (Ramasamy *et al.*, 1995).

VII. Kishangarh-Chhipri lineament: This 450 km long deep seated major lineament has played a significant role in the geological and structural history of the Aravalli range in Rajasthan. The northern segment of this lineament between Kelwara and Kishangarh defines the contact between two contrasting geomorphic regimes - the linear structural hills of the Aravalli range in the west and the pediplained pre-Aravallis in the east. It also forms the fault contact (Heron, 1936) between the Delhi metasediments in the west and the Bhilwara Supergroup of rocks in the east. The lineament segment between Keilwara and Himmatnagar demarcates the boundary between the Delhi and Aravalli Supergroup of rocks in the south.

VIII. Pisangan-Vadnagar lineament: It is a more than 320 km long lineament depicting a deep seated fault system which played a significant role during the Delhi orogeny and limiting the western margin of the Aravalli range. The northern segment of this lineament between Pisangan and Phulad is fault controlled and associated with the Ajabgarh group of rocks, whereas in the central part between Phulad and Sadri it marks the contact between the linear structural hills of Delhi rocks and the pediplained post-Delhi Erinpura granite. The lineament segment from Sadri to Vadnagar further south once again passes within the Ajabgarh Group of rocks defining the eastern boundary of the Sendra-Ambaji granite. While the eastern boundary of the Delhi basin is controlled by the Kishangarh-Chhipri lineament, its western margin in the Aravalli range is partly controlled by the Pisangan-Vadnagar lineament. These two deep seated lineaments had an important role in the Delhi orogeny, in that the uplifting of the Aravalli range has taken place along these two lineaments (Bakliwal and Ramasamy, 1987).

IX. Sadri-Palanpur lineament: This lineament marking the western flanks of the Aravalli hill range in the southwestern part, limits the main Aravalli range in the east and the pediplained Erinpura granite in the west. The triangular junction bounded by this lineament and the Pisangan-Vadnagar lineament is a region of profuse intrusions of the Sendra-Ambaji granites and ophiolite suite of rocks.

X. Sirohi-Disa lineament: It is a geologically significant lineament of limited extent only, occupying the central portion of Sirohi Group of rocks (Gupta *et al.*, 1980).

XI. Luni-Sukri lineament: The NE-SW trending 750 km long Luni-Sukri lineament, aligned along the Luni and Sukri rivers, forms a significant linear/curvilinear feature in the desertic tracts of Rajasthan. It extends from the Great Rann of Kachchh in the southwest to the Sambhar lake in the northeast. The southwestern segment of this lineament marks the contact between the Great Rann of Kachchh and the dune fields, whereas the northeastern extension between Bakhasar and Sambhar lake controls the Luni and Sukri rivers in the Thar desert. It is a system of parallel faults which have given rise to a graben structure or rift system. The absence of Delhi outcrops northwest of this lineament indicates that the lineament might represent the northwestern limit of the Delhi basin (Bakliwal and Ramasamy, 1987). The Luni-Sukri lineament reactivation is the latest among the lineament reactivations in the area, which culminated the Delhi orogeny and also emplaced the Malani suite of rocks (Bakliwal and Ramasamy, 1983a & b). The absence of Cambrian sediments of Marwar Supergroup beyond southeast of this lineament indicates that this lineament must have limited the Cambrian basin in the southeast during its evolution. Evidences of neotectonism along this lineament are the earthquake epicentres aligned along it which occurred during the period from 1819 to 1976 A.D in Kachchh area.

The Luni-Sukri lineament is traceable further northeast from Sikar to beyond Delhi and upto the Siwaliks, southeast of Dehra-Dun, by means of a subparallel lineament located between Mukalsar and Degana (Bakliwal and Ramasamy, 1987).

XII. Chittaurgarh-Machilpur lineament (The Great Boundary Fault): This lineament running for more than 400 km in a roughly ENE-WSW trend has been defined as a part of the Chambal-Jamnagar lineament system. This lineament separates two distinct geomorphic units, *viz.*, Bundi-Sawai Madhopur hill ranges in the south and the peneplained pre-Aravalli rocks in the north. This lineament marks an important site of tectonic significance between Chittaurgarh and Machilpur, a thrust fault *viz.* the Great Boundary Fault had been responsible in uplifting the older Proterozoic rocks and abutting them against the younger Proterozoic sedimentary sequence, "the Vindhyans". The Great Boundary Fault in Rajasthan has been placed under the age group of Tertiary faults (Ahmad and Ahmad, 1980), and is a major dislocation plane in the region.

The Chittaurgarh-Machilpur lineament is of considerable significance from the neotectonic point of view, causing the migration of the Chambal and Yamuna rivers (Bakliwal and Ramasamy, 1987). A number of sub-parallel faults/lineaments are associated with this lineament system.

XIII. Bharatpur-Mount Abu lineament: It is a significant deep seated lineament running between Bharatpur in the NE and Mount Abu in the SW, traversing the pre-Aravalli terrain of central Rajasthan for more than 550 km. It occurs as a deep seated fault in the Bharatpur-Pipalda section and from Pipalda to Bhilwara it clearly demarcates the Hindoli Group low grade metamorphic rocks (pre-Aravalli) and the high grade Sandmata complex migmatites. North of Udaipur, this lineament acted as an active sedimentational and deformational barrier. The Berach and Mount Abu granites occurring along this lineament may be probably related to it.

XIV. Chambal-Jamnagar lineament: This lineament depicting a fault, marks the northwestern margin of the Vindhyan basin and extends for more than 900 km from Dholpur in the northeast to Jamnagar/Little Rann of Kachchh in the southwest. It controls the course of the Chambal river for some distance. The general ENE-WSW trend of the Gulf of Kachchh shows that the Chambal- Jamnagar lineament must have affected its growth (Bakliwal and Ramasamy, 1987).

This lineament also has significant relations with the magmatic episodes involving Berach and Untala granites. The intermittent reactivation of this lineament is also indicated by its presence in the rocks of pre-Aravalli to recent times. This lineament has significantly influenced the drainage and physiographic expressions on its ENE and WSW ends.

XV. Lathi-Rajkot lineament: The N-S trending Lathi-Rajkot lineament extends between Lathi in the north to the west of Rajkot in the south. It originates from the Deccan Trap terrain in the south near Rajkot, cuts across the Jurassics in Kachchh, traverses the Thar desert between Bhuj and Barmer and finally cuts across the Mesozoics in Jaisalmer area. It is probably a pre-Mesozoic lineament that later got activated during the Tertiary times as evidenced by its occurrence in the Mesozoic and Cenozoic sedimentaries (Bakliwal and Ramasamy, 1987).

XVI. Sardarshahar-Ganganagar lineament: This N-S trending lineament has played significant role during the Neogene times (Ahmad and Ahmad, 1980).

Intermediate Lineaments

The intermediate lineaments are confined normally to a single basin or rocks of same age and their relation to geology and structure of the area indicates that these are mainly the surface expressions of lithological contacts, axial plane fractures of folds, faults and master fractures (Bakliwal and Ramasamy, 1987). The regional lineament setup in Rajasthan and Gujarat (Fig. 4.2) shows numerous intermediate lineaments associated with the major lineaments and also occurring isolated. A gist of some of the important ones is given below.

(i) A set of three NE-SW trending parallel lineaments in the Chittaurgarh region is associated with the Great Boundary Fault, one of them likely to be the extension of the GBF and the other two sympathetic fractures.

(ii) Between Udaipur and Rakhabdev there are two ENE-WSW trending lineaments associated with the Chambal-Jamnagar lineament and they show open fractures in the Aravalli metasediments (Bakliwal and Ramasamy, 1987).

(iii) In the pre-Aravalli pediplain country of Bhilwara and area east of Ajmer there are three NE-SW trending subparallel lineaments which mark the localisation of base metal occurrences.

(iv) There are a number of intermediate and minor lineaments in the Aravalli basin which are related to fault systems and ultrabasic suite of rocks.

(v) In the areas occupied by the Delhi metasediments there are some intermediate lineaments which are mainly axial plane fractures of folds or faults associated with the Delhi orogeny and some of them are sites of copper mineralisation as in the Khetri area.

(vi) Numerous intermediate lineaments with varying orientations and distribution occur in the Vindhyans of Rajasthan some of which represent faults associated with the Great Boundary Fault, others which limit the southwestern continuity of the Vindhyan basin and some others are fractures in the Vindhyan sandstones.

(vii) Few scattered NE-SW and NW-SE trending intermediate lineaments traverse the Thar desert occupied by Palaeozoic, Mesozoic and Cenozoic sediments which are sympathetic fractures of the Luni-Sukri, Chambal-Jamnagar and Raisinghnagar-Tonk major lineament systems.

In addition to these, numerous intermediate lineaments also occur in the Deccan Trap country of south Gujarat and Saurashtra.

Minor Lineaments

Numerous minor lineaments with random orientations occur in the northwestern parts of India. These are the surface manifestations of lithologic contacts, axial plane fractures of folds, faults, dykes and mega joints, and are mostly tectonic features in the Aravalli, Delhi and Vindhyan Supergroupsand in the Trans-Aravalli sedimentaries of western Rajasthan, whereas further south in the Deccan volcanics they are manifestations of river flow swarms and dyke swarms.

LINEAMENT FABRIC OF STUDY AREA

The studies of LANDSAT TM and IRS imageries of the study area have revealed an array of lineaments with sharp linear breaks in tonal appearance of the topographic features. Most of these lineaments have a roughly NE-SW and WNW-ESE orientations. The study of lineament fabric vis-à-vis landform characteristics has provided ample evidences on their reactivation during the Pleistocene period. The details on these aspects are dealt in the proceeding chapters on Geomorphology and Neotectonism. The broad spectrum of lineaments of varying dimensions. distribution and orientation typically reflects the nature of basement fractures; attributed to the phenomenon related to tectonism, magmatism and mineralization. Based on the author's own study and available information, an integrated regional lineament map of the study area has been prepared. These inferred lineaments have been further subjected to field checks from the point of view of their impact on major stratigraphic units, landform and terrain characteristics. The network of lineaments as deciphered from the satellite imagery studies and the subsequent field checks is depicted in the Figure 4.3.

The lineaments which have significantly influenced the ovearall terrain characteristics of the study area are:

1. Luni-Sukri lineament (Luni-Rupnagar/Rupangarh fault),
2. Kasganj-Didwana-Dausa lineament,
3. Raisinghnagar-Tonk lineament,
4. Kishangarh-Chhipri lineament,
5. Pisangan-Vadnagar lineament,
6. Ajmer-Sandia lineament, and
7. Sardarshahar-Ganganagar lineament.

1. <u>Luni-Sukri lineament</u>: A system of NE-SW trending two parallel faults manifesting a graben or rift configuration (Bakliwal and Ramasamy, 1987, Ramasamy *et al.*, 1991). These fault lineaments are aligned along the Luni and Sukri rivers and appear in the study area south of Jodhpur city and continue to stretch for about 350 km northeasterly in the study area. This

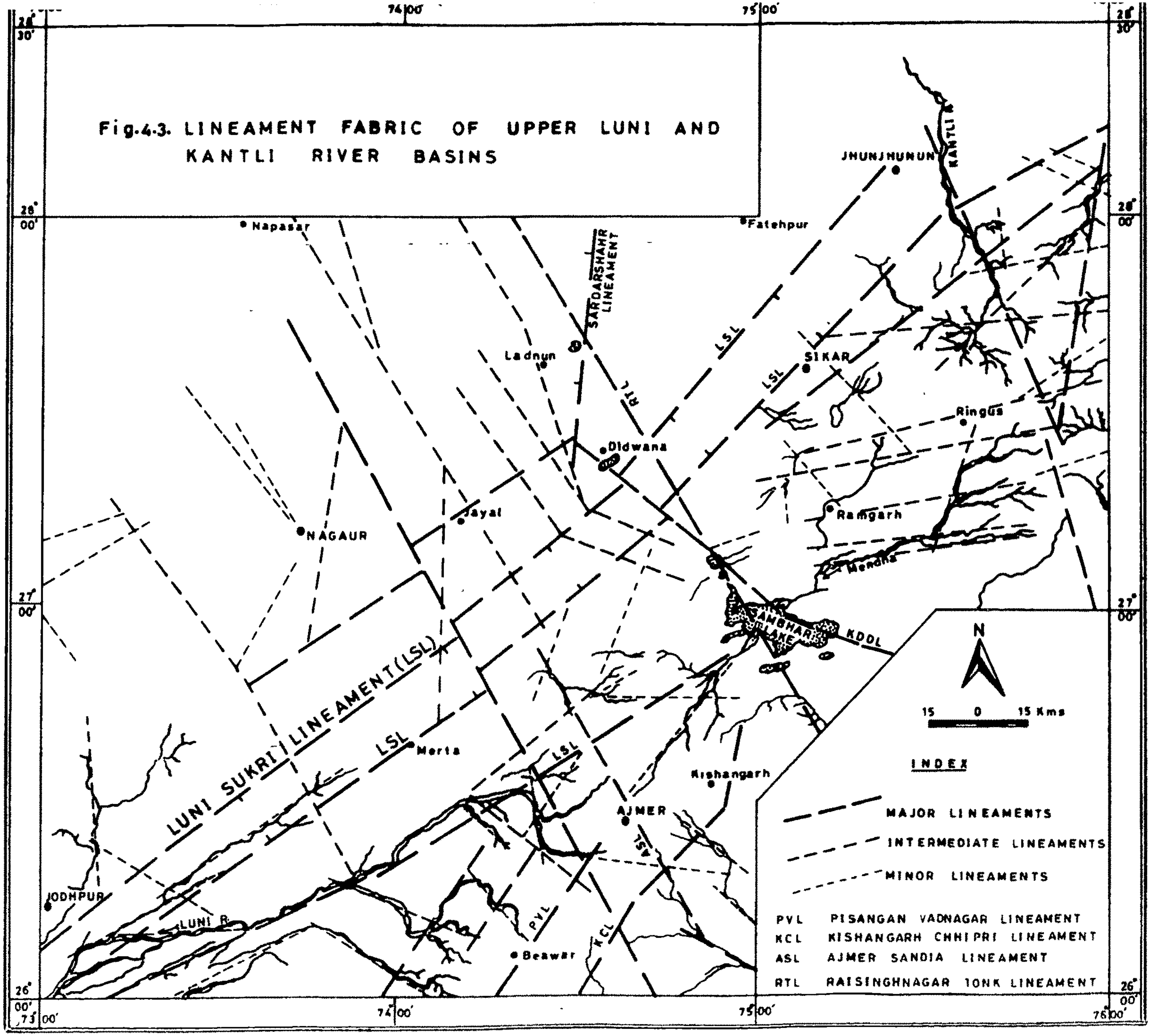

Fig.4.3. LINEAMENT FABRIC OF UPPER LUNI AND KANTLI RIVER BASINS

lineament extends further northeast through Sikar and is traceable from Sikar to beyond Delhi and upto the Siwaliks. Number of NNW-SSE trending intermediate and minor scale lineaments cut across this lineament. Sinha-Roy (1986) has designated this lineament as the Luni-Rupnagar left lateral strike-slip fault, which is traceable from south of Jodhpur upto Sambhar lake and extending further northeastward as the Nawa-Alwar left lateral strike-slip fault, and possibly delimiting the western boundary of the Sambhar lake.

2. Kasganj-Dausa-Didwana lineament: A regional lineament constituting two fault systems, *viz.* the Didwana-Dausa fault and the Kasganj fault, is of high tectonic significance. It has a WNW-ESE orientation, extending from Didwana in the northwest to Kasganj in the east through Dausa. The Didwana-Dausa fault is a strike-slip fault aligning the lakes of Didwana, Kuchaman and Sambhar. The Sambhar lake is located at the junction of two strike-slip faults *viz.*, the Luni-Rupnagar-Alwar and Didwana-Dausa faults.

3. Raisinghnagar-Tonk lineament: This NW-SE trending major Trans-Aravalli lineament running almost normal to the Luni-Sukri fault system and cutting across the Talchhapar, Sujangarh, Didwana, Kuchaman and Sambhar lakes, probably has played a significant role in the development of different salt lakes aligned along it.

4. Kishangarh-Chhipri lineament: This major lineament trending in a NNE-SSW direction has played a significant role in the geological and structural history of the Aravallis. It occurs to the southeastern part of the study area, in conformation with the Aravalli ranges and delimits the eastern boundary of the Delhi basin. The extension of this lineament is limited upto Kishangarh.

5. Pisangan-Vadnagar lineament: The northernmost segment of this major NNE-SSW trending lineament occurs in the study area, to the west of the Kishangarh-Chhipri lineament. This lineament delimits the western margin of the Aravalli basin and also partly controls the eastern margin of the Delhi basin. The Pisangan-Vadnagar lineament together with the Kishangarh-Chhipri lineament was responsible for uplifting the NNE-SSW trending Delhi blocks of the Aravalli Mountain Ranges during the Delhi orogeny (Bakliwal and Ramasamy, 1987).

6. Ajmer-Sandia lineament: A major Trans-Aravalli lineament with a NW-SE orientation, occurs in the southeastern part of the study area.

7. Sardarshahar-Ganganagar lineament: A major N-S trending regional fault extending between Didwana-Sardarshahar-Ganganagar. This fault has a throw of more than 250 m towards west. The Sardarshahar fault and the Great Boundary Fault are the possible locales for causing the upliftment of the Aravalli Mountain Range (Ahmad and Ahmad, 1980).

In addition to these major lineaments, many intermediate and minor lineaments occur in the study area with varied orientations. Most of these are concentrated in the southern, southeastern, eastern and northeastern parts. In the Upper Luni basin, these lineaments mostly have a NW-SE, NE-SW, N-S, NNW-SSE and NNE-SSW orientations. These are mostly the surficial expressions of shears, fractures, minor faults, etc., which are the products of reactivation of the major tectonic linears and responsible in shaping the various terrain attributes during the Quaternary period. The ultimate effect of these lineaments in terms of influencing landform characteristics, surficial processes and seismicity are discussed separately in the chapter on Neotectonism.