PART I

MORPHO-TECTONIC STUDIES

CHAPTER I

INTRODUCTION

INTRODUCTION

BACKGROUND INFORMATION

Predominantly aeolian sand filled vast terrain of Western Rajasthan, 'The Great Thar Desert' has attracted a large spectrum of the scientific community due to its uniqueness in the last phase of the earth's history, *viz.*, the Quaternary Period. The Thar and its neighbourhood areas have witnessed rapid changes in the terrain conditions from well-knitted perennial drainage systems to lost and defunct stream channels, innumerable pluvial lakes (fresh as well as saline) etc., which now form a part of the extensive aeolian tract. These fast changing terrain conditions were responsible for the extirpation of the once flourishing river valley civilizations of Palaeolithic, Mesolithic, Harappan and post-Harappan periods. In order to unfold the mysteries of the Thar Desert, related to its origin, evolution and lost drainage systems, a large number of researchers from different fields have made their contributions since last century. However, the major emphasis has been given to the single factor - 'the climate'. The studies from the geologist's angle is inadequate and hence, in spite of having ample contributions from the archaeologists, palynologists, etc., the evolutionary aspects of the Thar Desert remained full of gaps and intricacies.

In addition to this, 'The Thar' which is considered to be the arid region on this globe with the highest population density; has its own environment and resource management problems. Paucity of rainfall input, sparse vegetation cover, adverse agro-climatic conditions, poor land management and over grazing have further aggravated the desertification.

Having realised the significance of the studies of the kind meaningful to the scientific community as well as to the common man, the author has opted a research problem covering fundamental and applied aspects relevant to Morpho-tectonics and Hydrogeology of the only existing watershed in the Thar region i.e., the 'Luni-Kantli River Basins'. The author's effort to understand this multi-facet problem has necessitated to extend the study area limits further north eastward up to the Yamuna river.

In this study, the author has endeavoured to reconstruct the evolutionary history of the Eastern Thar and give an elaborate but critical appraisal of the factors governing the groundwater regime of the region.

AIMS AND OBJECTIVES

AIMS OF STUDY

The present studies on the Upper Luni and Kantli river basins of Western Rajasthan aims:

(i) to carry out morpho-tectonic studies of the study area and envisage an overall evolutionary model; considering the aspects of geology, geomorphology, neotectonism, palaeo-geography, etc., and

(ii) to undertake Hydrogeological studies from the point of view of groundwater occurrence, distribution, quality and water resources management.

OBJECTIVES OF STUDY

The present study aims at achieving the following objectives:

(i) To study the geological setup of the area

(ii) To work out the tectonic framework, lineament setting including neotectonism of the study area

(iii) To study the detailed geomorphology of the watersheds and adjacent areas

(iv) To work out the subsurface geology through bore hole records and available literature

(v) Palaeodrainage reconstruction and causes of drainage disruption

(vi) To work out the morpho-stratigraphy of the area

(vii) To envisage a morpho-tectonic evolutionary model of the study area

(viii) To study the Hydrogeological setup and categorise the area from the point of view of groundwater potential

(ix) To assess the groundwater quality and its distribution pattern

(x) To study the water resources management of the area (present day practices and new strategies).

THE STUDY AREA

LOCATION AND EXTENT

The present studies are confined to a part of eastern and central Thar Desert. The study area covers about 60,000 sq. km and is bounded between North latitudes 26° 00' to 28° 30' and East longitudes 73° 00' to 76° 00', falling within the limits of Jodhpur, Ajmer, Pali, Nagaur, Churu, Sikar, Jaipur, Bikaner and Jhunjhunun districts (Fig. 1.1). The study area encompasses the drainage basins of two major ephemeral rivers, *viz.*, the Luni and Kantli and few minor tributaries. The NE-SW striking Aravalli Mountain Range delimits the study area in the south. In the northeastern parts, the political boundary between Haryana and Rajasthan marks the limits. However, in order to study the aspects of palaeogeography, the limits of the study area has been extended further northeast up to the Yamuna river. In the southwestern parts, the study area is limited to the Luni bridge on Jodhpur-Pali highway.

COMMUNICATION

A good network of metalled and unmetalled roads crisscross the area connecting various towns and villages. Most of the villages are connected by a network of kachcha tracts with varying

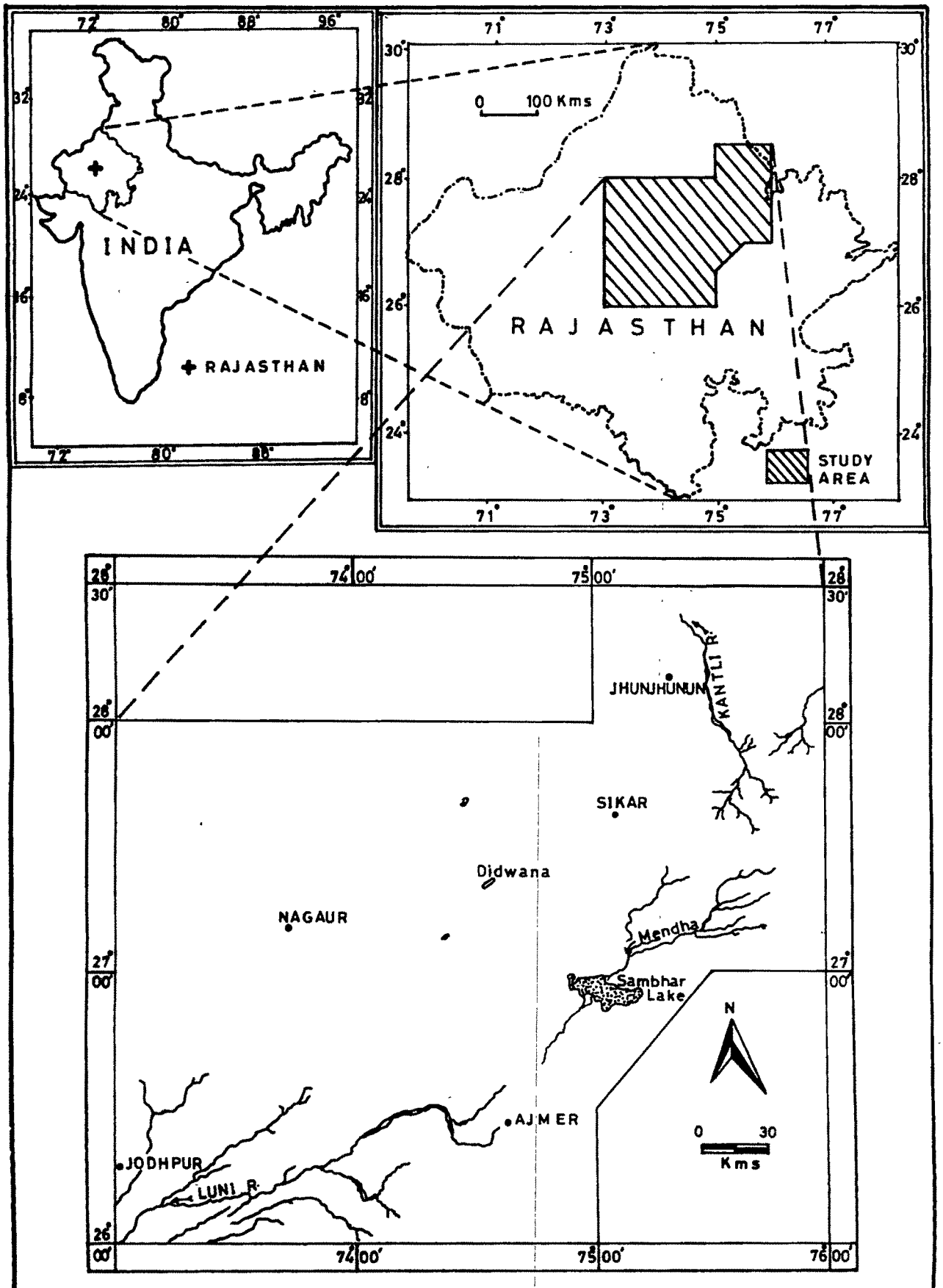

Fig. 1.1. LOCATION MAP OF STUDY AREA

degrees of negotiability by jeep or other four wheelers. Several cart tracks in the area are motorable in the dry season. National highway Nos.8 and 11 pass through the study area. Some of the important cities in the study area are Jodhpur, Nagaur, Ajmer, Sikar and Jhunjhunun.

Ajmer is a railway junction connecting Jaipur, Chittaurgarh and Ahmedabad. The Ahmedabad-Delhi railway line passes through important locations in the area. Jodhpur is another main railway junction connecting Bikaner, Jaisalmer, Ahmedabad and Delhi. Other important sectors of railway lines within the area include: Merta Road-Nagaur-Nokha-Bikaner, Degana -Didwana - Ladnun - Sujangarh, Fatehpur - Sikar - Jaipur, Sikar - Jhunjhunun - Loharu and Phulera-Ringus (Fig. 1.2).

PHYSIOGRAPHY

Physiographically, the study area exhibits vast diversity in landforms, altitudinal variations and other terrain attributes. The NE-SW trending Aravalli Mountain Range is the major landmark feature, delimiting the southern boundary of the study area. The pediment plains and dunal plains with the intermittent river valley deposits and rocky inselbergs are the characteristic features occurring on the northern sides of the mountain range.

The study area being a part of arid terrain, has a poor drainage network which is characterised by ephemeral rivers/streams, internal drainages, playas, etc. The general slope of the study area is southwesterly; however, in the northeastern extremity i.e., in the Kantli watershed, the slope is northerly.

Altitude wise, the Raghunathgarh hill (1050 m AMSL) in the northeastern parts of the area constitutes the highest point in the study area. However, the average ground elevation is in the range of 250 m - 750 m AMSL.

DRAINAGE

The study area is drained mainly by two rivers *viz.*, the Luni and Kantli. Except Kantli and its sister streams, the overall drainage is of southwesterly flow. The river Luni originates in the

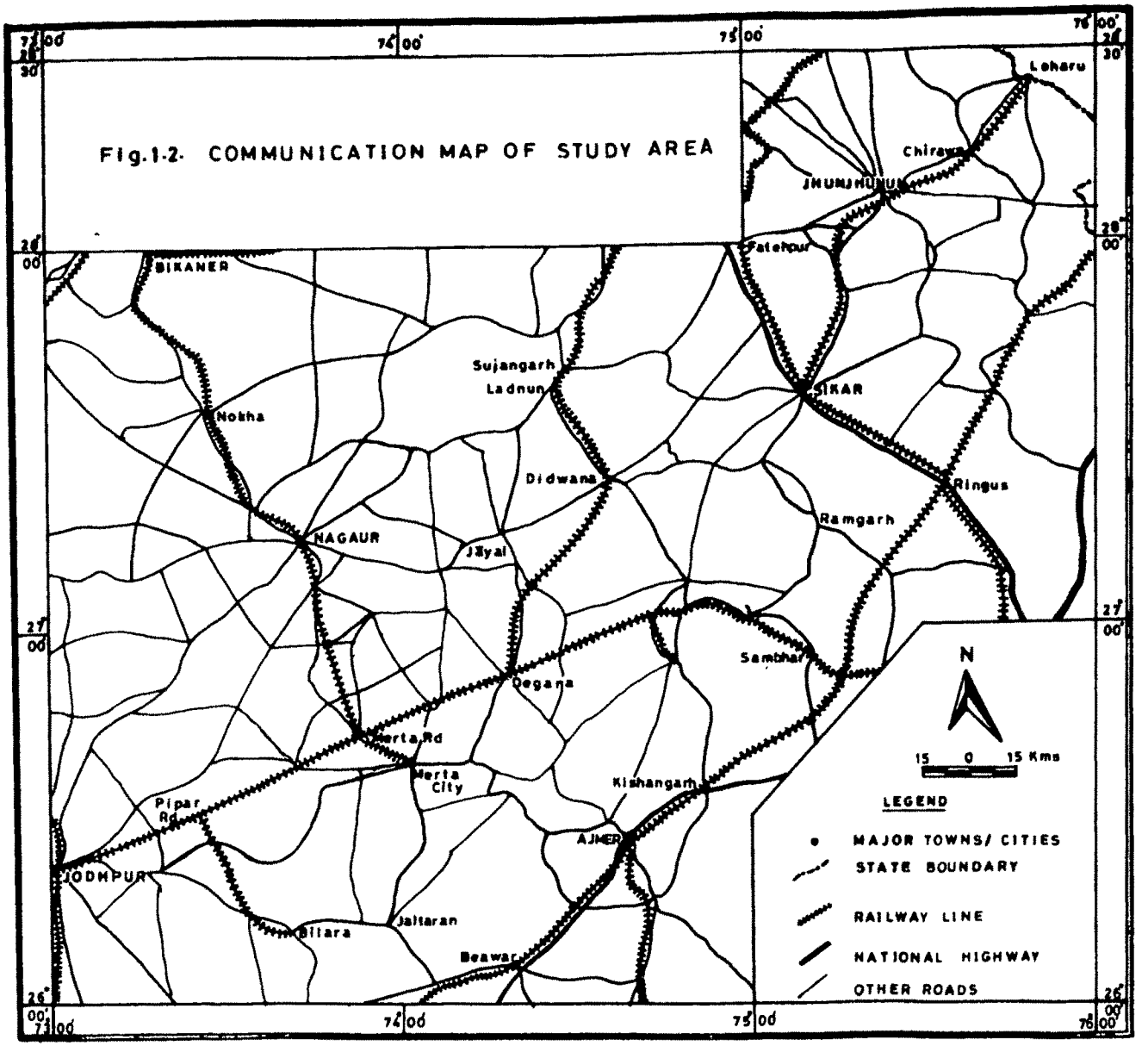

Fig.1.2. COMMUNICATION MAP OF STUDY AREA

hills of Pushkar, as two tributaries *viz.*, the Saraswati and the Sagarmati, forms a single channel, the Luni, then flows southwesterly and gets lost in the Great Rann of Kachchh. The rivers Lilri (Sukri), Jojri and Raipur Luni are the major tributaries meeting the Luni in the downstream areas. Rupangarh is a small river which drains into the Sambhar lake. Pushkar, Budha-Pushkar and Bhagwanpura lakes are the important lakes in the Upper Luni basin. A number of artificial reservoirs have also been constructed across the Sagarmati river, *viz.*, Foy Sagar, Ana Sagar, Bisal Sagar, etc.

The Kantli watershed occupies the northeastern parts of the study area and exhibits somewhat anomalous characteristics. The river Kantli originates in the hills near Gidala village of Udaipurwati in Sikar district, flows northwesterly/northerly cutting across the Aravalli Mountain Range, enters the aeolian plains and gets lost in the dunal sands near Rajgarh in Churu district. Other smaller rivers falling within this basin are the Dohan, Dongar, Chandrawati, Udaipur - Lohargarh ki Nadi, Budhi Nala, Sukh Nadi/Singhana Nadi, Mendha and Sabi. The important salt water lakes in this area are the Sambhar, Didwana, Kuchaman, Talchhapar and Sujangarh lakes.

GENERAL GEOLOGY

Geologically, the study area comprises the rock types belonging to five major lithostratigraphic units, *viz.*, Archaean, Precambrian, Cambrian, Tertiary and Quaternary. The generalised stratigraphy of the area as worked out by others is given as under:

Generalised Litho-stratigraphy of the Study Area.

Sediment Nature	Thickness (m)	Group
Wind blown sands,fluvial and lacustrine sediments, kankars, soils and other duricrusts	50 - 120	Quaternary
Clays, evaporates, bentonites and limestones	-	Tertiary
Sandstones, shales, limestones, siltstones, conglomerates and gravels (Marwar Supergroup)	750 - 950	Palaeozoic
Rhyolites and granites (Intrusives), schists, gneisses, amphibolites, limestones, marbles, quartzites, conglomerates (Delhi Supergroup)	-	Precambrian
Unclassified gneisses, granites etc. (Bhilwara Supergroup/BGC)	-	Archaean

METEOROLOGY

The climate of the study area is semi-arid with prolonged scorching summer, highly erratic monsoon and mild winter. Broadly, the area is characterised by three seasons with distinct weather conditions, *viz.*, the winter, lasting from November to February, the summer, lasting from March to June and the monsoon from July to September. October is a transitional month between the monsoon and winter. During the summer months the evaporation is high.

TEMPERATURE

Temperature extremes, with cold winter and hot summer are characteristic of the study area. The temperature ranges between as far as freezing point during winter to more than 43° C during summer. January being the coldest month, the temperature varies from 3° C to 10° C; while May, the hottest month has temperature variations between 40° C to 42° C sometimes even reaching up to 48° C and 50° C.

HUMIDITY

The humidity in general is minimum in the hot weather months, and maximum during the rainy months; the relative humidity ranges between 25% and 85%.

WIND

The winds are mostly from the southwest and west during summer and monsoon seasons and have average speeds between 5.1 km/hr and 11.7 km/hr. Dry and hot dust raising winds blow in the western to northwestern parts of the area, during the onset of summer, the wind direction slowly changes from northerly and northeasterly to southwesterly with significant increase in the wind speed. The average wind speed during June is between 10 km/hr and 15 km/hr. The wind speed near Sikar which forms a part of the Kantli river basin, ranges from 3.9 km/hr to 11.7 km/hr and the wind speeds are generally high during the months from May to July.

EVAPORATION

The mean annual evaporation for the arid and semi-arid regions is about 431.8 cm. The annual evaporation from small pools and surfaces is about 305 cm, whereas from large lakes it is about 229 cm. The highest rate of evaporation occurs during May and June and lowest during December - January. About 50% of the annual evaporation is accounted for during the three summer months of April, May and June characterised by high temperature and low humidity.

Nearly 20% of the evaporation occurs during the months of July, August and September. The rest of the six months accounts for about 30% of the evaporation.

RAINFALL

About 90% of the rainfall in the area occurs during the monsoon period, usually commencing in July. The average annual rainfall of the study area is about 450 mm and the areas to the east of the Aravallis receive comparatively higher rainfall, i.e., between 500 mm and 900 mm. July and August are the months of highest rainfall, but rainfall in general is highly erratic.

FLORA AND FAUNA

The flora and fauna of the study area are characteristic of those belonging to typical arid and semi-arid regions.

FLORA

Vegetation in the region is influenced by ecological factors like erratic and inadequate rainfall, high diurnal variations in the air and soil surface temperatures, increasing aridity and biotic interferences by man and livestock. Thorny species dominate the vegetation in the area (Plate I. 1.), thorny trees consisting of *Prosopis cineraria*, *Capparis decidua*, *Acacia leucophloea*. *Prosopis juliflora*, *Acacia catechue*, *Calotropis procera* and *Salvadora* spp. The major vegetation types characteristic of diverse physiographic setup are:

Plate I.1 Field photograph depicting typical thorny, shrubby vegetation. Location: Budsu

Plate I.2 A view of camel herd characteristic of desertic terrains of the study area.

a) *Calligonum - Leptadenia* type,
b) *Prosopis - Capparis - Zizyphus* type,
c) *Prosopis - Acacia nilotica* type,
d) *Salvadora oleoides - Prosopis - Capparis* type,
e) *Acacia nilotica - Acacia cupressiformis* type.

In addition to these the Halophytic shrubs belonging to the *Saueda fruiticosa* type colonises the margins of salt water lakes and other saline playas in the study area.

FAUNA

The animals reared by the people include sheep, goat, camel (Plate I. 2.) and cattle. In addition to these, the wildlife potential of the area includes black-buck, chinkara, nilgai, desert hare, fox, grey-francolin, great Indian bustard, field rodents, snakes, lizards, peacocks and a variety of insects.

CROPS

The study area is characterised by two principal crop seasons i.e., the kharif and rabi. A large part of the cultivated area is under food grain crops. The important crops are bajra, barley, wheat, maize, moong, gram, mustard and groundnut. The farmers also raise well adapted crops like pearl millet, green gram, moth bean, cluster bean, sesamum and high value crops like mustard, chilies, tomatoes and a variety of condiments.

APPROACH AND METHODOLOGY

APPROACH

Looking to the complexity in the terrain conditions, logistic and resource constraints and the scope of the research problem, the author has developed his own approach for evaluating various aspects of the study, wherein he has carried out integrated studies of the area, by blending the geological and geomorphological, meteorological and remote sensing parameters for the purpose

of evaluating the aspects of morpho-tectonic evolution and hydrogeology. As it has already been elucidated that the study area so far has been investigated in detail by the archaeologists and the palynologists, the author's effort to synthesise an overall evolutionary model and groundwater regime is purely from a geologist's angle for which a multidisciplinary approach has been adopted.

METHODOLOGY

The adopted methodology in the present studies can be described as under:

A. Basic Studies

(i) Study of topographic maps (1:250,000 and 1:50,000 scale) and preparation of base maps.
(ii) Creating data base through literature survey and critical compilation.
(iii) Detailed studies on the geology and geomorphology through available literature, satellite imagery and preparation of geological and geomorphological maps.

B. Morpho-tectonic Studies

(i) Litho-tectonic setup of the basement rocks.
(ii) Pre-Quaternary structural configuration.
(iii) Landform characteristics and their classification through satellite data studies and field checks.
(iv) Lineament fabric and their influence over the landforms and surficial processes.
(v) Past and present day drainage system and causes of drainage disruption and migration with the help of major tectonic features, remote sensing data and bore hole records.
(vi) Supportive evidences through archaeological findings, palynological records etc.
(vii) Synthesis of an overall evolutionary model.

C. Hydrogeological Studies

(i) Data collection on meteorology, geohydrology, water quality, etc., from various state and central government organisations.

(ii) Scrutinising the various data obtained and their compilation.

(iii) Detailed hydrogeological categorisation of the area, using satellite imageries and other standard techniques. Preparation of hydrogeological map through field checks.

(iv) Detailed fieldwork and groundwater sampling for determining various chemical and physical parameters.

(v) Analysis of water samples by standard laboratory techniques and subsequent groundwater quality classification.

(vi) Preparation of maps showing distribution pattern of various chemical constituents and groundwater facies construction.

(vii) Studies on the aspects of water resources management i.e., present day practices and suggestive strategies for its efficient use and quality improvement.

THE THESIS

The study presented in this thesis on the Morpho-tectonic Evolution and Hydrogeological Framework of the Upper Luni and Kantli River Basins in Western Rajasthan consists of two parts. Part-I deals with the Morpho-tectonic Evolution aspects (chapters I to VIII) and Part-II deals with the Hydrogeological Studies (chapters IX to XII). Chapter wise details are given as under:

Chapter I **Introduction** covers the details on background information, aims and objectives, general description of the study area and the adopted approach and methodology.

Chapter II **Geological Framework** gives the detailed idea on the regional geological setup and the geology of the study area.

Chapter III **Quaternary Geology** gives an account of the regional information on Quaternary deposits and the detailed Quaternary Geology of the study area.

Chapter IV **Tectonic Setup** includes the regional tectonic setting, the lineament studies and a detailed appraisal on the tectonic setup and neotectonic aspects of the study area.

Chapter V **Geomorphology** appraises on the terrain characteristics, landform features and their categorisation, the weathering profiles and the morpho-stratigraphy of the study area.

Chapter VI **Neotectonism** emphasises on the neotectonic features of the study area and their implications.

Chapter VII **Drainage and Playas** gives a detailed account on the present day and the past drainage systems, the pluvial lakes and playas, their origin and significance in the evolutionary history of the study area.

Chapter VIII **Morpho-tectonic Evolution** deals with the evolutionary model of the Proto-Luni watershed.

Chapter IX **Hydrogeological Framework** deals with the groundwater occurrence and distribution, groundwater level and its fluctuations, groundwater movement direction and broad hydraulic characteristics of different aquifers.

Chapter X **Groundwater Quality** includes the hydrochemical characteristics, the groundwater facies, groundwater quality and distribution and their correlation with the provenance.

Chapter XI **Hydrogeological Area Categorisation** deals with the hydrogeological evaluation of the study area through critical appraisal of lithological, structural and geomorphological parameters and the hydrogeological area categorisation from the point of view of groundwater potential.

Chapter XII **Water Resources Management** discusses the aspects of present day practices (i.e., mode of extraction and utilization) and envisaged management strategies.