ENVIRONMENT AND LANDFORM EVOLUTION IN DOON VALLEY OF UTTARANCHAL

Dissertation submitted in partial fulfillment of the requirement for the award of the degree of

MASTER OF PHILOSOPHY

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CERTIFICATE

I, **RAKESH ARYA**, certify that the dissertation entitled "**ENVIRONMENT AND LANDFORM EVOLUTION IN DOON VALLEY OF UTTARANCHAL**" for the degree of **MASTER OF PHILOSOPHY** is my bonafide work and may be placed before the examiners for evaluation.

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In memory of my
papa

To my amma

ACKOWLEDGEMENT

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At the very outset, I take the opportunity to acknowledge my gratitude to Dr. Milap Chand Sharma, my supervisor for whose invaluable guidance, erudite ideas and suggestions, I have been able to complete this arduous task. I am highly thankful to the other staff members of CSRD who have always been a source of inspiration to me.
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Last but not the least thanks to all whose well wishers who have helped me in this huge task.
The responsibility for what I have done in this dissertation however is mine.

RAKESH ARYA

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Chapter One

Introduction

1.1 INTRODUCTION:

Since the collision of Indian and Eurasian plate between 54 – 49 Ma ago, India has continued to move northward at the rate of 4 – 5 cm/yr (Wadia, 1975). This lead to the continued rise of Himalayan block of mountains, it have altered climate in number of ways. Firstly the rising plateau would have deflected and block regional air systems, such as jet streams, which in turn would have effected atmospheric air circulation on global scale. Secondly the elevated region would have enhanced temperature driven atmospheric flows, as higher and lower atmospheric pressure system developed over plateau during summer and winter respectively. This would have intensified Indian monsoon, leading to heavier rainfall along the frontal ranges of the Himalayas.

Tectonism in the Himalayas has affected macro level climate on global scale and micro level climate within the Himalayas. Keeping in view the utilitarian approach in Physical Geography, purpose of this study is concentrated in the Duns between the river Ganges and river Yamuna. Dun and Doons have synonymously used.

"Duns are the flat floored structural valleys. Duns of Sub – Himalayas are the instances of tectonic valleys, these being synclinal troughs enclosed between two contiguous anticlinal flexures." (Wadia, 1975)

Doon is an inter- mountain valley located within Siwalik foreland basin in Garhwal Himalaya. It is 80 km. in length and 20 km in average width within Siwalik range to its South and Mussoorie range to its north. Along the northern margin of the Doon valley, the Main Boundary Thrust (MBT) bring the Precambrian rocks to the lesser Himalaya zone to override the Siwalik range demarcates the Himalayan Frontal Thrust (HFT), locally called the Mohand Thrust that separates the Siwalik group from the recent alluvium of the plains. The large part of the valley is occupied by a broad synclinal depression called the Doon syncline. To its south lies a complementary fold structure called Mohand anticline and to its north is Satokgarh anticline. These fold structure have folded the Siwalik strata and owe their origin as fault- propagation fold, developed as a result of southwestward propagating Mohand thrust (HFT). The Mohand anticline is a growing fold structure, uplifted the Siwalik range and restricted the drainage within the Doon valley. The uplifting of Siwalik created a water- divide separating the NE flowing streams into the Doon valley, from the SW flowing streams across the Siwalik range into the Bhabar plains. Doon gravels, the post Siwalik sediments, were deposited as coeval sediments with the growth of fold structures and neotectonic activity along the Main Boundary Thrust (MBT). It is inferred that tectonic evolution of Doon valley began around 500,000 B.P. With the initiation of Himalayan frontal thrust and accompanied by synchronous development of Mohand anticline, Doon syncline and Santokgarh anticline, together with reactivation along the MBT and coeval deposition of the Doon gravel (Thakur, 1995).

After the creation of Dehra Doon as capital of Uttaranchal, this region may need planned attention for its development in the coming year. A study of landform evolution and future trend can provide a base for planners of that area, since it is based on geological characteristics such as climate, sediments, process intensity and so on.

1.2 RATIONALE BEHIND SELECTION OF PRESENT THEME:

Doon valley presents an extreme fragile ecosystem that needs to be preserved and a sustainable development to be carried out which can support growing civilization. Climatic change, that include extreme weather phenomenon can pose a serious threat and may have harmful impact on the life of the earth therefore past climatic changes also need to be studied in order to make the future projections. The study area represents a complete geomorphic unit. River Asan watershed and river Song are the two sub- watersheds present in this region which drains into river Yamuna and River Ganges respectively. After the creation of Dehra Doon as the capital of Uttaranchal state this region is expected to have an immense population pressure and probably will have environmental deterioration. This region falls in the zone of "active tectonic."

"Active tectonic refers movements that are expected to occur within a future time span of concern to society"(Philip, 1995).

This also makes it more imperative for studying it in environmental entirety. A lot of has already done on the tectonics of this region, an attempt to construct relationship been in palaeo-climatic conditions and landform evolution, keeping in mind the tectonic situation of the region.

Climate of our globe is of vacillating nature. There are many evidences in its support. We are still in an early stage to explain these changes in terms of factors responsible but there is no argument over the proposition of change as we have some irrefutable evidences in its support. Geomorphic processes are controlled by climate. It is the climate that decides the type and the intensity of the agents of the gradation and thus the resultant landform.

The factors responsible for the selection of the present theme can be summarized as below:

- It responded to the glacially induced climatic changes so far that area has never been covered with glaciers or directly influenced by periglacial or proglacial conditions.
- They are located in tectonically active region and affected by the Pleistocene and post- Pleistocene movements.
- Doon valley is made up of fan deposits that are now dead, like landscape fossils. The existing streams are deeply entrenched and hardly modify the surface configuration.
- Moreover frequent personal visits to Dehra Doon during Masters of Art programme, and recent creation of Dehra Doon as capital of Uttaranchal developed an interest to study the Doon valley, to evaluate past and suggest some trend for future.

1.3 STUDY AREA:

The study area for this analysis extends from approximately 29°58'02"-30°32'04" N latitude to 77°34'02"-78°18'06" E longitude between River Yamuna and River Ganges in the state of Uttaranchal in the NW and SE, respectively; and between the Main Boundary Thrust and Himalayan Frontal Thrust in the NE and SW, respectively; which coincides with Doon tehsil (administrative sub- unit) of Dehra Doon *(Fig. 1.1)*. This region lies in the crucial environmental belt. It is also the watershed area of the two major Rivers i.e. the Ganges and Yamuna. A number of perennial and seasonal drainage channels issuing from lesser Himalayas and Siwalik debuch into the major River system of Tons and Asan in the west; and Suswa and Song in the east which drain into the Yamuna and Ganges, respectively.

The study area exceeds the limits of main Doon valley or Doon valley proper because of the following reasons:

- Doon valley is formed out of deposits brought by rivers from the adjoining hills and mountains.
- It corresponds to the Dehra Doon tehsil of Dehra Doon district in Uttaranchal.
- Its extent corresponds to the natural boundaries that are rivers and water divides.
- Demographic and land use data can be easily obtained for any integrated analysis.

LOCATION MAP OF DOON VALLEY

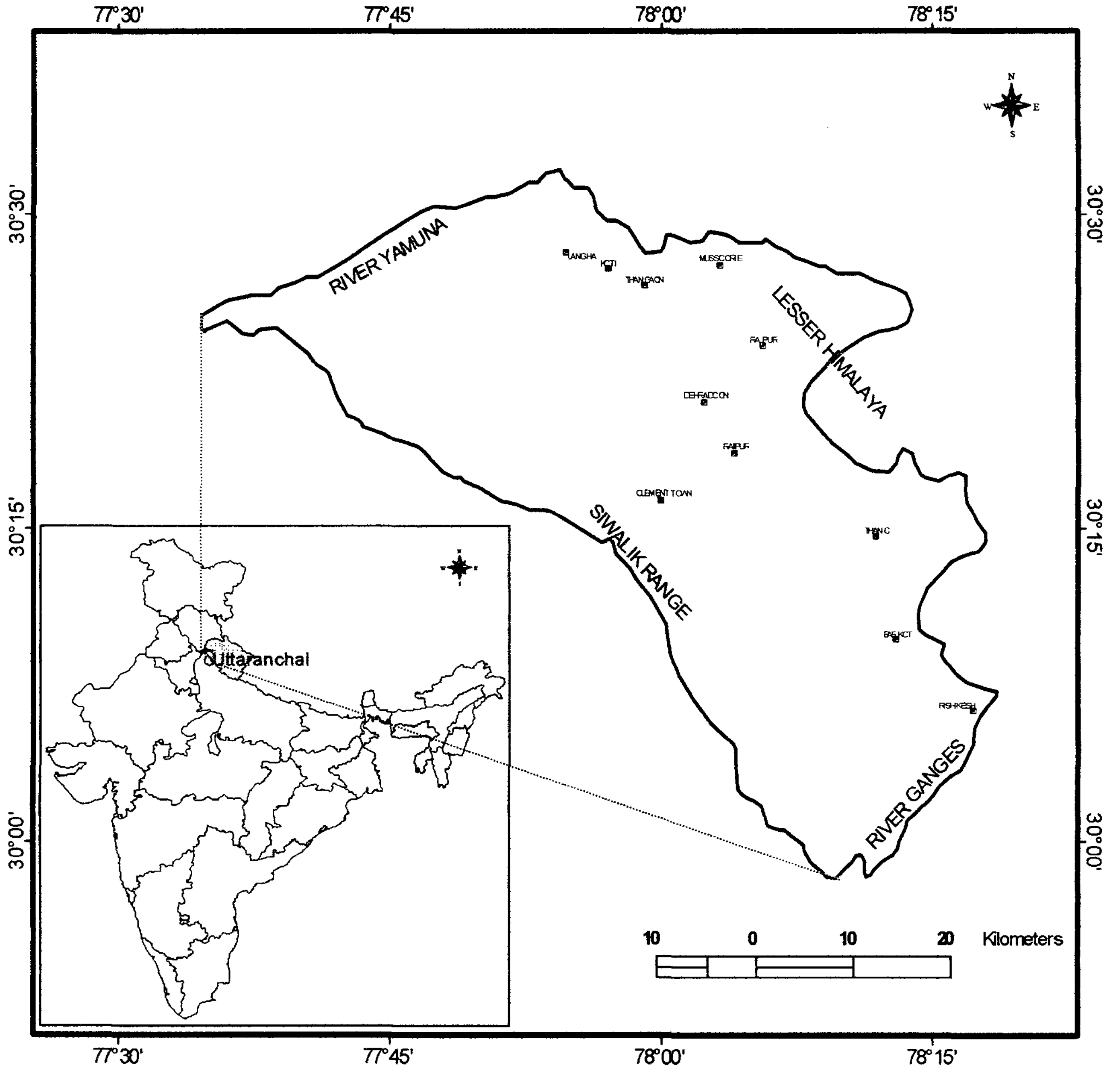

Fig.1.1

1.4 SURVEY OF LITERATURE:

In order to have an appraisal of the development achieved on the topic, literature survey has been considered out. This literature helps in the development of idea on the subject and provides required direction and suggestion for the progress of the work. Findings of various scholars have been compiled below.

Clay mineral study has been extensively carried out in oceanic sediment, whereas continental sediments have received little attention. Recently, (Chamley, 1989) clay mineralogy studies have shown the significance in deciphering climate as well as source area tectonics. Clay mineral suits show temporal variation and is not related to lithofacies, while they show good relationship with provenance and climate. The distribution in the lower part (up to 640 m) indicates frequent ponding/ lacustrine conditions. The source area also changed from the lower part to the upper part, i.e., from dominance of igneous/ metamorphic to meta sedimentary and sedimentary rocks. During this period, climatic oscillations were frequent from cold to dry, warm humid and warm sub-arid. The clay mineral data are in fair agreement with other sedimentological parameters (Bagati and Rohtas, 1995).

Alluvial fans are abundant in the valleys or in the foothills of the mountains in all latitudes irrespective of climatic conditions. They were formed and still are being formed, at the front of ice caps and glaciers as well as in moderate semi- arid and arid regions.... but at present, alluvial fans used little as indicator of palaeo-climate (Rachocki, 1981). Alluvial fans develop at base of a mountain front or other upland areas, where emerging mountain streams deposit a segment of a cone. Development of these fans is generally related to tectonic activity in source area; however, the climatically induced events can also result in the development of such features (Rohtas and Ghosh, 1995).

The drainage map of Dehra Doon reveals that the area under study might be divided sharply into two sectors by bisecting the area transversely into (a) SE sector and (b) NW sector. The SE sector is associated with the streams and rivers (Bindal, Rispina, Susva and song) that join the major river system Ganges towards the eastern boundary i.e. they come under the Yamuna catchment. The NW sector on the other hand is associated with rivers and streams (Asan, Sitla, Moti, Koti and Tons) that join the river Yamuna i.e. the Ganga catchment. This geomorphological feature has therefore given rise to a water divide known as Landour-Asharodi water divide. Landuse wise also the Yamuna catchment is less densely populated with large area under forest cover as compared to the Ganga catchment sector (Saini et el, 1997).

Important geomorphic features of this region are raos (torrents), which remain usually dry. These are the braided channels with gravel beds. A vigorous process of erosion was initiated in the Himalayan zone during the Pliocene period when a multitude of stream draining the area carried detrital waste down the mountain and deposited in the indo - Gangetic trough. The first laid sediments were involved in the latest mountain building activity that resulted not only in the uplift of Himalaya but also in the creation of parallel range of Siwalik Hills in the south. The valley between the Himalaya and the Siwalik was filled with the sediments from both sides, though the contribution from former was greater because of its huge drainage area. The alluvial plains, broken by streams represent the landscape of Doon valley (Gupta and Sharma, 1995).

It is composed of alluvial fans and river terraces and traversed by seasonal braided streams/ rivers. The underlying deposits are the clay mineral study has been extensively carried out in oceanic sediment, where as continental sediment have received little attention. Recently, clay mineralogy study has shown the significance in deciphering climate as well as source Gravels. (Roy A.K., 1995.)

The entire structure of Siwalik from top to bottom is extremely fragile and prone to erosion by wind and rain if shorn of its vegetative cover. This extreme vulnerability gives rise to exceptional conservation needs (Ghosh, 1995).

In the earth sciences, the term "tectonic" refers to all the deformational structures and architecture of the earth crust and the evolution of these features through time. The term " neotectonics" (introduced by Obruchev, 1948), describes the study of 'young and recent movements taking place at the end of tertiary and the first half of the quaternary'. Recently, neotectonics has been defined (Pavlides, 1989, Steward and Hancock, 1994) as the branch of tectonics concerned with understanding of earth movements that occurred in the past and are continuing in the present day. "Active tectonics" is a term, which refers to movements that are expected to occur within a future time span of concerned to society. Nossin (1971) prepared the first geomorphological map using aerial photographs. He determined that this synclinal valley to be post upper Siwalik age and that the regional uplift of the valley since the upper Siwalik times is about 950 to 1250 ft. Thereafter, Nakata (1972, 1975) studied the geomorphic surfaces in the valley and described some recent movements. He suggested that the Doon valley evolved by the intricate superimposition of alternate depositional and erosional phases, caused by climatic changes and crustal movement over the hundred thousand years. It was Rao (1977, 1978) who for the first time mentioned the occurrence of tilted post-Siwalik boulder bed, the *Langha Boulder* bed, which rests uncomfortably on the upturned Siwalik sediments in Doon valley. The cross profile shows that the eastern portion of the fan is at higher elevation than the western lateral side, which indicates the westerly tilt of the whole fan sequence. The migrations of the two Himalayan antecedent rivers are therefore in an opposite direction, which is probably due to the compression between the Siwalik and the Lesser Himalayas, resulting in the recent uplift of the Doon valley. The geomorphological analysis indicated that a regional uplift of the Doon valley of about 380 m took place after the end of Siwalik deposition (Rao, 1986). Tectonic rates are reflected in rates and pattern of geomorphic processes and forms (Philip, 1995).

Erosion is high in the Himalayas because of the presence of highly fractured jointed unstable rocks. Further, there are also areas of instability having frequent magnitudes of seismic activity and causing severe landslides contributing enormous amounts of loose debris to the streams and to river systems of the region. These geologicaly unstable formations occur in the seismic zone (Valdiya, 1975) and are prone to serious erosional problems at slight disturbances (Sastry et el, 1995).

The Doon valley is a longitudinal, synclinal valley between the Siwalik range and lesser Himalayas. It extends between gaps where Yamuna and the Ganges leave the Himalayas and break through Siwalik range. Large gravel fans descend from Himalayan front into the Doon valley. The gravels are largely derived from the reworked Upper Siwalik conglomerates, and also from the northern front (the Mussoorie range). The gentle uniform gradient of the fans is related to the monsoon rainfall and runoff system. The Main Boundary Fault (MBT) of the Himalayas separates the Doon valley from the mountain scarp of the Mussoorie range. Uplifted high level fan terraces overstep the boundary fault, and principal fans are deeply dissected at the mountain foot. Terraces indicate various episode of incision and infilling. The various sub-units in the morphology of the Siwalik range are all lithologically controlled. All channels are braided; the Yamuna and Ganges break through the Siwalik range along the transcurrent fault lines, while there is no other break through the range in this region. The two main rivers are flanked by several terrace level, all below the level of principal Doon fans (explained later). Uniformity of incision suggests the regional uplift of the area, supplementing that differential movements have occurred especially along transversal offshoots of main boundary fault. These movements continue up to the present day. From the configuration of the terraces and upheaved fan parts, a total regional uplift in the order of 950 – 1250 ft is concluded (Nossin, 1971).

1.5 OBJECTIVES OF THE STUDY:

The main objective of the study is to understand the relationship between present landforms and associated environment. This will precede the examination of geographic activities of the region, which can help in better understanding of the surface features and agents related to their evolution. Emphasis is placed on the depository features, as they are resultants evidence of past climate. Other evidences will also be examined where ever found necessary. The objective can be summarized as given below:

1. To reconstruct the palaeo-environmental conditions in the evolution of Doon valley through geomorphic and stratigraphic evidences.
2. To study the spatial distribution of various geomorphic features.
3. To investigate other than related possibilities, which led to the formation of present Doon valley.

1.6 DATABASE:

Primary:

- Terrestrial photographs and observation of sediment deposits, tectonic evidences over exposed surfaces along the road and river valleys were obtained from various field surveys.

Secondary:

- Toposheet numbers 53F12, 53F14, 53F15, 53F16, 53G9, 53J3, 53J4, 53J7, 53J8, 53K1, 53K5 and 53F11 (on scale1: 50000) by Survey of India.
- Digital satellite imagery obtained by IRS – 1D, LISS-III on date 1st April 2001 in RGB bands and processed at NRSA Hyderabad.
- Thematic maps of Dehra Doon prepared by (NATMO).
- Weather data (IMD)

1.7 METHODOLOGY:

Methodology for the study of following themes include:

- Field observation includes the understanding of deposits along the exposed surfaces along the roads and riversides exposures.
- For better understanding of some morphological and relief records, large-scale SOI toposheets (1:50000) were used.
- The data derived from toposheets, satellite imagery and other various secondary sources is analyzed with the help of GIS software. ERDAS IMAGINE 8.4 is used for sub setting, geo referencing, supervised classification and other statistical data extraction. ARC VIEW 3.2a is used for interpolating grids, digitization, statistical data extraction, labeling, 3- D analysis, area extraction etc.
- For the modifications of the maps and diagrams acquired from secondary sources, the software Abode Photoshop is used.
- Inferences from field and data from secondary sources are incorporated together for realizing the study of present theme.

1.8 ORGANIZATION OF MATERIAL:

Chapter 1: This is the present chapter, which includes literature survey, to provides direction to the study. Objectives are specified along with type and source of the data used. This also includes the location of study area.

Chapter 2: This chapter gives a general description of the background of the study area, which includes physiography, geology, soil, climate (temperature, rainfall, humidity, cloudiness, wind, special weather phenomenon), vegetation, and general land use and landform characteristics. It also includes introduction of various important streams and other seasonal streams, known, as raos in local language along with information about various thrust and faults.

Chapter 3: This section includes morphometric analysis and tectonic setting of the area. Structure and tectonic have been discussed in detail. This section presents the information on intensity of processes working on Doon surface in present time.

Chapter 4: This chapter deals with the relationship between landform, climatic influence in relation to the impact of tectonic activities and resultant landform.

Chapter 5: Summary and conclusion.

1.9 LIMITATIONS OF THE STUDY:

- The reliability of study is linked to authenticity of secondary sources.
- Satellite imagery for the NW portion of the study area is not available, which is tectonically very active, and therefore reducing the scope for understanding the particular region in detail.
- For understanding micro environmental conditions, the micro facies analysis needs to be done. This requires completed laboratory techniques and deep cores.
- The field was visited twice but due to bad weather and malfunctioning of camera, not many field photos could be obtained.

Chapter Two

Introduction of the Study Area

2.1 PHYSIOGRAPHY:

The study area can be divided into two broad physiographic divisions:

A: Montane tract

B: Sub- montane tract

A: Montane tract:

Montane tract includes two major physiographic divisions -

- NW and NE parts of the valley- the lesser Himalayan Mussoorie range
- The continuous chain of hills in the SW and SE forming parts of the valley- the Siwalik range

B: Sub – montane tract:

It is the central synclinal trough or the Doon valley proper (Fig. 2.1). It is an open valley bounded by the Siwalik hill in the south and the outer scarp of the Himalayas in the north. It is apparently a single valley but in reality it belongs to two great river systems, those of the Ganges and Yamuna. It can be further sub–divided into two divisions as the eastern Doon and the western Doon. In the eastern Doon, Himalayas rise abruptly from the valley and consequently there are fewer of the long sloping plateaux that form such a marked characteristic of the western sub division. The surface of the center of the valley is diversified by two isolated hills as Nagsidh, an offshoot of the Siwalik, and Kalanga, an outlier of the lower Himalayas. Both these hills are divided from the parent ranges by rivers, the Nagsidh by the Suswa and the Kalanga hill by the Song. In the western Doon, the lower slope of Himalayas rise at a gentler gradient. (Gazetteer of Dehra Doon)

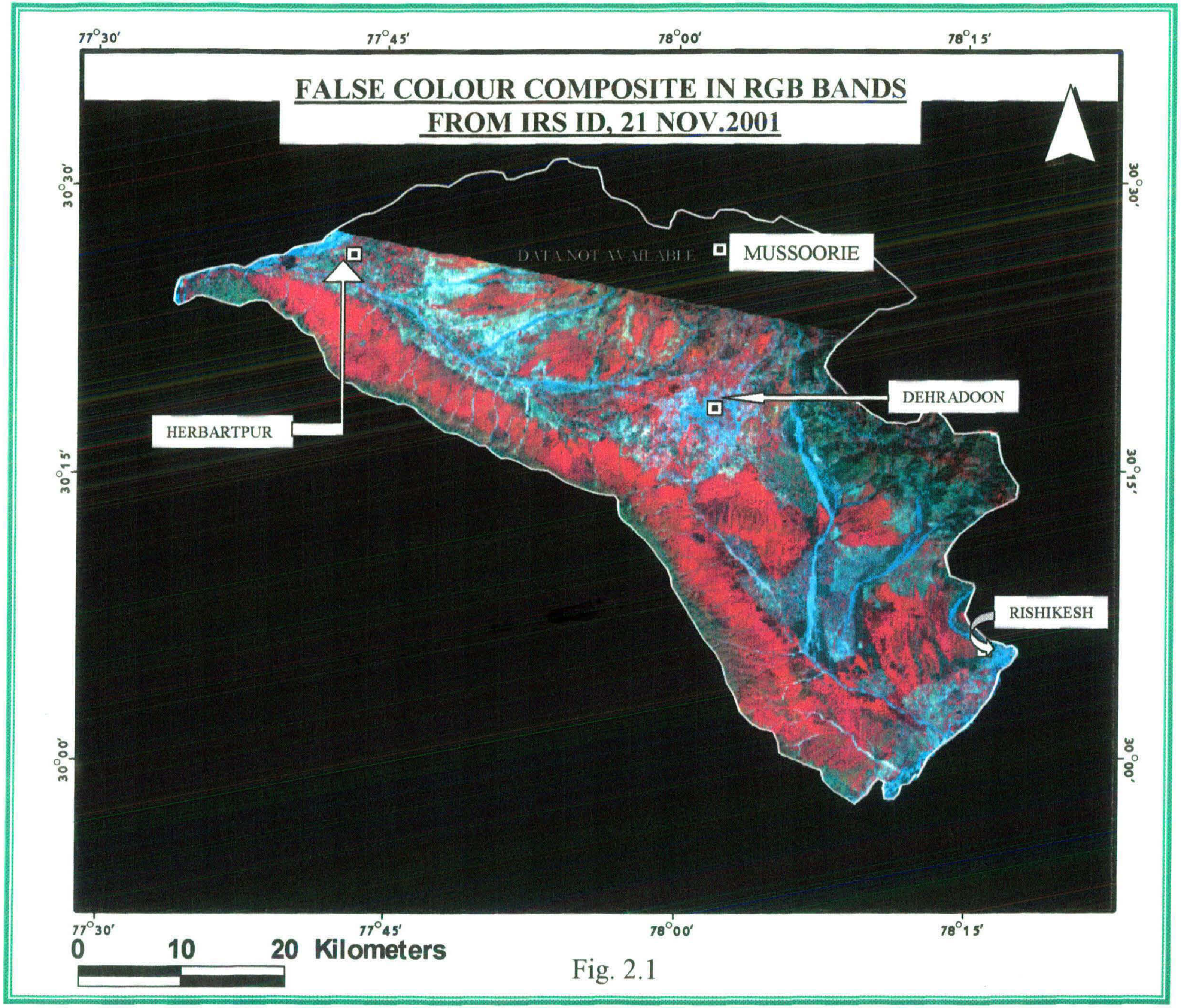
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Fig. 2.1

2.2 RELIEF AND SLOPE:

According to the relief and slope map prepared from the NATMO (Fig.2.2) from planning atlas, Uttar Pradesh, 1987. The area is divided into four categories viz. 300 – 600 m, 600 – 1000 m, 1000 – 2000 m and above 2000 m.

Only NE part of the region shows elevation between 1000 m – 2000 m. Only few patches have elevation above 2000m. The zone between 600 m – 1000 m flanks the elevation range between 300 m – 600 m by two sides, forming a border at its NE and SW sides.

Slope in the region is again divided into four categories in meters/per/km viz. 10 - 50, 50 – 150, 150 – 300 and 300 – 600. The NE region shows rugged topography and shows steeper gradient ranges between 300 – 600 meters per kilometer. The SW region along Shiwalik hills has gradient between 150 – 300 meters per kilometers and the Doon valley proper have the least gradient of 10 – 50 meters per kilometers. While the small portion in the SE of the region, along the river Ganges shows peculiar characteristics of slope between 50–150 meters per kilometers. This may be due to down cutting done by the river Ganges.

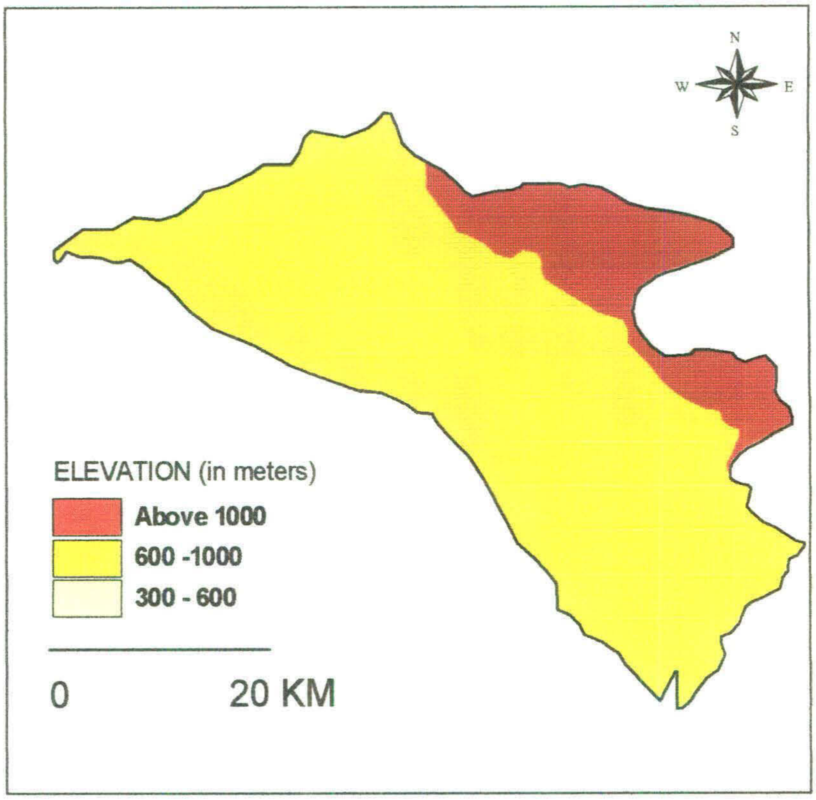
Doon valley shows a characteristic feature of longitudinal strike valley. Its structural setting is as such it draws the attention and develops the interest to know the actual relief configuration of the valley and will also help in the better understanding of the evolution of Doon valley. For this purpose, various maps have been created in GIS environment with the help of 40ft contour intervals for Doon valley proper. The digital terrain model with illuminated and non-illuminated surfaces has been created in

ArcView 3.2a (Fig. 2.3). The software create it by triangulation method i.e. it interpolate the surface by taking neighboring three points in sequence. The illuminated surface means that triangulated surface is highlighted and shaded where as non-illuminated surface means smooth representation of the surface.

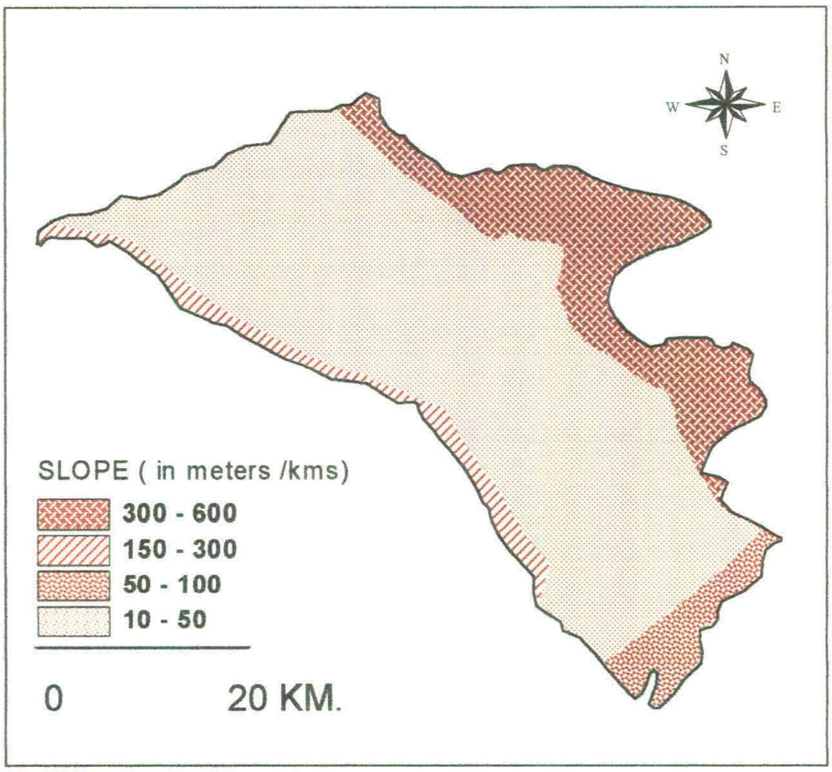
The three dimensional Digital Terrain Model (DTM) is made for viewing the valley from different directions with vertical exaggeration of five times against contour of minimum value. Views from the north, east, west and south are given (Fig. 2.4), to lighten in understanding valley relief configuration.

Aspect map is shown in two-dimensional and three-dimensional scenes (Fig. 2.5) with the help of Digital Elevation Model. Aspect is an important terrain parameter from land utilization point of view. As for the climate and global position (i.e. northern hemisphere) of India is concerned the south, southwest and southeast facing slopes are best suited for settlement and agricultural activities whereas others are utilized for grasslands, plantation, orchards etc.

RELIEF (DEHRA DOON)



SLOPE (DEHRA DOON)



Modified after, Planning Atlas, Uttar Pradesh, 1987
Source:NATMO

Fig. 2.2

DIGITAL TERRAIN MODEL

DOON VALLEY (DEHRA DOON)

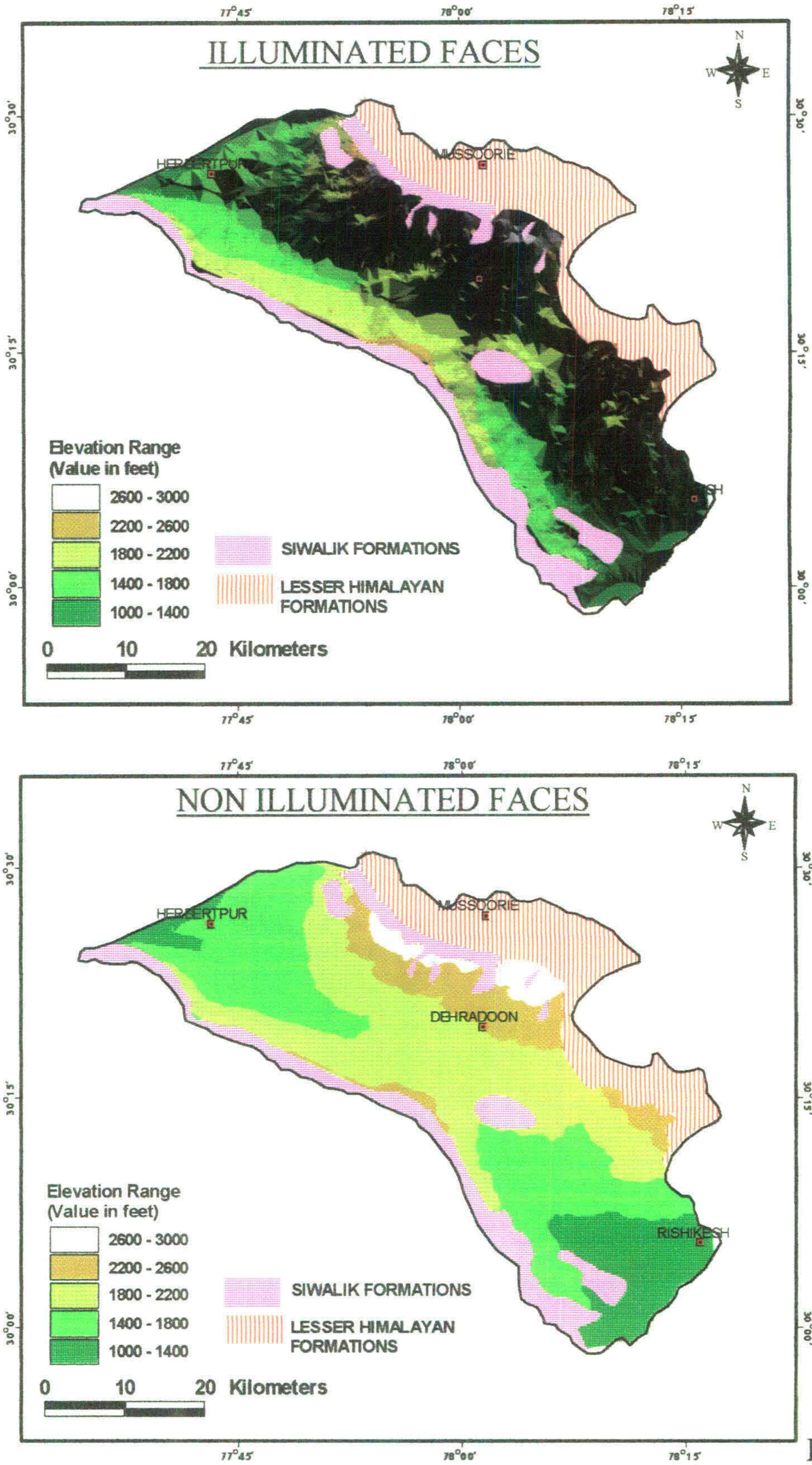
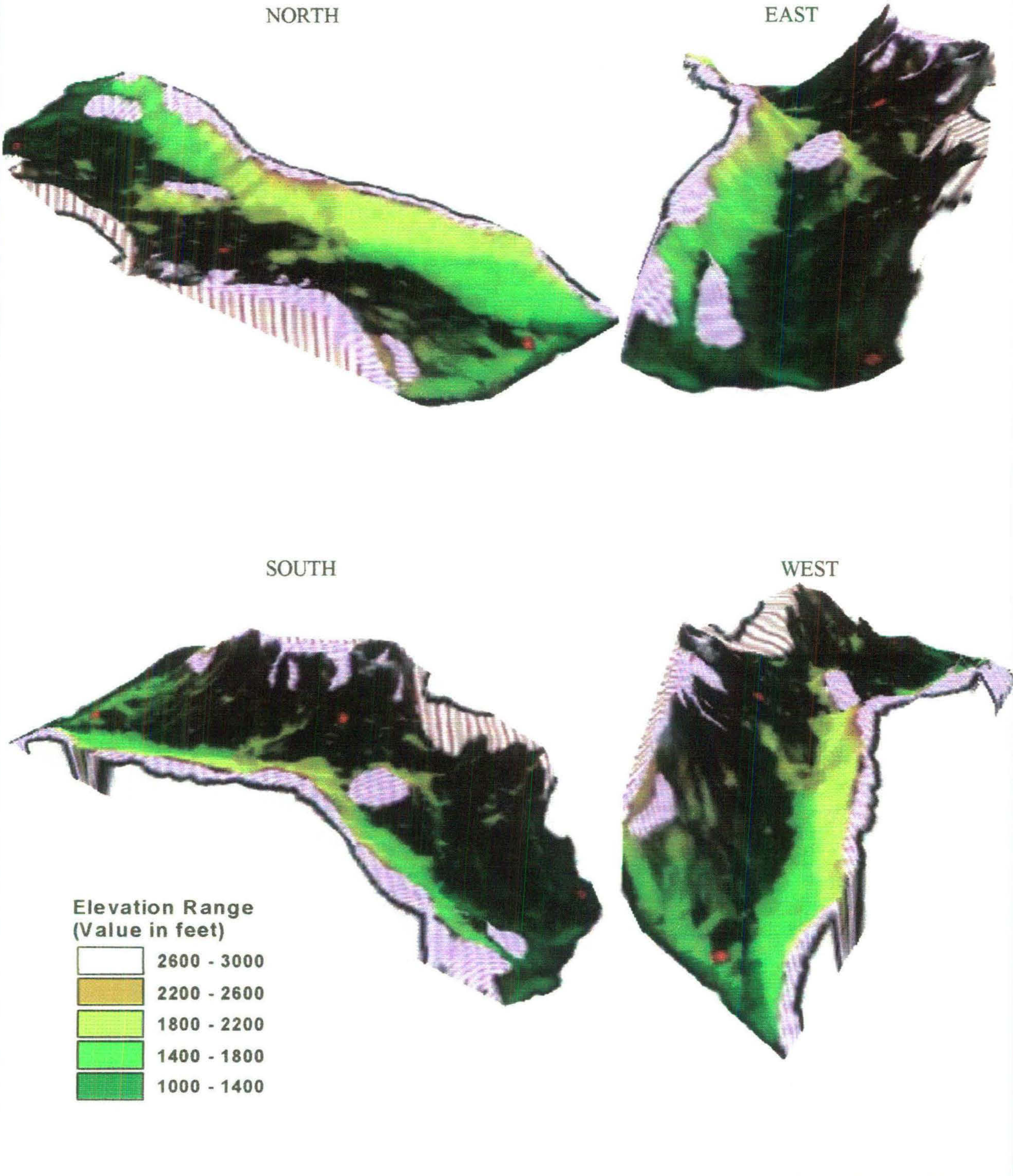


Fig.2.3

DIGITAL ELEVATION MODEL

VIEWED FORM DIFFERENT DIRECTIONS

DOON VALLEY (DEHRA DOON)

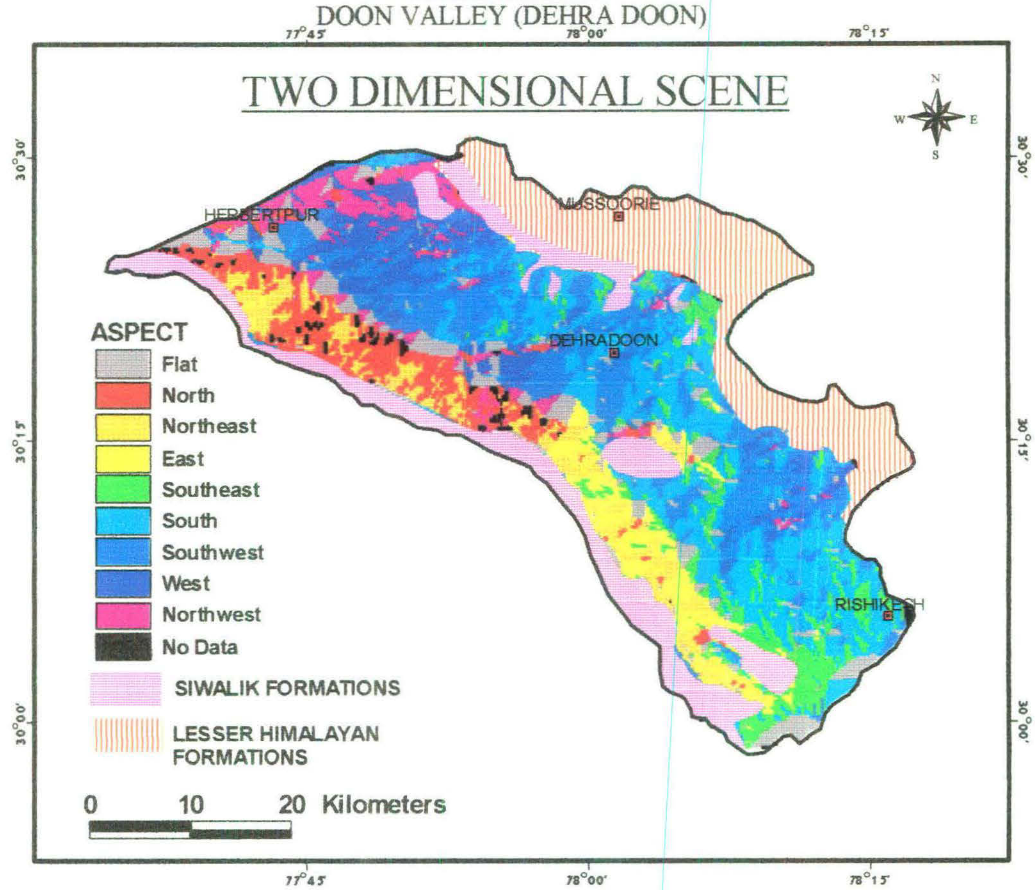


MAPS NOT TO SCALE

Fig.2.4

ASPECT

DOON VALLEY (DEHRA DOON)



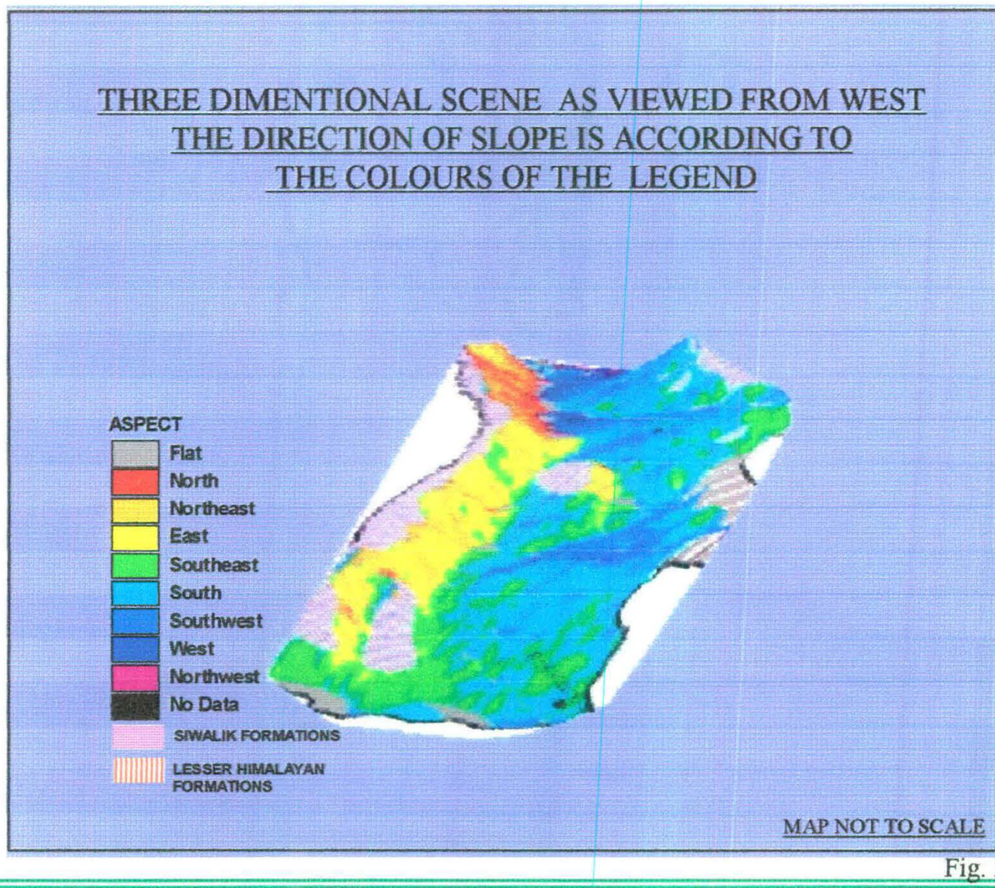


Fig. 2.5

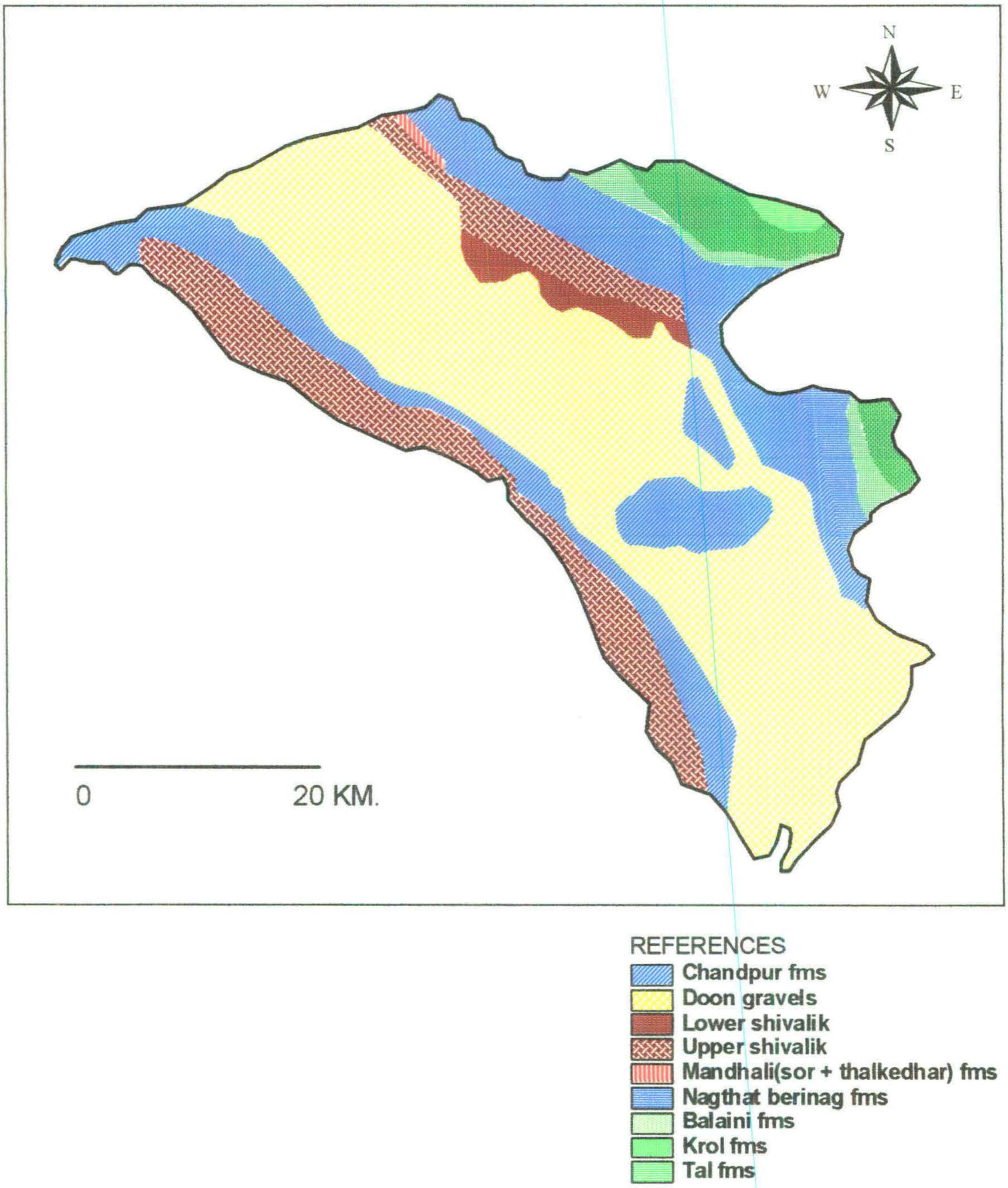
2.3 GEOLOGY:

Geology is considered to be an important natural resource since it regulates genesis formation and type of soil, occurrence, distribution and flow of groundwater, and determines presence of minerals. Geology deals with different rock types that constitute the earth's crust, their origin, composition, chronology and tectonic settings. The geological surveys are based on field observations made along a traverse line at regular intervals on a topographic base.

Doon valley is bounded to the north by the Main Boundary Thrust (MBT) that separates the Precambrian rocks of the Krol belt of the Lesser Himalaya from the Cenozoic sediments of the outer Himalaya (Thakur, 1992). To the south, sudden topographic rise of the Shiwalik ranges is demarcated by the Himalayan Frontal Thrust (HFT) that brings the Shiwalik group of rocks against the recent alluvial sediment. The Himalayan frontal thrust, locally called the Mohand thrust, dips towards NE, and in seismic section is interpreted as extending below the Doon valley (Thakur, 1995). The lesser Himalayan zone of this region shows complex geology in comparison to Doon valley proper and Siwalik zone. According to the geological map prepared from NATMO (Fig 2.6) the study area has various types of geological formations. These are Tal, krol, Baliani, nagthat bearing, Mandhali (Sor and Kedhar), chandpur formations and upper Siwalik, lower Siwalik, Doon gravels.

Mandhali formation is named after village Mandhali (30° 51' – 77° 59') in northern Chakrata area (not in study area). This formation of grayish green and black carbonaceous pyretic Phyllites or slates inter bedded and inter banded with marmorised

GEOLOGY DEHRA DOON



Modified after, Geological Map: Kumaun Lesser Himalaya – K.S Valdiya
Source: NATMO, 1991 Fig. 2.5

and plastically folded blue – banded limestones and the variety of paraconglomerates occurring lentiforms. Thus the clasts of quartzite, limestone, dolomites and slates are embedded in the matrix of black limestone and carbonaceous slate (the Sor and Thal are the name of similar formations in Pithoragarh district in eastern Kumaon), (Valdiya, K.S., 1980).

The Chandpur formation named by Auden (1934) after the peak (30° 42' – 77° 40') in southeastern Himachal Pradesh. These are the olive green and grey phyllite interbedded and finely interbanded with metasiltstone and very fine-grained wackes, with local metavolcanics. These also represent low-grade metamorphism, (Valdiya, K.S., 1980).

Nagthat formations are the assemblage of purple fawn, white and green quatzarenite (orthoquartzites) that are locally pebbly or conglomeratic, and interbedded with greenish and purple slates that succeed the Chandpur. The equivalent of the Nagthat of the Krol belt in the inner sedimentary zone is known as Berinag formation (Valdiya, 1962).

Blaini formation embodying conglomerate with siltstone, greywake and slates of grey, olive green, and black colour, and impersistent lenticular beds of purple and red limestone, associated with purple slate and sandstone that rests upon the Nagthat quartzite in the Krol belt, (Valdiya, K.S., 1980).

Krol formations are sequence of limestone, grey and greenish grey and purple slate, siltstone in the upper part massive dolomite, which follows the Blaini without perceptible break, was named by Medlicott (1864) as the Krol series after the Krol mountain (30°32'–77°51') near Solan in Himachal Pradesh (Valdiya, K.S., 1980)

Tal formation first studied at the Bibasini – Tal confluence ESE of Rishikesh comprises various opinions. (1). Black carbonaceous often pyretic mudstone interbedded in basal part by phosphatic chert and limestone in the Mussoorie hills and by conglomeratic mudstone and greywacke (pebbly mudstone). (2) A variety of sand stone of whitish pale yellow, deep brown and black colour quartzite of variable grain- size and characterized by deep limonite staining or presence, or feldspar as a component, interbedded with subordinate purple as well as black slates. Significantly the Tal happens to be the only Lesser Himalayan formation (except Bansi and Subathu), which has yielded reliably datable fossils, bryozoans and brachiopods. The Tal has now assumed a prominent position in the stratigraphic scheme of the outer lesser Himalaya, (Valdiya, K.S., 1980).

Doon gravels are post Siwalik sediments. Doon gravels are mainly composed of quartzite and quarzitic sandstone. These appear to have been derived from lesser Himalayan formation to the north or reworked from the boulder conglomerate of the Siwalik. Secondary carbonate precipitates are widely distributed within the fan gravels and at many places they form lime-indurated breccias.

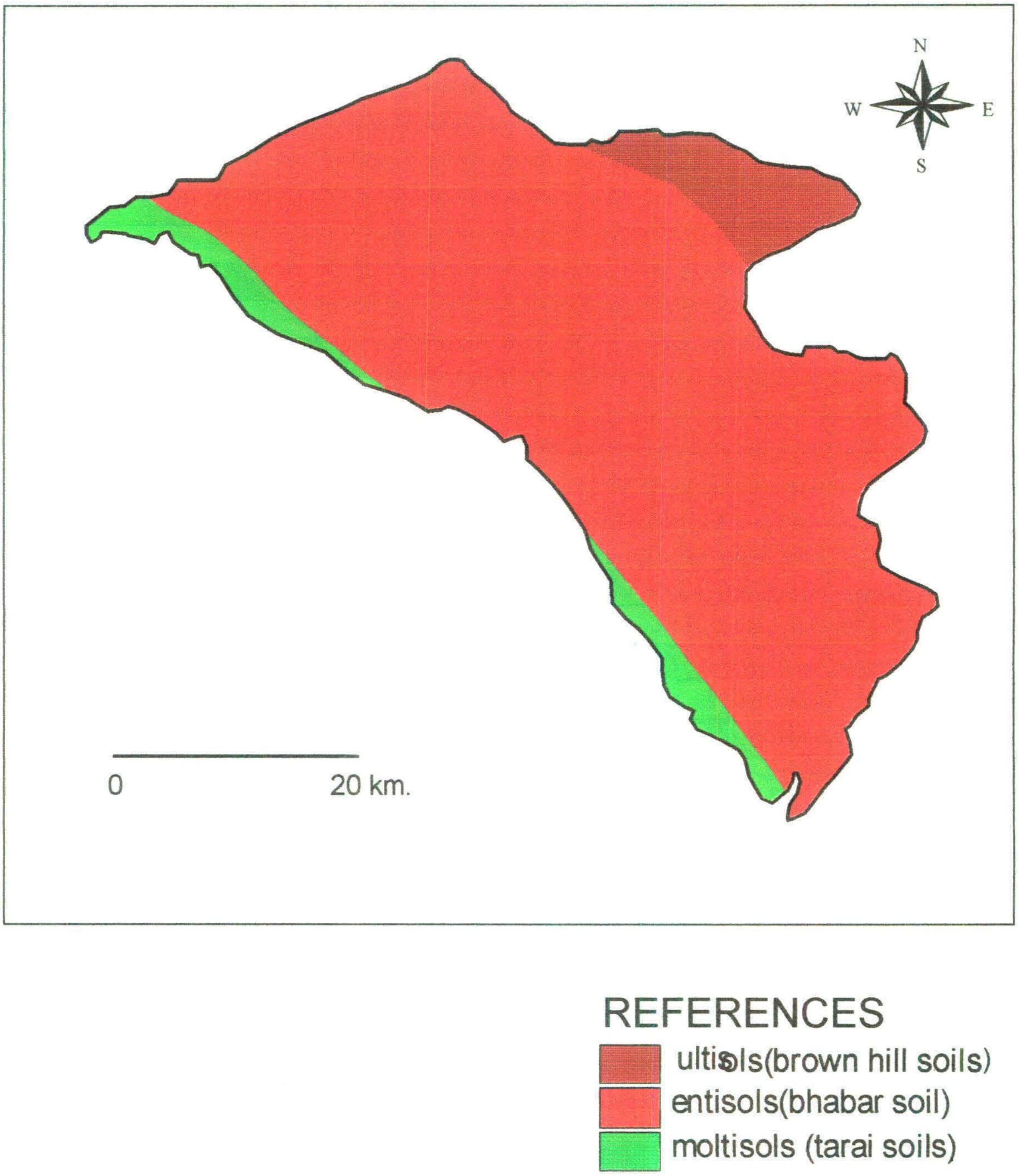
The lower Siwalik is exposed in northern part of the Doon valley. It consists of brown, grey, indurated, fine to coarse-grained sandstones, interbedded with brown and grey mudstones. The sandstone bodies occur in ribbon and or sheet geometry with low angle cross–stratification and with horizontal laminations. The mudstone shows pedogenic modification, mottling and bioturbation (Thakur,V.C., 1995).

Upper Shiwalik is well exposed in the alluvial plain and southern border of the Doon valley and to the north of the lower Siwalik exposure. The upper Shiwalik is composed of thickly bedded conglomerate in sandy matrix and interbedded sandstone and minor mudstone and having total thickness of 2000 meters. Overall clast size of conglomerate shows an upward coarsening trend. In the lower part conglomerate are well stratified, imbricated and show fining upward whereas in upper part these are massive.

2.4 SOILS:

The soil resources of the Doon valley are being affected by high level of human activities and there is a strong need to recognize the importance of watershed management as the base for development of the valley for a balanced growth in future (Sharma, et al 1995). The microclimatic conditions of the valley, with soil accumulated over centuries through the rivers, place this area to the high porosity landscape. Soil constitutes a major element in the natural environment, linking climate and vegetation and having profound effect on men's activity through its relative fertility. According to the USDA soil taxonomy (based on the map of NATMO), (Fig.2.7). The Soil resources of the Doon valley can broadly be classified into three categories, ultisol, entisol and mollisol. The soil ultisol or the brown hill soil is found in the northwestern part of the study area i.e. the lesser Himalayan zone. It is deeply weathered leached acidic soil. The entisol or the bhabar soil covers the major portion of the Doon valley. The southern most portion of the study area is covered with the mollisol or the tarai soil. This soil commonly occurs in the foothills and lower portions of the gentle slopes. The main characteristics of these soils are their fine loamy to coarse loamy texture, with thick organic rich surface layer.

SOILS
DEHRA DOON



Modified after, Planning Atlas, Uttar Pradesh, 1987.
Source: NATMO

Fig.2.6

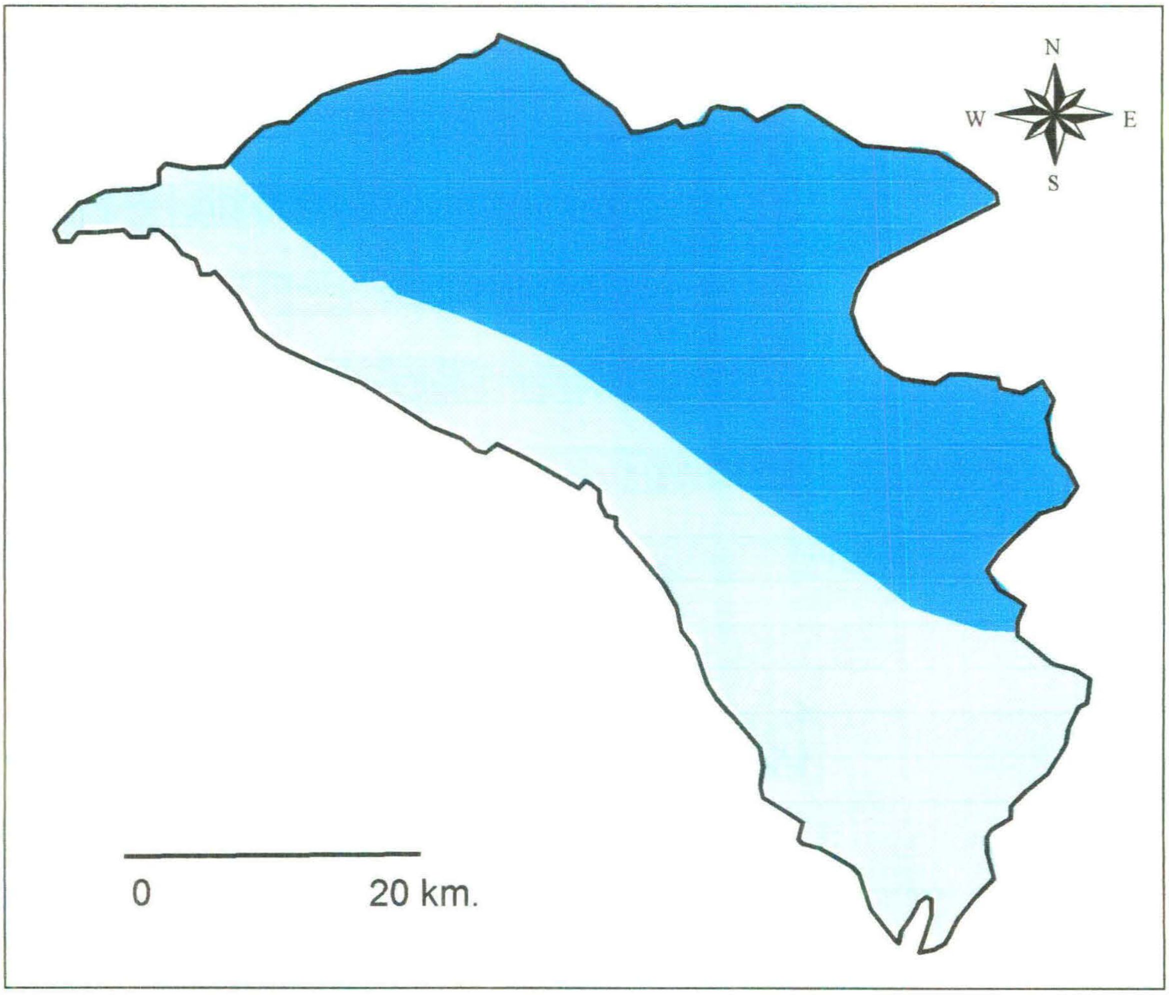
2.5 CLIMATE:

The broad climatic pattern can be regarded as a permanent feature, although the land use/land cover to some extent can modify the microclimate. Similarly, of all the resource factors, climate has the most direct significance, on the general characteristic and broad pattern of biological activity. The climate of this region is similar to those in the plains. Locally, the temperature varies according to the elevations. In general climate is temperate and the year may be divided into four seasons viz. cold, hot, monsoon and post- monsoon season.

2.5.1 Rainfall:

Rainfall is a major weather parameter and is a precious natural resource. It is received in measurable and sometimes predictable amount. In the Doon valley, generally rainfall increases as one proceeds from the south–west towards the north–east, the region around Rajpur gets the maximum rainfall, while the areas around Ambari and to the east gets the least rainfall in the district. About 87 percent of the rainfall is received during the months from June to September, generally July and August being the rainiest (Gazetteer of Dehra Doon). The area has monsoonal climate. The heavy concentration of rainfall in the monsoon month causes many of the rivers in the area to carry water only in that season (Nossin, 1971). Broadly the region can be divided into two class categories viz. medium (1400mm – 2000mm) and high (above 2000mm), (Fig.2.8). The NE part shows high rainfall category while SW part shows medium rainfall zone, basically due to windward and leeward side effect Lofty Himalayas acts as a good

CLIMATIC CONDITIONS
DEHRA DOON



REFERENCES

RAINFALL
(in mm)

- Medium (1400 - 2000)
- High (above 2000)

TEMPERATURE
(in degree C)

	MAX	MN
Summer	39	19
Winter	27	3

Modified after: Planning Atlas, Uttar Pradesh, 1987

Fig.2.8

Source: NATMO

barrier for the moisture bearing clouds to precipitate while the SE part falls in the rain shadow region of the Siwalik.

2.5.2 Humidity:

The relative humidity is high during the SW monsoon season, generally exceeding 70 percent on an average. The mornings are comparatively more humid than afternoons. It is less during the rest of the year, the driest part of the year being the summer season with relative humidity in the afternoons becoming less than 45 percent (Gazetteer of Dehra-Doon)

2.5.3 Cloudiness:

The skies are generally heavily clouded or overcastted during the SW monsoon season and short spells of rains are associated with the western disturbances. Hills are often seen enveloped in clouds. During rest of the year, it is usually lightly clouded or clear (Gazetteer of Dehra Doon).

2.5.4 Wind:

Wind system in the region shows variable directions in different season but is generally light. In the Doon, winds in the post monsoon and in the mornings in the rest of the year are variable in direction, though northerly to north-easterly winds are sometimes experienced during post-monsoon and winter mornings. In the afternoons winds are mostly from direction between south-west and north-west through out the year, except in October and November. In the hilly regions, from May to September, wind blow from direction between south-west and south-east. In the post- monsoon and cold season these winds continue to be most common, but on many days in the mornings northerly and north- easterly winds also blow. In March and April, morning winds are northerly to north-easterly and afternoon winds are south-easterly to south-westerly.

MONTH WISE MEAN WIND SPEED FOR DEHRA DOON AND MUSSOORIE IN KILOMETER PER HOUR (data from 1931- 1961)

MONTHS	MEAN WIND SPEED IN KM. PER HOUR	
	DEHRA DOON	MUSSORIE
JANUARY	2.6	6.7
FERUARY	3.1	7.4
MARCH	3.6	7.9
APRIL	**4.2**	7.9
MAY	**4.1**	**8.4**
JUNE	3.6	7.3
JULY	2.7	5.6
AUGUST	**2.5**	**4.7**
SAPTEMBER	2.8	5.4
OCTOBER	3.3	6.1
NOVEMBER	3.0	6.3
DECEMBER	*2.6*	*6.8*
ANNUAL	***3.2***	***6.7***

Source: Climatological tables, IMD. Table 2.1

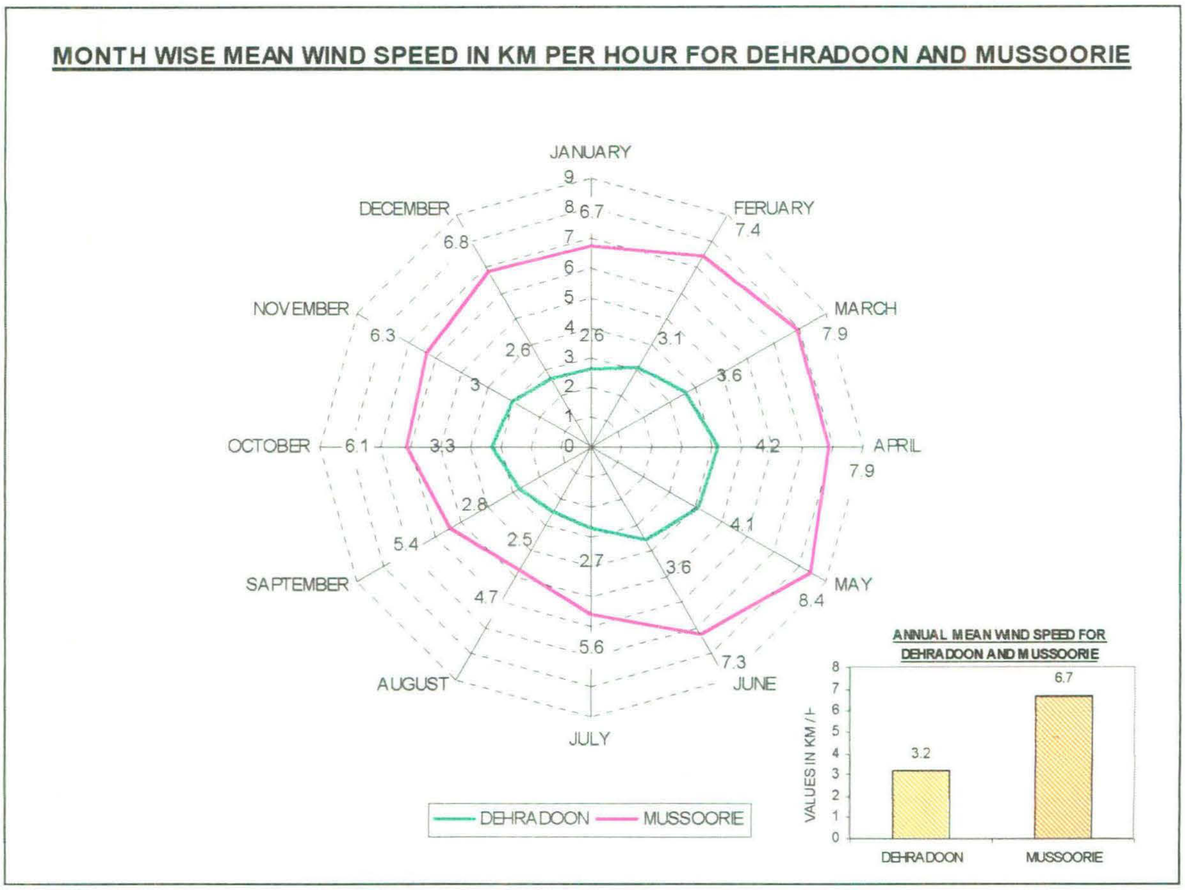


Fig. 2.9

If we observe thoroughly the wind rose, we finds that annual wind speed of Mussoorie (6.7 km/h) has more than double wind speed that to Dehra-Doon (3.2 km/h). This may be due to the rising winds along the slopes of Mussoorie hills and its wind ward location. Month-wise analysis show that Dehra-Doon has maximum wind speed in the months of April and May i.e.4.2 km/h and 4.1 km/h respectively, and least wind speed in the month of August i.e. 2.5 km/h. After June, wind speed shows decline in its speed again in October and November speed increases but remains below the annual average. The wind speed at Mussoorie also shows somewhat similar trend but speed is approximately double the wind speed recorded at Dehra Doon, (Fig. 2.9).

2.5.5 Special weather phenomenon:

Here special weather phenomenon mainly refers to thunderstorms, hail, fog etc. During the cold season, passing western disturbances affects the weather over the district, causing occasional thunderstorms, some of which are accompanied with hail. Thunderstorms occur during summer and monsoon season as well. Fog occurs occasionally during the cold season.

FREQUENCY OF SPECIAL WEATHER PHENOMENON FOR DEHRA-DOON AND MUSSOORIE (NUMBER OF DAYS PER MONTH):

(Based on the observations from 1931- 1961)

MEAN NUMBER DAYS WITH										
MONTHS	THUNDER		HAIL		DUST STROM		SQALL		FOG	
	D	M	D	M	D	M	D	M	D	M
	2	3	4	5	6	7	8	9	10	11
JANUARY	3.0	1.6	0.2	**2.0**	0.0	0.0	0.0	0.3	0.2	3.0
FERUARY	2.0	1.6	0.1	**1.7**	0.0	0.0	0.1	0.3	0.3	1.6
MARCH	5.0	4.0	**0.3**	**1.8**	0.0	0.0	**0.4**	**0.5**	0.0	0.7
APRIL	4.0	5.0	0.2	**1.2**	0.0	0.0	**0.3**	**0.5**	0.0	0.4
MAY	8.0	8.0	0.2	0.8	**0.2**	**0.2**	0.1	**0.8**	0.0	0.5
JUNE	**10.0**	**9.0**	**0.5**	0.2	**0.1**	**0.1**	0.1	0.3	0.2	6.0
JULY	**12.0**	**9.0**	0.0	0.0	0.0	0.0	0.0	0.0	**1.1**	**19.0**

AUGUST	**12.0**	**9.0**	0.0	0.1	0.0	0.0	0.0	0.0	**0.8**	**17.0**
SAPTEMBER	**10.0**	**9.0**	0.0	0.1	0.0	0.0	0.0	**0.3**	0.0	**13.0**
OCTOBER	3.0	2.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	3.0
NOVEMBER	**0.5**	**0.5**	0.0	0.1	0.	0.0	0.0	0.0	0.1	1.0
DECEMBER	0.7	1.4	0.0	0.7	0.0	0.0	0.0	0.1	0.1	2.0
ANNUAL	***70.0***	***60.0***	***1.6***	***9.0***	***0.3***	***0.3***	***1.0***	***3.0***	***8.0***	***67.0***

(Climatological tables, IMD) Table 2.2

D - Dehra Doon

M – Mussoorie

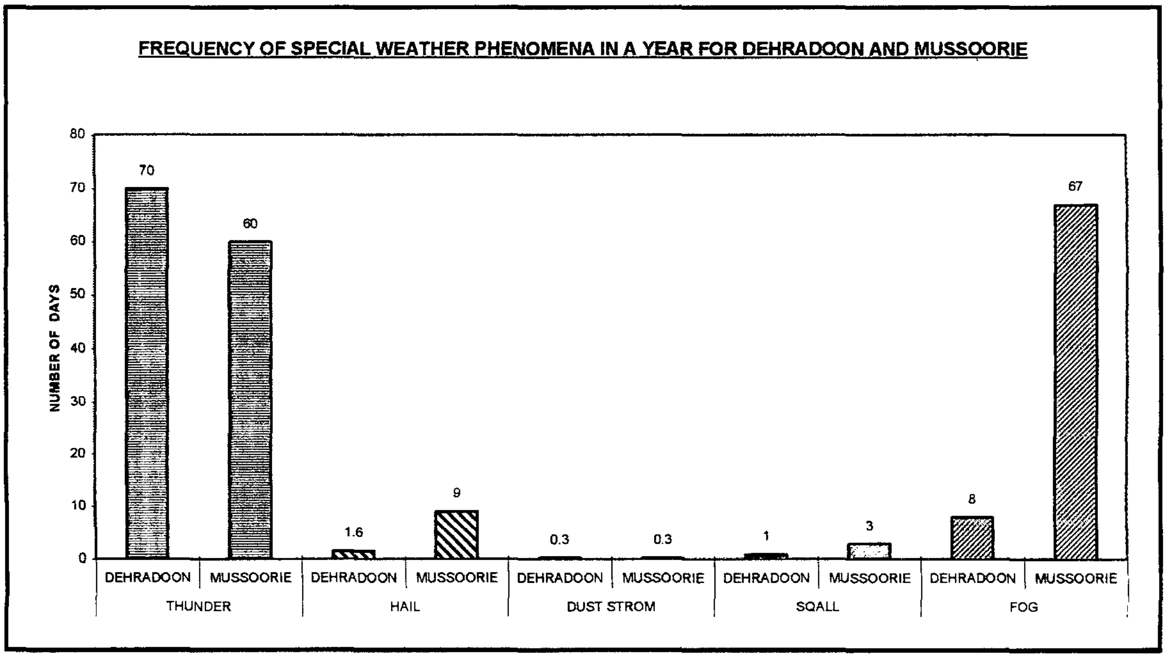


Fig. 2.10

Table 2.2 can be summarizes the following headings –

2.5.5.1 Thunderstorms:

The maximum numbers of days with thunder stroms are confined to the months of June, July, August and September at Dehra-Doon and Mussoorie both. But number of days with thunder at Dehra Doon is more compared to Mussoorie. This may be probably due to its lower location or valley floor location. Minimum days with thunderstorm occur in the month of November due to subsiding wind that causes calm weather (Fig. 2.11).

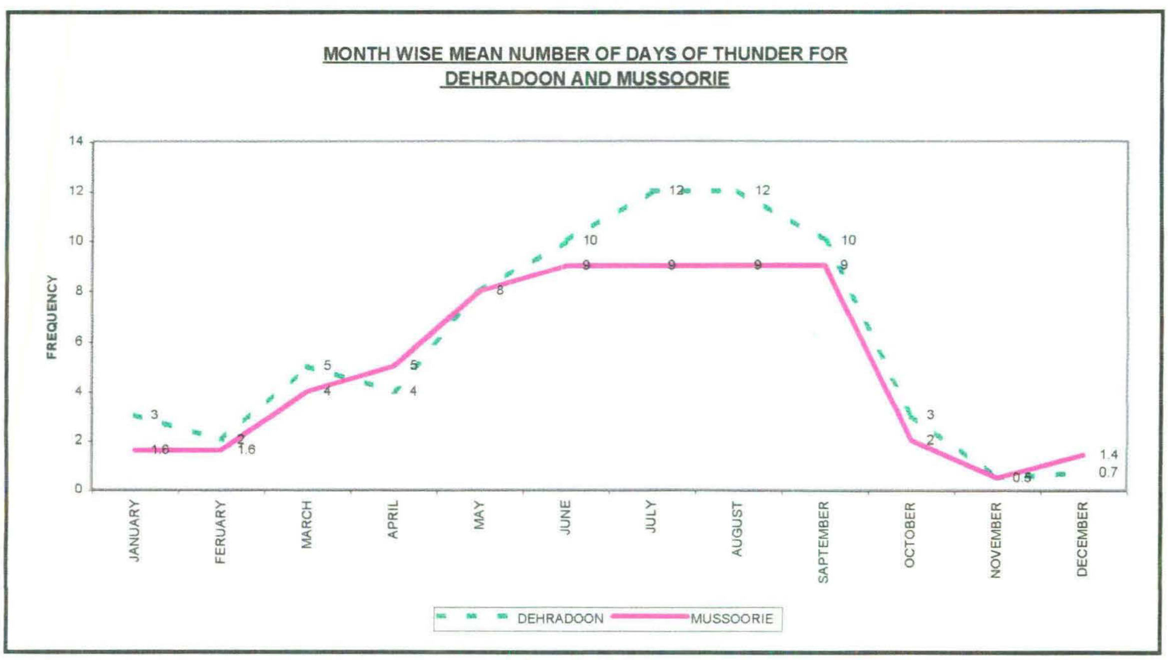


Fig. 2.11

2.5.5.2 Hail:

Mussoorie has annually more then five times the number of days with hails then Dehra-Doon. At Mussoorie, maximum number of days with hail are confined to the months of January, February, March and April. This may be due to cold weather season and high altitude. (Fig. 2.12) While at Dehra Doon, maximum number of days with hail is during the month of June. This may be due to uprising convectional current resulting out of intense heating.

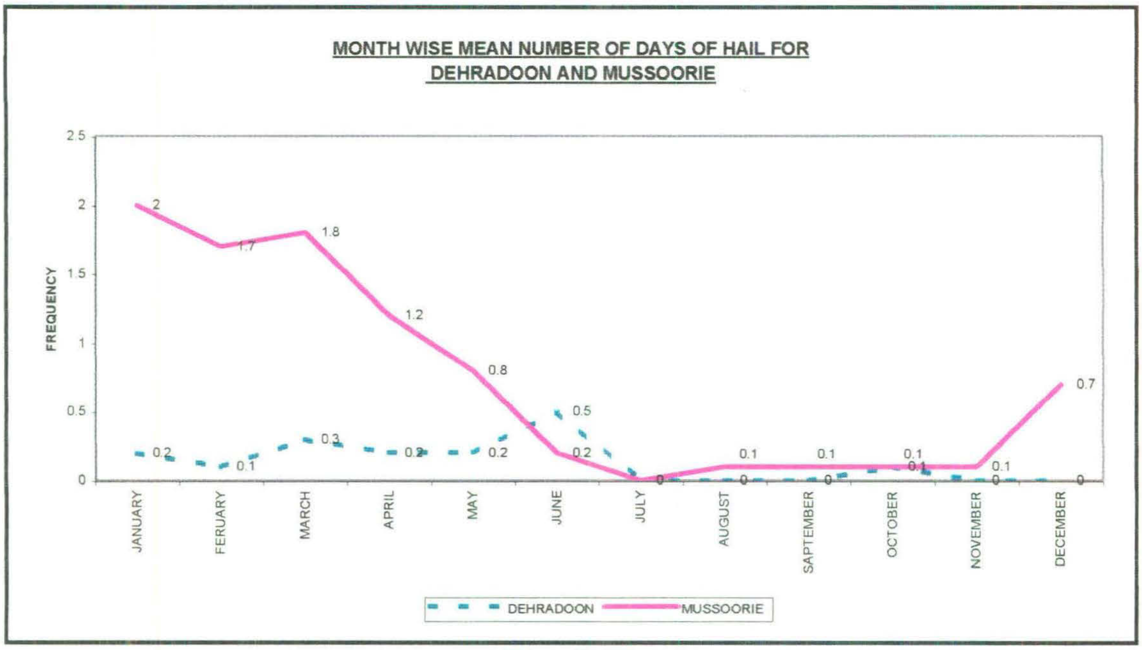


Fig. 2.12

2.5.5.3 Dust- storm:

Dust storms are very less in numbers both at Mussoorie and Dehra-Doon, occurring in the months of May and June. This is due to dry summer season.

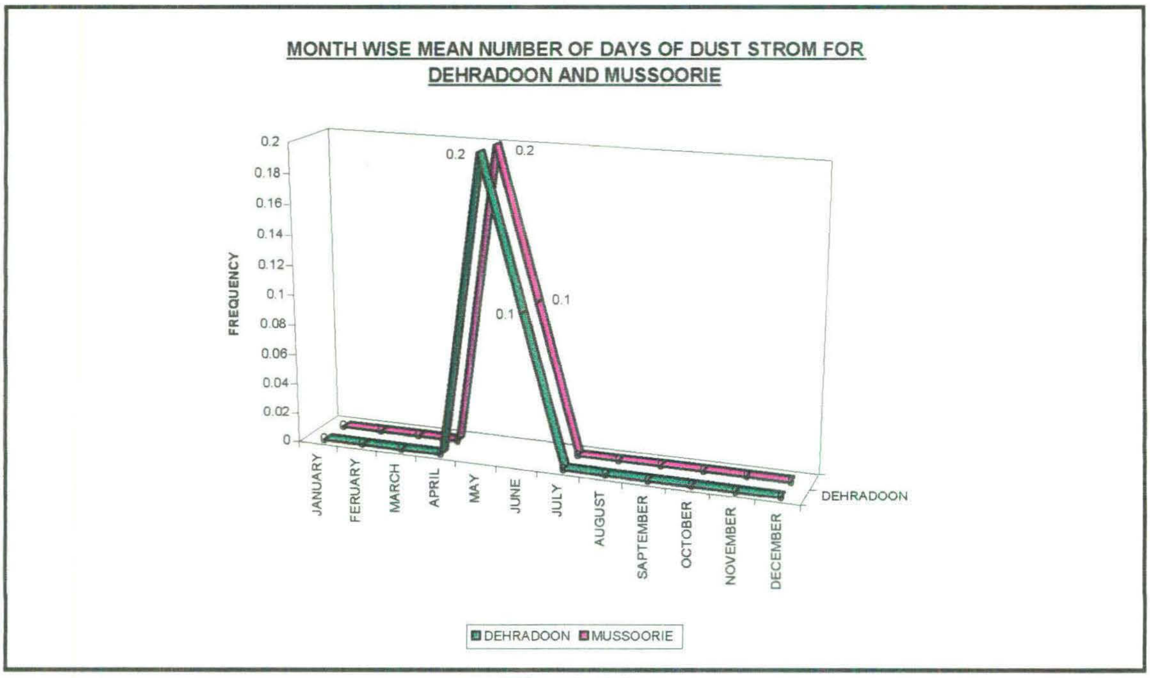


Fig. 2.13

2.5.5.4 Squalls:

Dehra-Doon experiences maximum numbers of squalls in the months of March and April,While Mussoorie has maximum number of days with squalls in the month of March, April and May. These all months are pre-monsoon months. Mussoorie also experience squalls in the month of September (Fig. 2.14). These are post-monsoon squalls. Annually, Mussoorie has more number of days with squalls than Dehra-Doon.

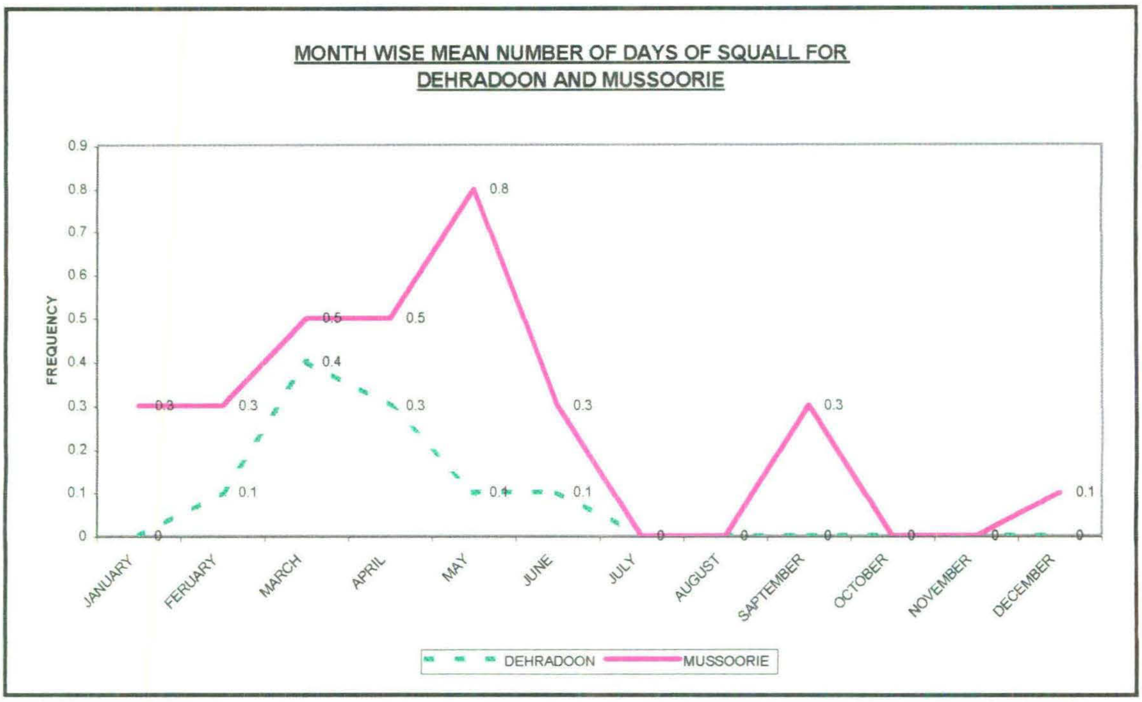


Fig. 2.14

2.5.5.5 Fog:

Dehra-Doon has maximum no of days with fog in the month of July and August. While Mussoorie has maximum number of days is in the months of July, August and September. This may be due to the presence of clouds in the rainy season. Annually maximum number of days with fog at Mussoorie are much more higher than Dehra-Doon. This may be due to its higher altitude and windward location than Dehra Doon. Mussoorie has fog every month; while most of the months at Dehra Doon are fog free (Fig. 2.15)

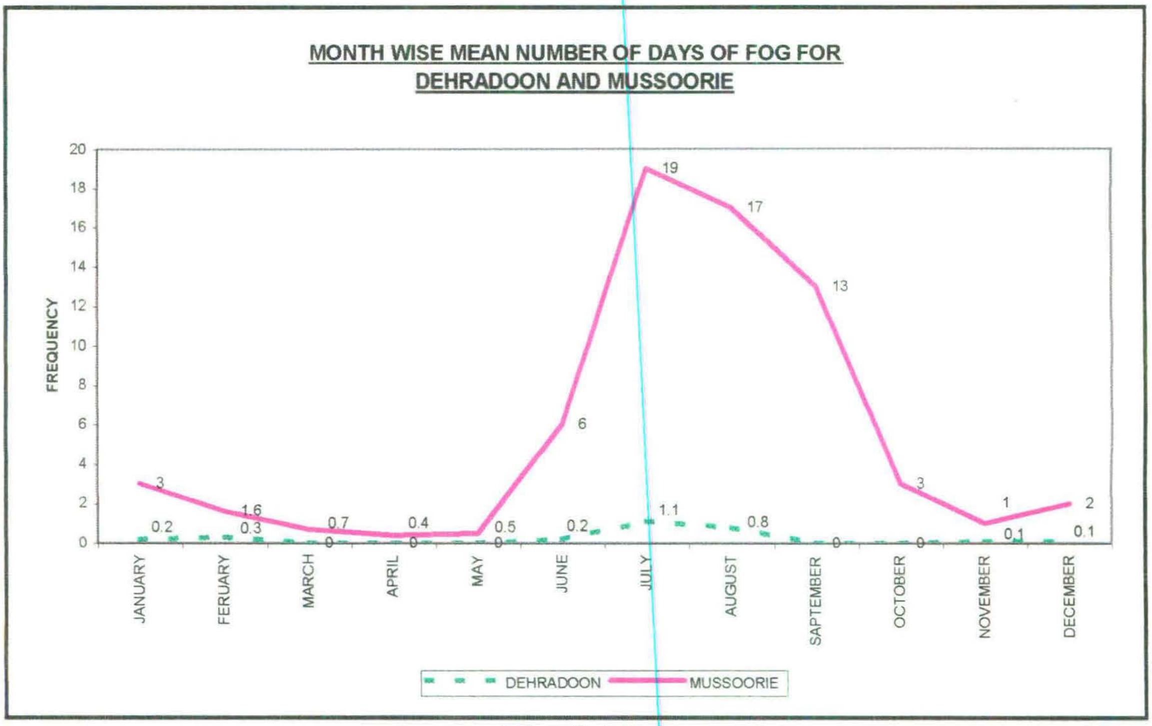


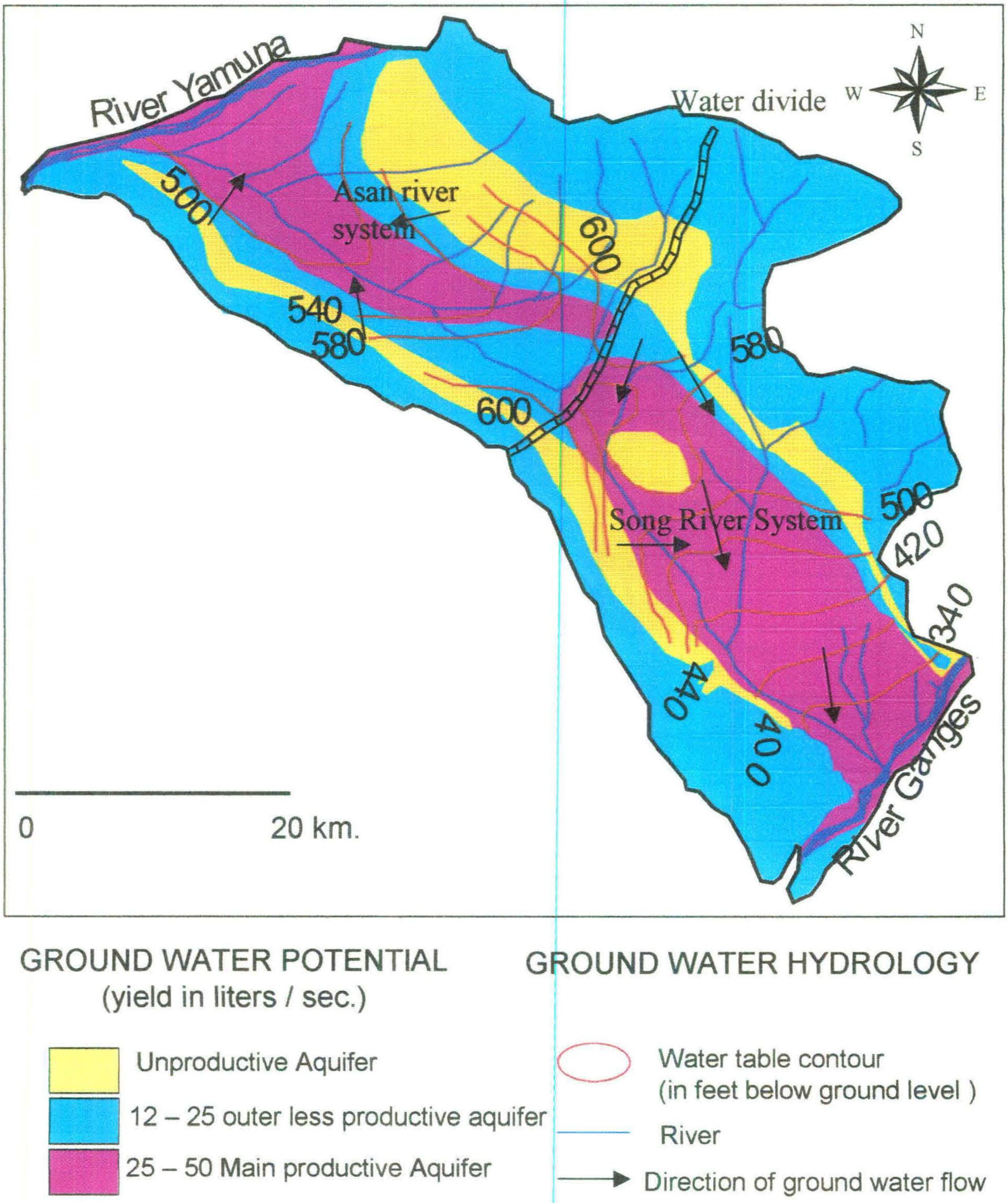
Fig. 2.15

2.6 GEOHYDROLOGY:

Geohydrologcal studies of intermontane Doon valley have revealed three Geohydrologcal zones namely: - lesser Himalayan zone –characterized by springs and seepages; synclinal central zone–forming the main aquifer of the Doon valley and characterized by the occurrence of tube wells and dug wells, and Shiwalik zone – characterized by springs (Bartarya, 1995).

In terms of ground water potential, comparing the above statement with the geohydrologcal map prepared from by NATMO data (Fig. 2.16) one finds that the lesser Himalayan zone falls in the category of outer less productive aquifer (yield 15 – 25 liters/ sec) and unproductive aquifer. This is the steeply sloping north- easterly flank of the valley.

GEOHYDROLOGY
DEHRA DOON



Modified after, Survey of India maps and Central Ground Water Board, Lucknow
Source: NATMO1991

Fig. 2.16

comprising of rocks of the lesser Himalayan formation such as quartzite, schist, phyllite, hard sand stone, lime stone and dolomite of Chandpur, Nagthat, Blaini, Krol and Tal formation having secondary porosity and permeability characterized by springs and seepages the zones of lineament, fault and main boundary thrust shows pockets of high secondary porosity. The ground water/sub surface water in this zone occurs largely as disconnected local bodies in favorably perched aquifers under both confined and unconfined conditions and also in the zones of jointing, fracturing and faulting. Cavities and solution channels oriented along WNW–ESE and NW–SE trending joints characterize the limestone and dolomite of the krol formation. Selective solutions along these fractures and joints have created network of underground water courses leading to almost complete lack of 1st and 2nd order perennial streams over surface. The sand-gravel deposits of fluvial and colluvial origin in the lesser Himalayan zone lying in the lower reaches of the streams or near the confluence of the two streams in the form of fans and terraces are highly porous and permeable and therefore, hold sufficient quantity of water.

The Siwalik zone also corresponds with the outer less productive aquifer (yield 12 – 25 liter/sec) and unproductive aquifer zone in the Geohydrologcal map prepared from NATMO. Though, the conglomerate unit of the upper Siwalik is highly porous ands permeable but because of steep slopes, due to fan forming piedmont zone along the southern fringe of the valley and moderate to steep dips of the beds, the water quickly goes as runoff.

The main productive aquifer (yield 25–50 liters/sec) in the geohydrologcal map by NATMO corresponds with the synclinal central zone. The groundwater is present in the multitired aquifers under unconfined and confined conditions. The zone is classified under piedmont zone occupied by Doon gravels, having primary porosity and permeability. The course sand and gravels underlain by clay beds are the main water bearing strata. It is characterized by high infiltration rate. A number of dug wells and tube wells are confined in this zone.

The main productive aquifer is found in the synclinal zone along river Asan and Song, and also along river Ganges and river Yamuna. The water table contour that is the depth of water table below ground surface shows variations from 340 feet to 600 feet. Water table contour map shows that it is shallowest towards river Ganges in Song catchment area and it is deepest close to the water divide of Asan and Song River, north of Dehra Doon. In general water table occur at shallow depth towards the distal parts of the fans, which is towards the Asan and Song River and at higher level towards the proximal parts of the fan.

Although the groundwater flow pattern is locally modified by fractures, faults, colluvial and fluvial deposits. But in general the ground water flow in the lesser Himalayan region is roughly south, south– east and south– west direction, where in Siwalik region groundwater roughly flows in north and north- eastern direction. Moreover the ground water contour suggests that eastern and western parts of the valley flows towards the river Ganges and river Yamuna respectively, through the river terraces and fans in the form of sub- surface runoff in the lower reaches of Song and Asan rivers.

2.7 NATURAL VEGETATION:

The natural vegetation in the region includes the vast range varying from tropical to alpine species owing to the variation in altitude and aspects. The Doon valley is best known for its excellent Sal *(Shorea robusta)*. Forest in the northeastern slopes of Siwalik shows high density (Fig. 2.17). The other dominant species that are found here are, Chir Pine *(Pinus roxiburghii)* and Oak *(Quercus incana)*. The dominant species of shrubs are Dhaula *(Woodfordia latifolia)* and Siaru *(Debregeasia hypoleuca)* and dominant herb species are Kala Bansa *(Colebrookia oppositifolia)* and *Lantana camara*.

2.8 GENERAL LANDUSE/ LANDCOVER:

The general land use in the Doon valley is correlated with the types of landforms and is summarized in the table below:

LANDFORMS	**LANDUSE**
High mountains	Barren with scattered bushes and forest
Medium high	Barren with grass and bushes, occasional forest
Upper reaches of piedmont	Forest comprising grass and shrubs and cultivation
Lower reaches of piedmont	Usually cultivated
Northern Siwalik	Forest
Southern Siwalik	Forest with occasional cultivation
Terraces	Usually cultivated
Uplifted terraces	Forest with occasional cultivation

Table 2.3

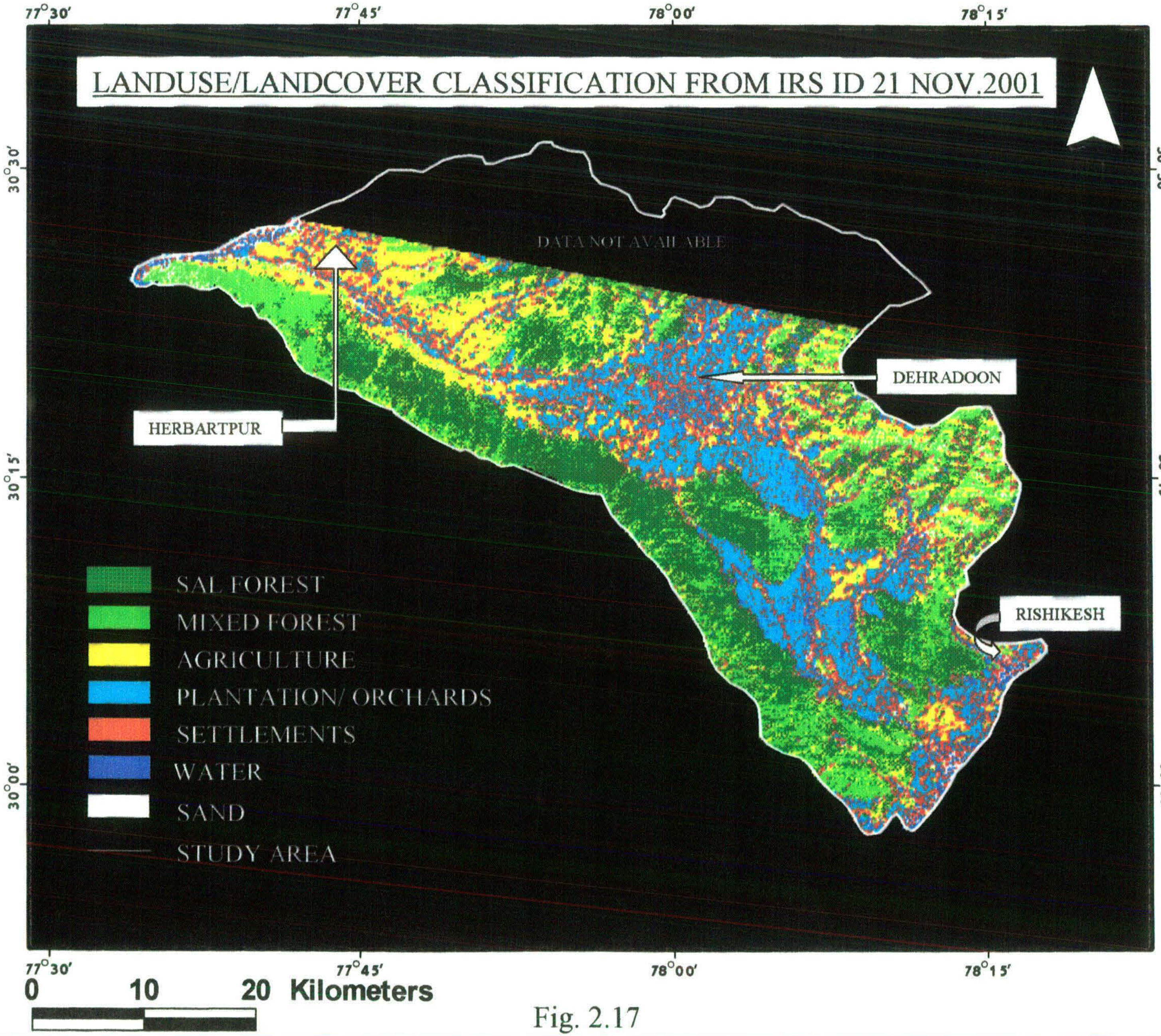
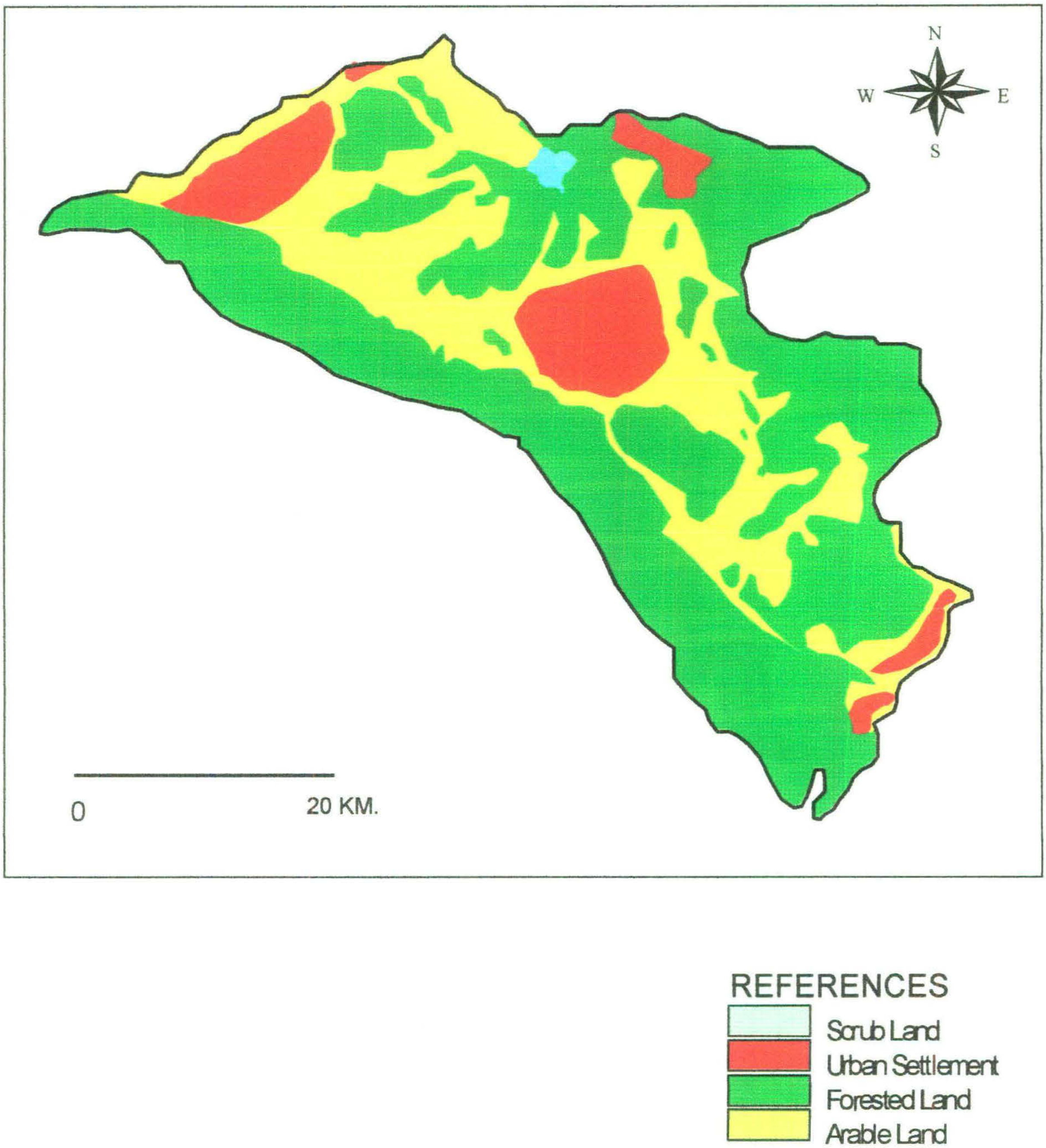

LANDUSE/LANDCOVER CLASSIFICATION FROM IRS ID 21 NOV.2001
77°30'
77°45'
78°00'
78°15'
30°30'
30°15'
30°00'
DATA NOT AVAILABLE
DEHRADOON
HERBARTPUR
RISHIKESH
SAL FOREST
MIXED FOREST
AGRICULTURE
PLANTATION/ ORCHARDS
SETTLEMENTS
WATER
SAND
STUDY AREA
0 10 20 Kilometers

Fig. 2.17

GENERAL LANDUSE
DEHRA DOON



Modified after, Survey of India maps and District Industrial Centre, Dehradoon
Source: NATMO, 1991

Fig. 2.18

The general land use map prepared by NATMO (Fig. 2.18) Shows that most of the area of the valley is covered by forest, next to it comes arable land and most of the urban settlements are confined in the east, west, central and northern part. Scrub is shown only in a small patch. For better understanding, a landuse/ landcover map is prepared with the help of satellite imagery with the help of toposheet by supervised classification by IRDAS IMAGINE 8.4 software (fig. 1.17). It has been classified into six classes. These classes are Sal forest Mixed forest, Agriculture, Plantation/ orchards, Settlements, Water, Sand.

Sal is the most dominant species found in this region and covers the maximum area among the tree vegetation. The mixed forest species include Chir Pine, Oak, Dhaula, Sissaru, Kala Bansa etc. Agriculture is mainly confined in the main valley in the west and east. Terraces are also cultivated as some patches are traceable in the mountainous region. Orchards are mainly confined around settlements and easy modes of transport lines that is why it covers more area in the eastern half of the valley. Plantation orchards mainly include tea gardens, Litchy garden, and other tree plantations. Settlements are in clusters and scattered throughout the valley, main clusters are shown in western, central and eastern part of the valley. Water and sand is shown along the river channels and in few scattered patches here and there.

Chapter Three

Morphometric Analysis and Structural Setting of Doon Valley

3.1 MORPHOMETERIC ANALYSIS:

Morphomteric analysis are applied in character as well as integrated in approach. It provides a clear picture of the physiograhy of a region. To divide a region into certain homogenous regions we need to necessarily deal it. Spatial variations in socioeconomic condition of a region are directly influenced by physiograhy and physiographic environment of particular region. So we have to take into account certain parameters which influence physiograhy. Terrain characteristics of particular region are important in evaluating their influence over one another, which are interdependent. With the help of morphometric parameters we will be able to draw the lines of simulation or uniqueness occurring throughout the region.

Morphomteric analysis generally deals with a drainage basin but this study area is not a single basin but combination of several basins. The main two river basins are of river Asan and river Suswa basin, which are lower order basins of river Yamuna and river Suswa, respectively. Moreover natural features such as water divide and rivers form its boundaries. All the drainage discharge from this region either flows into river the Yamuna or river Ganges. Therefore this area can be considered as a complete geomorphic unit for the purpose of this study.

The basin morphometry constitutes three types of properties, such as areal, linear and relief properties. For the purpose of this study few of them have been dealt with. Linear properties are stream ordering, bifurcation ratio, stream numbers, stream length etc; and areal properties are stream frequency, drainage texture, and drainage density. Relief properties are average relief, relative relief, dissection index and ruggedness index.

A quantitative approach is adopted here to show the morphometric characteristics of the region. The database for this purpose has been generated with the help of various sources such as satellite imagery, toposheet and contour and drainage maps drawn by other researchers. Only prominent streams and contours of 50 ft. intervals are taken into account (Fig. 3.1). GIS techniques are used for making maps and calculations.

The linear properties are examined for whole of the study area whereas areal and relief properties are examined in the main Doon valley or Doon valley proper because of the following reasons:

- Topic mainly focuses on the evolution of Doon valley.
- Drainage network starts beyond the Doon valley so that it should be examined from the point of its beginning.
- Areal and relief properties do not concern much about origin, it only concerns with the presence of streams and relief in an area.

3.1.1 Drainage characteristics:

Study of drainage pattern and their network is very important for the study of landform and environment. Drainage pattern refers to the particular plan or design which individual streams collectively form. By channel pattern it is meant that the configuration of stream as viewed from air. The drainage pattern of the Doon valley shows interesting characteristics; the southern part shows parallel pattern whereas the northern and central

CONTOUR MAP

DOON VALLEY (DEHRA DOON)

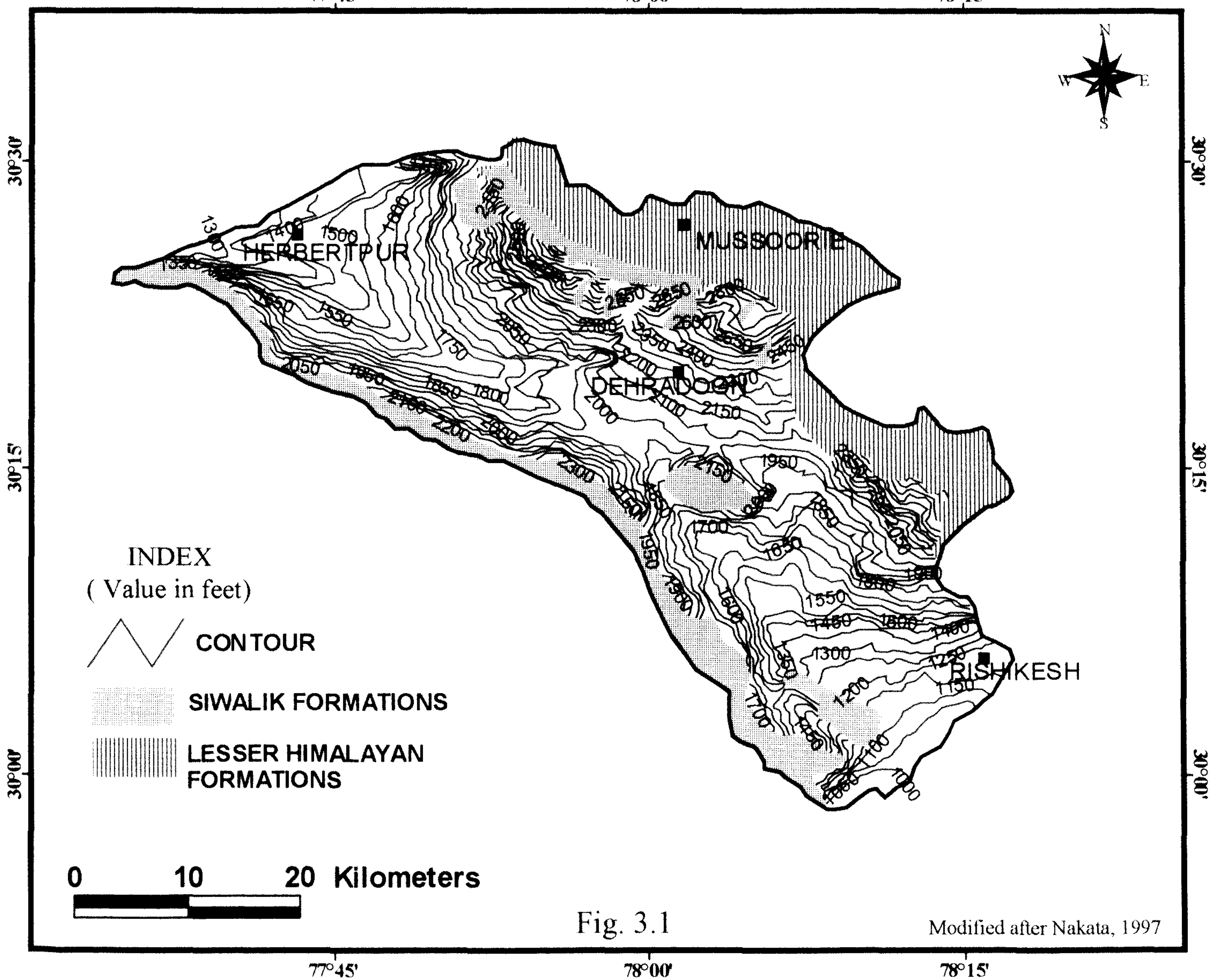


Fig. 3.1

part shows dendritic pattern. Parallel pattern are usually found where there are pronounced slope or structural controls which leads to regular spacing of parallel or near parallel streams (Fig. 3.2) The southern part of Doon valley along the Siwalik Hills is a dip-controlled slope due to propagation of Mohand thrust. Dendritic pattern is the most common pattern. Irregular branching of tributary streams are in any direction and in almost any angle, although usually at considerably less than right angle characterizes it. These develop the over rocks of uniform resistance and imply a notable lack of structural control. Dendritic patterns are most likely to be found upon nearly horizontal sedimentary rocks or in the areas of massive igneous rocks, but could be seen on the folded or complexly metamorphosed rocks, particularly when imposed upon them by superimposition (Thornbury, 1969). Northern and central part of the study area has the folded sedimentary rocks and covers almost entire Doon gravel that confirms the above statement.

3.1.2 Linear properties:

3.1.2.1 Stream ordering:

It was first introduced in USA by Horton in 1945 and later modified by Strahler (1952, 1964). The scheme of Strahler is being used for present analysis. According to him, the first order streams are those that have no tributaries. When first two order streams meet, the second order streams are formed, and two second order streams form the third order and so on (Fig. 3.2). The trunk stream through which all the water and discharge passes is the segment of the highest order.

STREAM ORDERING

DEHRA DOON

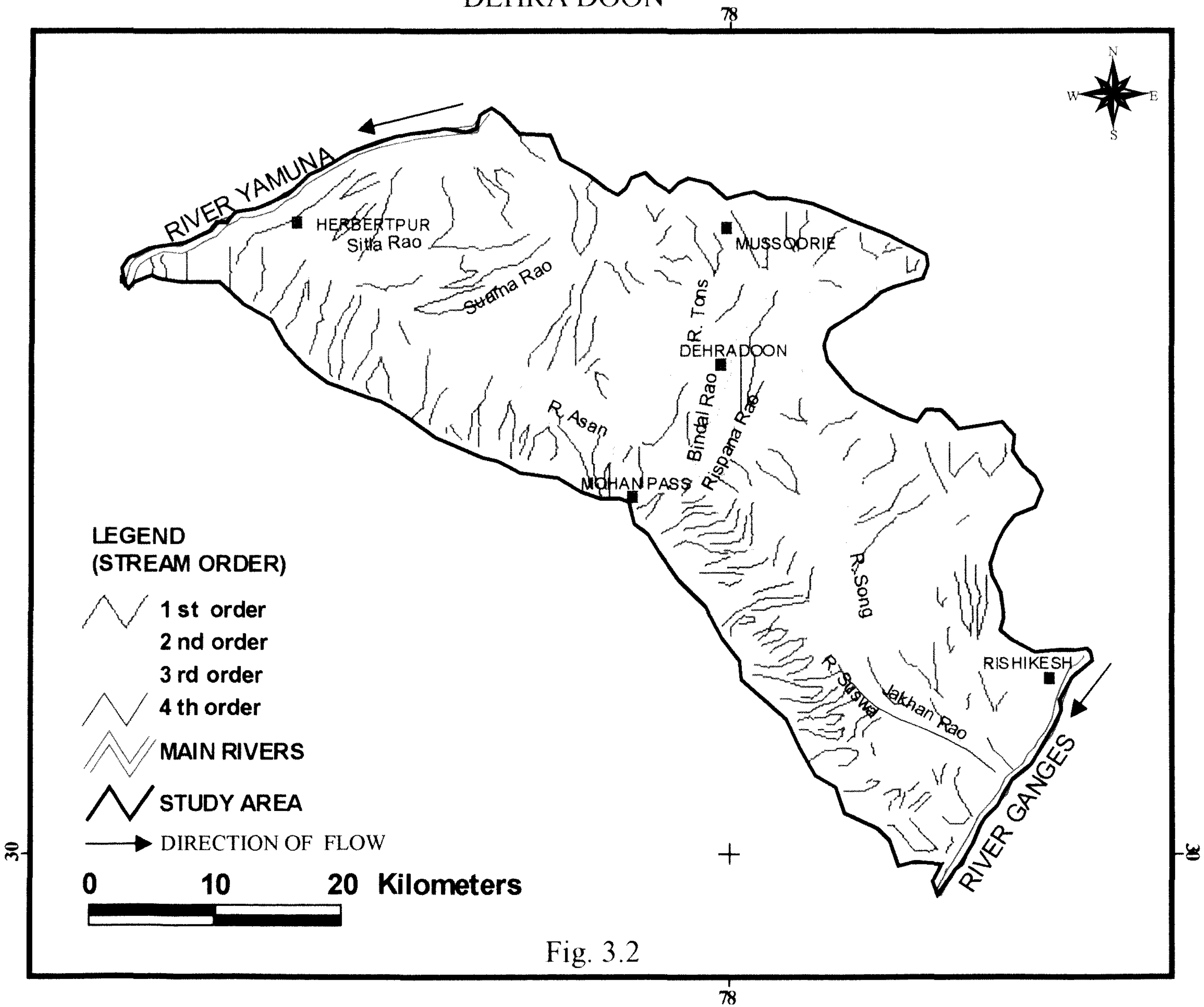


Fig. 3.2

STREAM ORDER		
STREAM ORDER	NO. OF STREAMS	LENGTH OF STREAMS IN KM.
1st	183	704.39
2nd	49	247.11
3rd	7	147.18
4th	2	19.33

Table 3.1

Horton noted that the number of streams of different orders in a watershed decreases with increasing order in a regular way. When the logarithm of the number of stream of given order are plotted against the order, the points lie on straight line. This is called as the law of stream numbers of Figure 3.3 tentatively confirms this law.

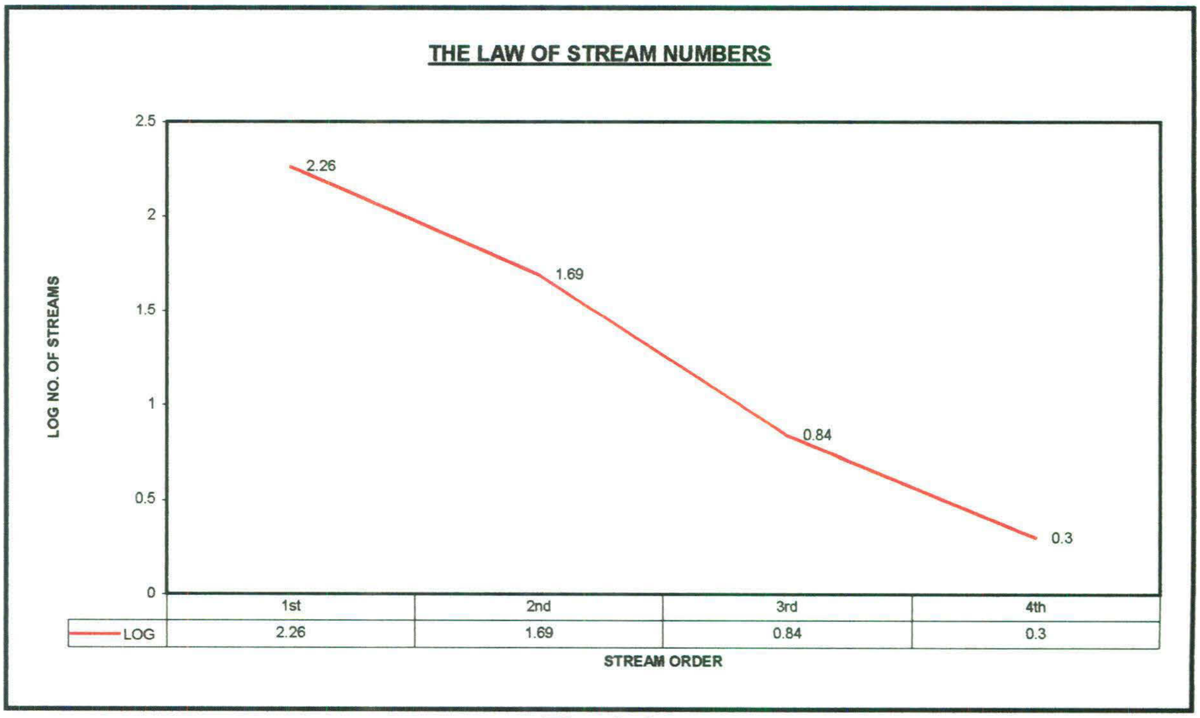


Fig. 3.3

3.1.2.2 Bifurcation ratio:

The bifurcation ratio is the ratio between the numbers of stream segments of any given order to the number of segments of the next higher order (Strahler, 1960). It shows the degree of integration prevailing between the streams of various orders in a drainage basin. The bifurcation ratio is calculated by using the following formula:

Bifurcation ratio = N / N +1

Where N is number of segment of given order

And N + 1 is the number of segment of next higher order.

The value of bifurcation ratio ranges from 2 to 5. High value of ratio indicates a lower degree of drainage integration and vice versa. The ratio is generally influenced by variation in physiographic and climatic conditions prevailing in the basin. Basin with similar rock composition, tectonic history, uniform climatic conditions and in similar age of development are characterized by more or less similar values of bifurcation ratio.

BIFURCATION RATIO		
STREAM ORDER	NO. OF STREAMS	BIFURCATION RATIO
1^{st}	183	3.73
2^{nd}	49	7
3^{rd}	7	3.5
4^{th}	2	--

Table 3.2

Table 3.2 shows that very high value at 2^{nd} order. The reason should be understood in the light of above statement. The other reason for its value being very high is only because main streams are taken for the analysis.

Number of streams in different order and their total lengths are given in table 3.1.

3.1.3 Areal properties:

3.1.3.1 Stream frequency:

Stream frequency is defined as the total number of stream segments per unit area. The occurrence of stream segments depends upon the nature and structure of rock, nature and amount of rainfall, vegetation cover and infiltration capacity of soil. Stream frequency is obtained by the following formula:

Stream frequency (S.F.) $= \sum N / A$

Where $\sum N$ *is the total number of stream segments*

And A is the unit area, which is usually in km^2.

STREAM FREQUENCY			
S.N.	CLASSES	FREQUENCY CLASSES	% OF AREA OCCUPIED
1	Very high	0.42 - 0.5	8
2	High	0.34 – 0.42	18
3	Moderate	0.25 – 0.34	26
4	Low	0.17 – 0.25	21
5	Very low	0.9 – 0.17	26
TOTAL			100

Table 3.3

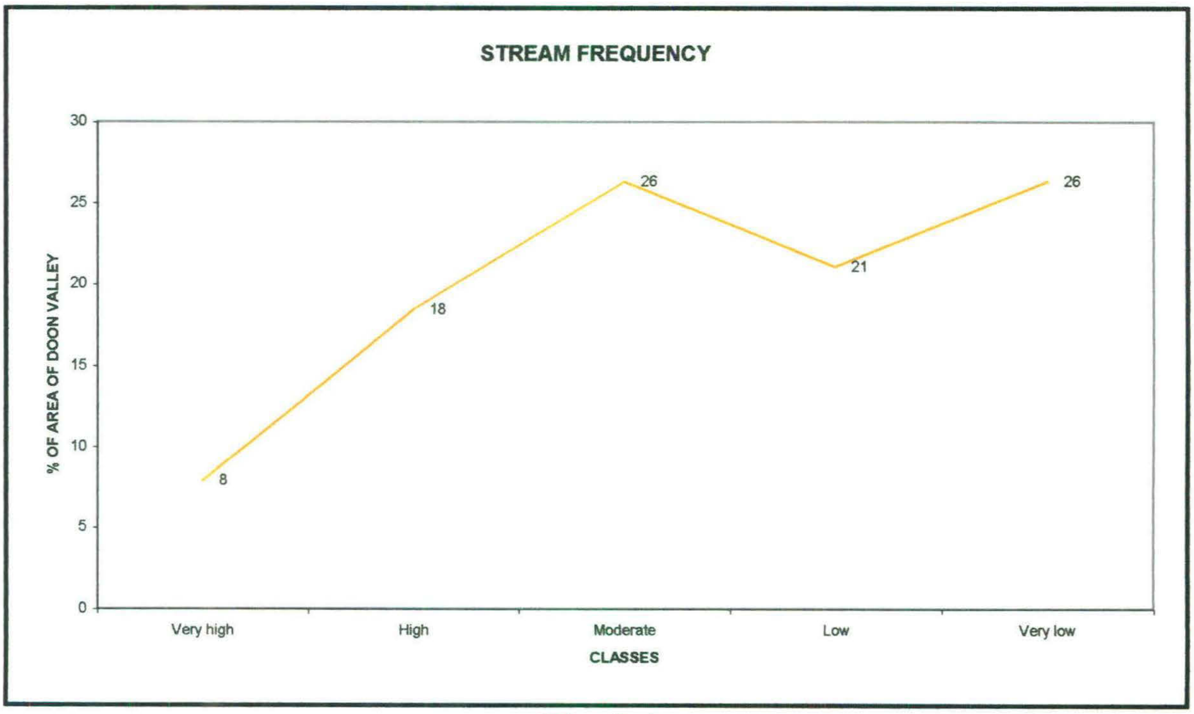


Fig. 3.4

STREAM FREQUENCY

DOON VALLEY (DEHRA DOON)

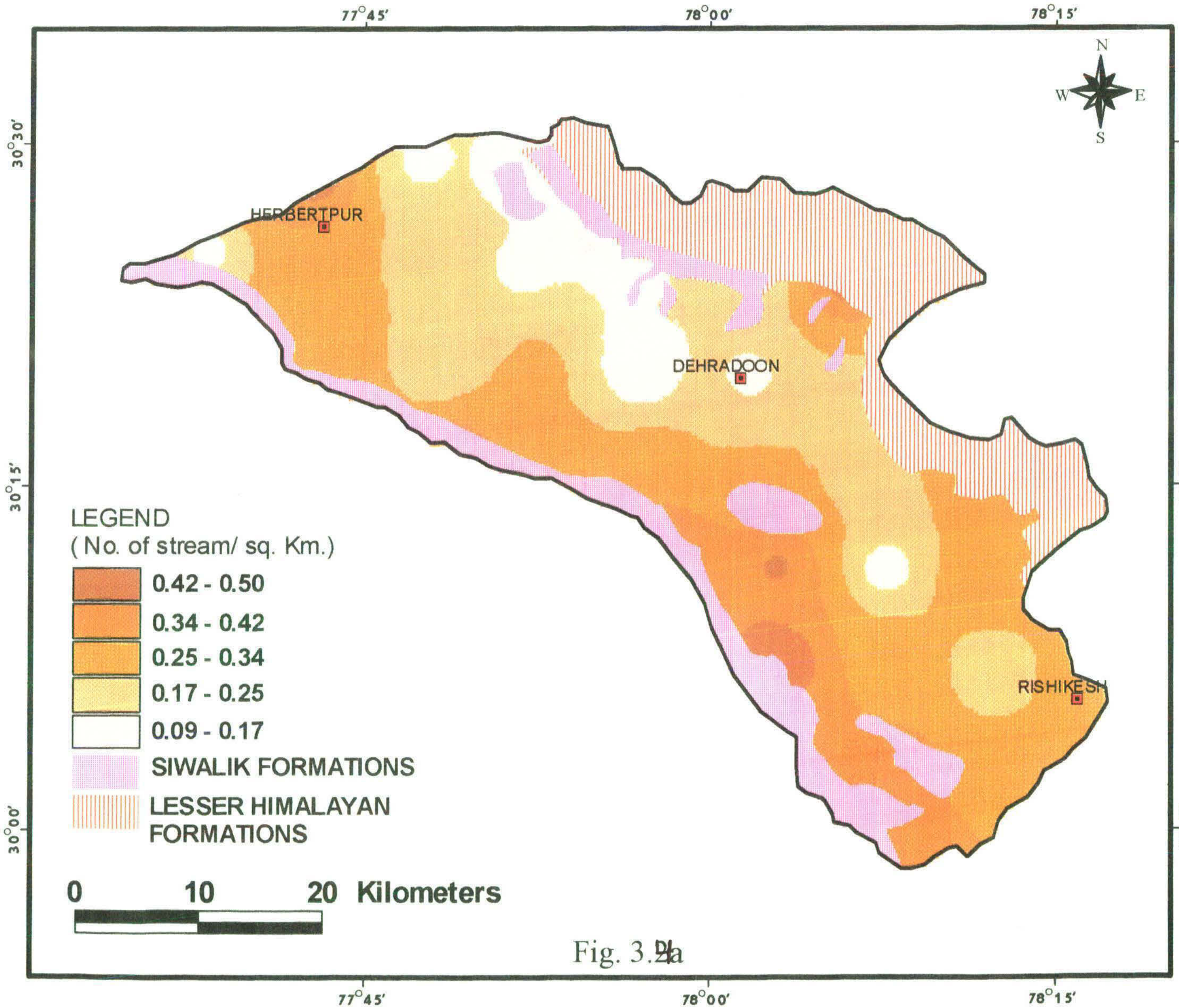


Fig. 3.4a

High to very high stream frequency is found in the eastern and southeastern, western and northern part in patches (fig.3.4a), which together constitute the area of about 26 percent. The moderate frequency is found along Siwalik Hills and towards river Ganges. The reason may be due to the numerous seasonal streams coming out of the Siwalik Hills and under-cutting done by the river Ganges.

3.1.3.2 Drainage density:

Drainage density is the length of stream channels per unit sq. area. It is generally influenced by several factors like geology, climate, permeability of soil etc. (Morisawa, 1968). High drainage density represents the fine texture and low the coarse texture. Drainage density is calculated by the following formula:

Drainage density (DD) $= \sum L / A$

Where $\sum L$ *is total length of stream segments, in km.*

And A is the unit area in sq. km.

DRAINAGE DENSITY			
S.N.	CLASSES	FREQUENCY CLASSES	% OF AREA OCCUPIED
1	Very high	1.13 – 1.33	11
2	High	0.93 - 1.13	21
3	Moderate	0.73 – 0.93	19
4	Low	0.53 – 0.73	22
5	Very low	0.33 – 0.53	8
TOTAL			100

Table 3.4

DRAINAGE DENSITY

DOON VALLEY (DEHRA DOON)

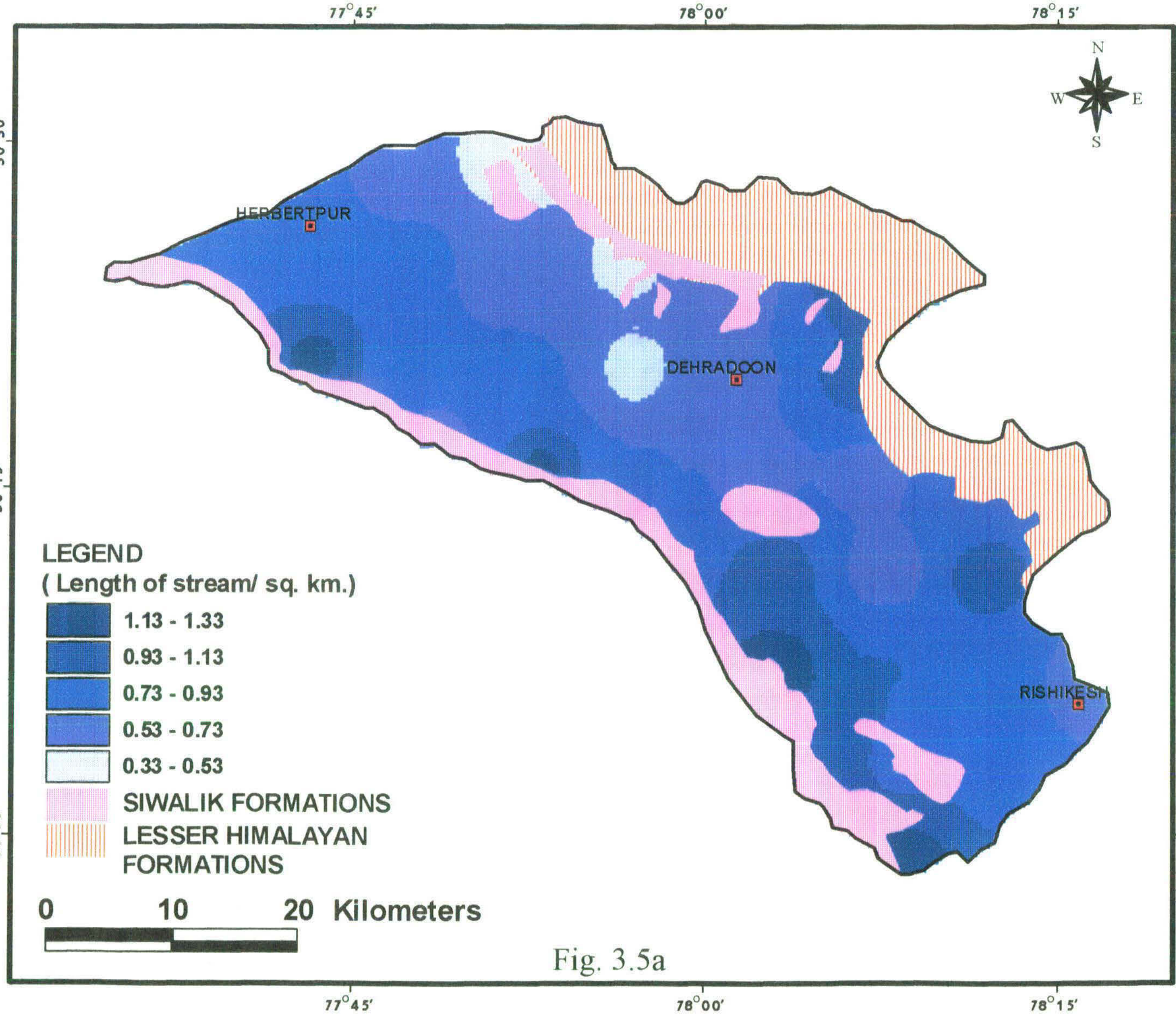


Fig. 3.5a

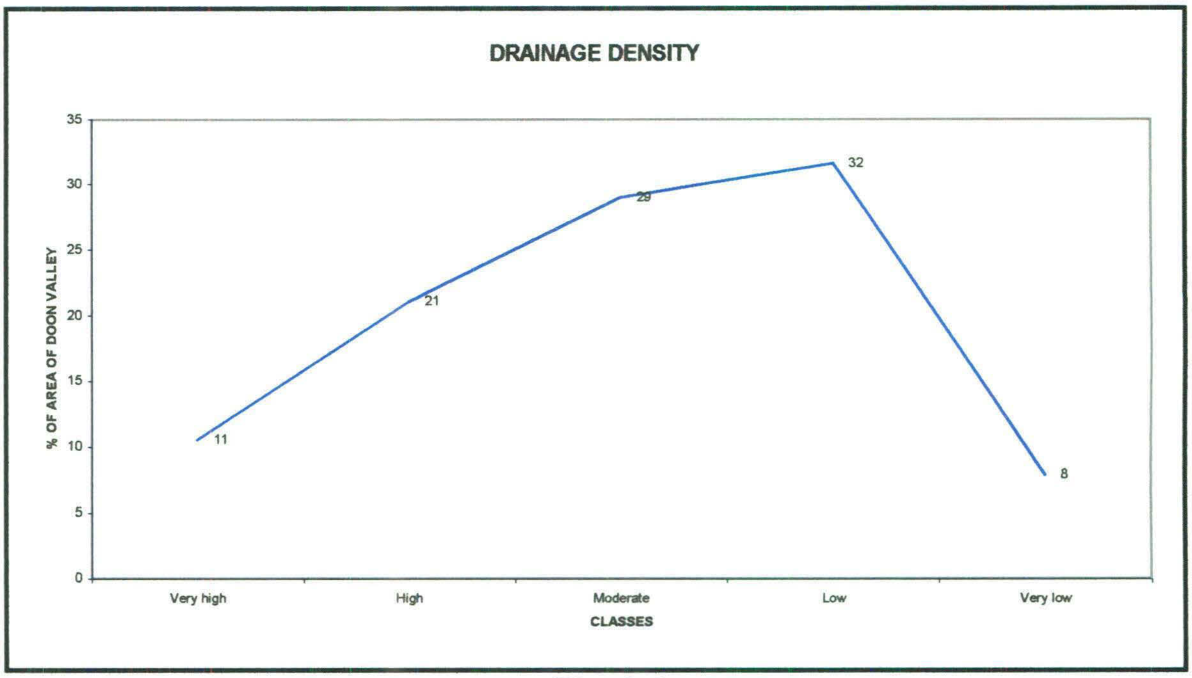


Fig. 3.5

Fig. 3.5a shows the high to very high drainage frequency found along Siwalik Hills and towards the river Ganges. Explanation for this could be the same as is for stream frequency. It is also found that the upper Siwalik shows fine drainage whereas the middle Siwalik shows a coarse texture.

3.1.3.3 Drainage texture:

It is an important geomorphic concept. The term drainage texture indicates relative spacing of streams in a unit area along a linear direction. It has advantage over stream frequency and drainage density, as it is combination of both. It is calculated by the following formula:

*Drainage texture (DT) = stream frequency (SF) * drainage density (DD)*

DRAINAGE TEXTURE

DOON VALLEY (DEHRA DOON)

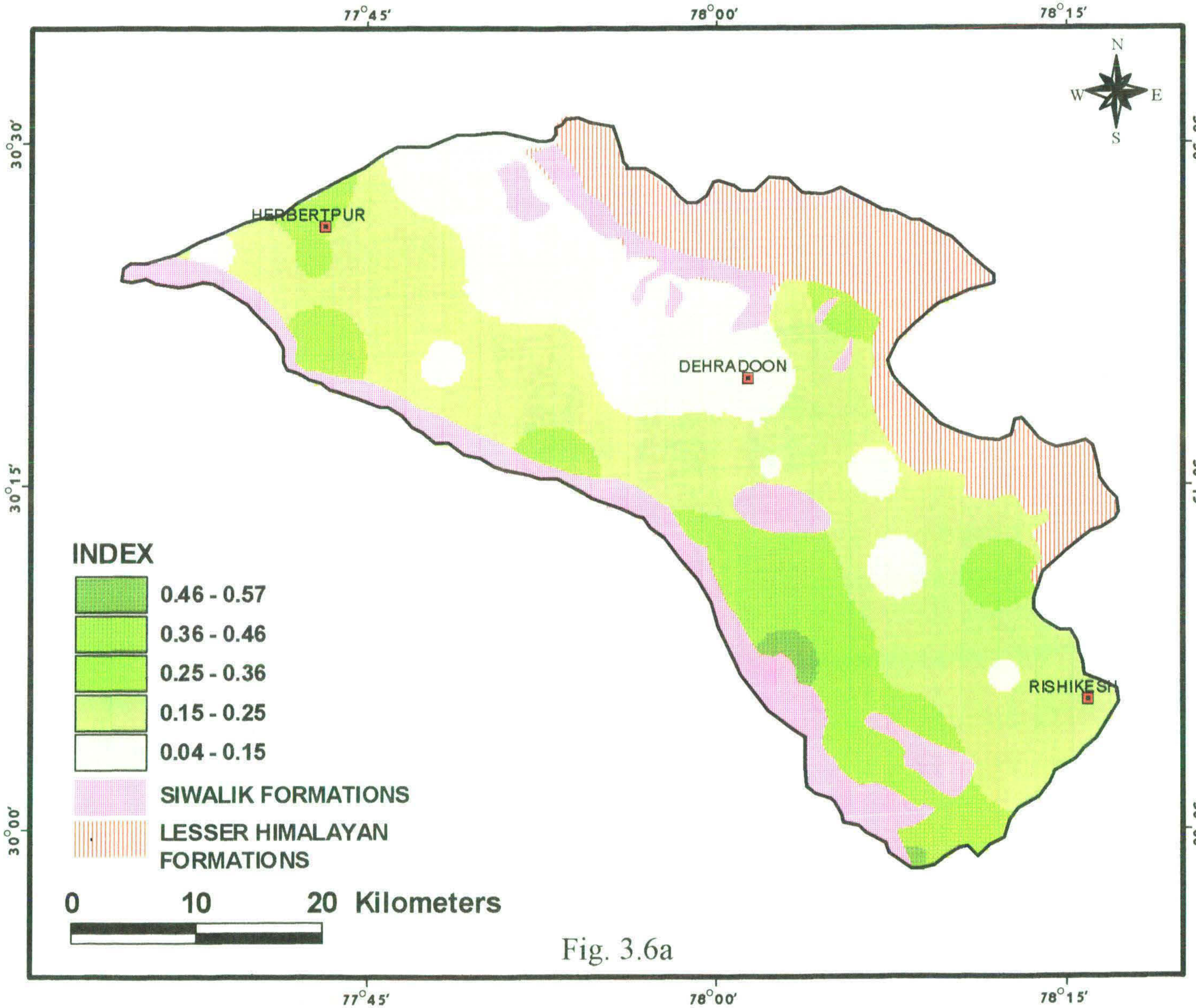


Fig. 3.6a

DRAINAGE TEXTURE			
S.N.	CLASSES	FREQUENCY CLASSES	% OF AREA OCCUPIED
1	Very high	0.46 – 0.97	8
2	High	0.36 – 0.46	13
3	Moderate	0.25 – 0.36	16
4	Low	0.15 – 0.25	24
5	Very low	0.04 – 0.15	39
TOTAL			100

Table 3.5

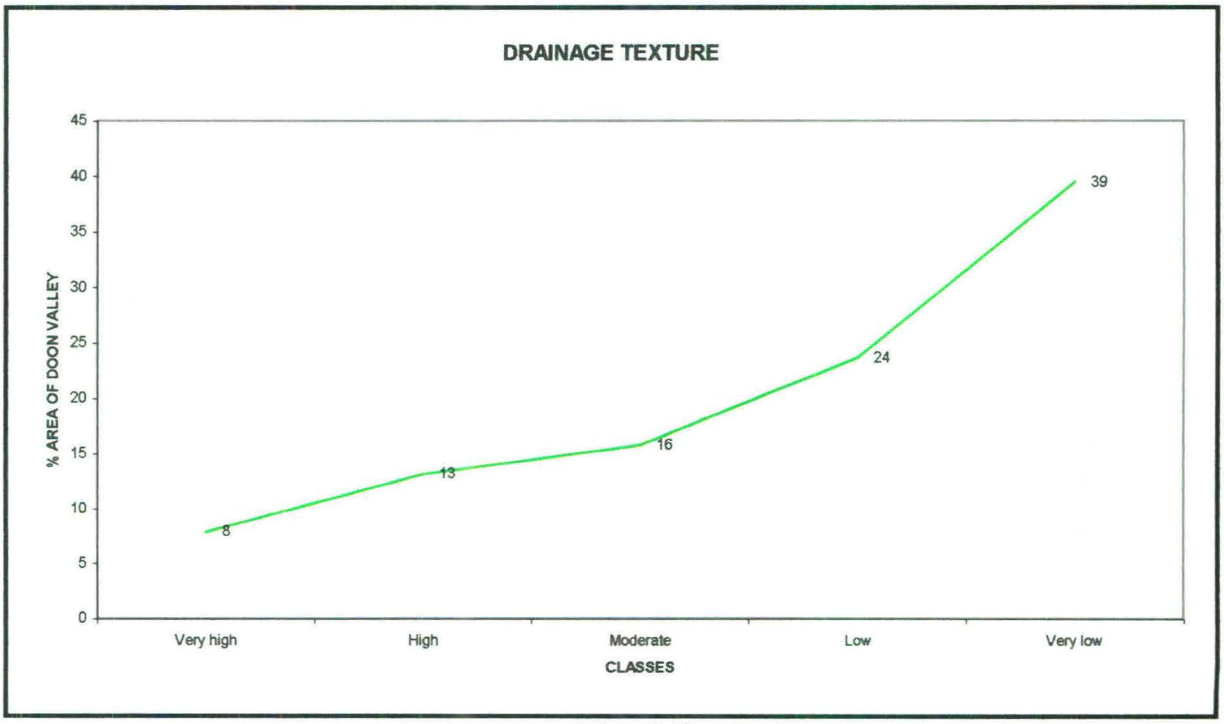


Fig. 3.6

High to very high drainage texture is found along the Siwalik Hills due to dip-controlled slope (Fig. 3.6a) and occurrence of the upper Siwalik rocks. The moderate to very low drainage texture covers maximum area, because of the presence of surface having high porosity (table 3.5).

3.1.4 Relief properties:

3.1.4.1 Absolute relief:

Absolute relief gives the elevation of any area above the sea level in an exact figure. It is useful in showing terrain morphology. It is plotted in Fig. 3.6a with the help of contours intervals of 15 meters.

ABSOLUTE RELIEF			
S.N.	CLASSES	FREQUENCY CLASSES	% OF AREA OCCUPIED
1	Very high	793 – 901	18
2	High	685 – 793	18
3	Moderate	576 – 685	29
4	Low	465 – 576	18
5	Very low	360 - 468	18
TOTAL			100

Table 3.6

ABSOLUTE RELIEF

DOON VALLEY (DEHRA DOON)

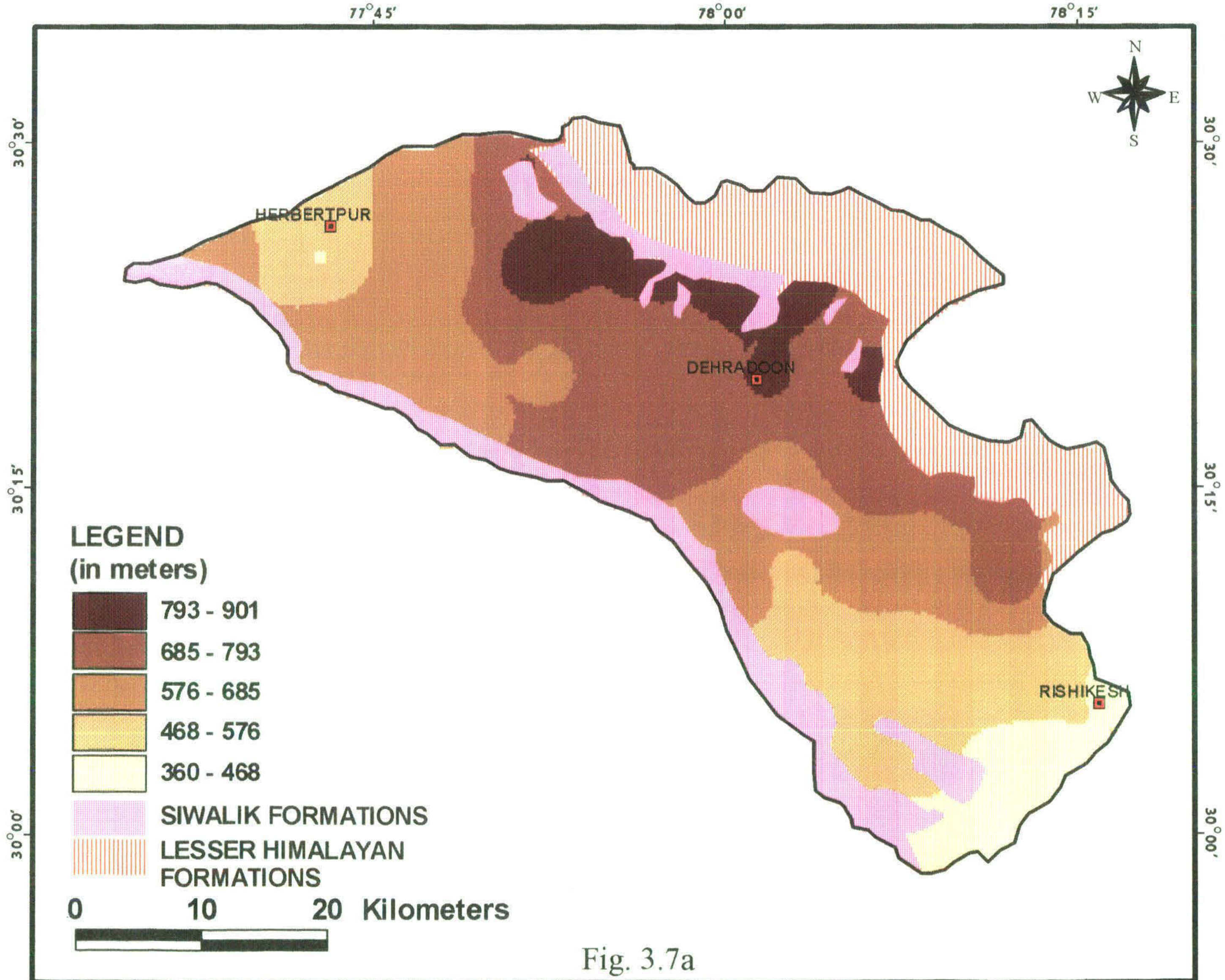


Fig. 3.7a

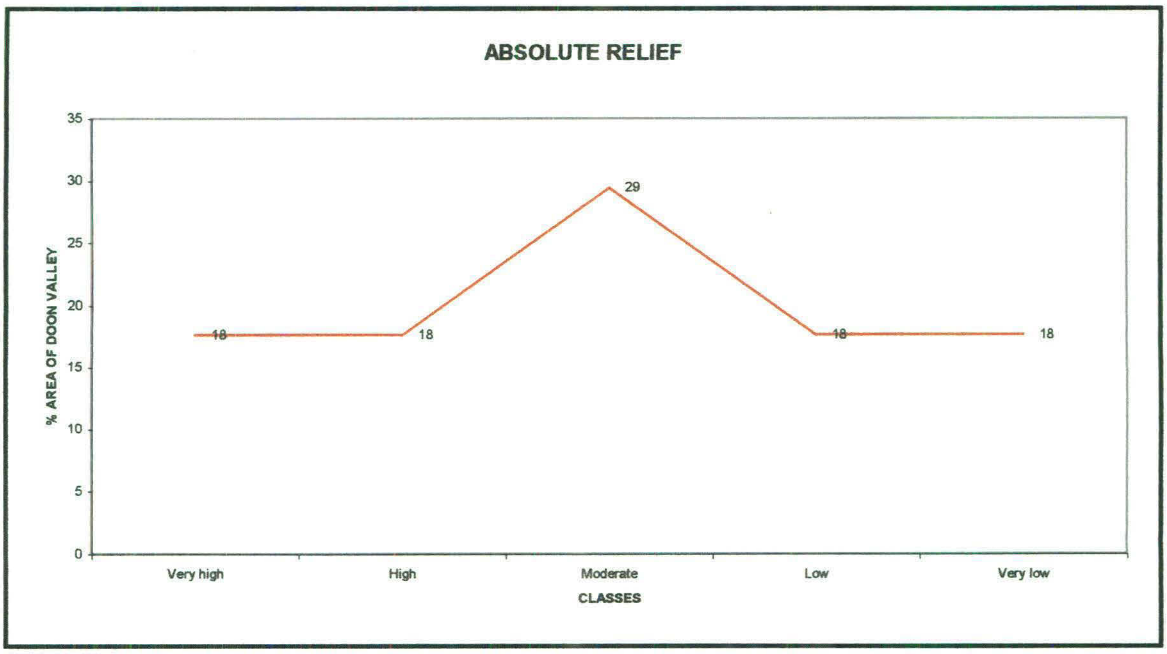


Fig. 3.7

Fig. 3.7a shows the absolute relief as high in the central and upper part of the valley. The upper or northern part is made up of high level fan deposits and the central part acts as a water divide. The entire class is equally well distributed among the five classes. The moderate frequency class occupies maximum area, which is between 576 to 685 meters.

3.1.4.2 Relative relief:

Relative relief is also termed as amplitude of local relief. It is defined as the difference in height between the highest and lowest point in a unit area. Relative relief is a very important morphometric variable, used for overall assessment of morphological characteristics of terrain and degree of dissection (Singh, 1998). More is the degree of dissection greater is the relative relief. Relative relief is calculated by the following formula:

Relative relief (RR) = highest contour value - lowest contour value

RELATIVE RELIEF

DOON VALLEY (DEHRA DOON)

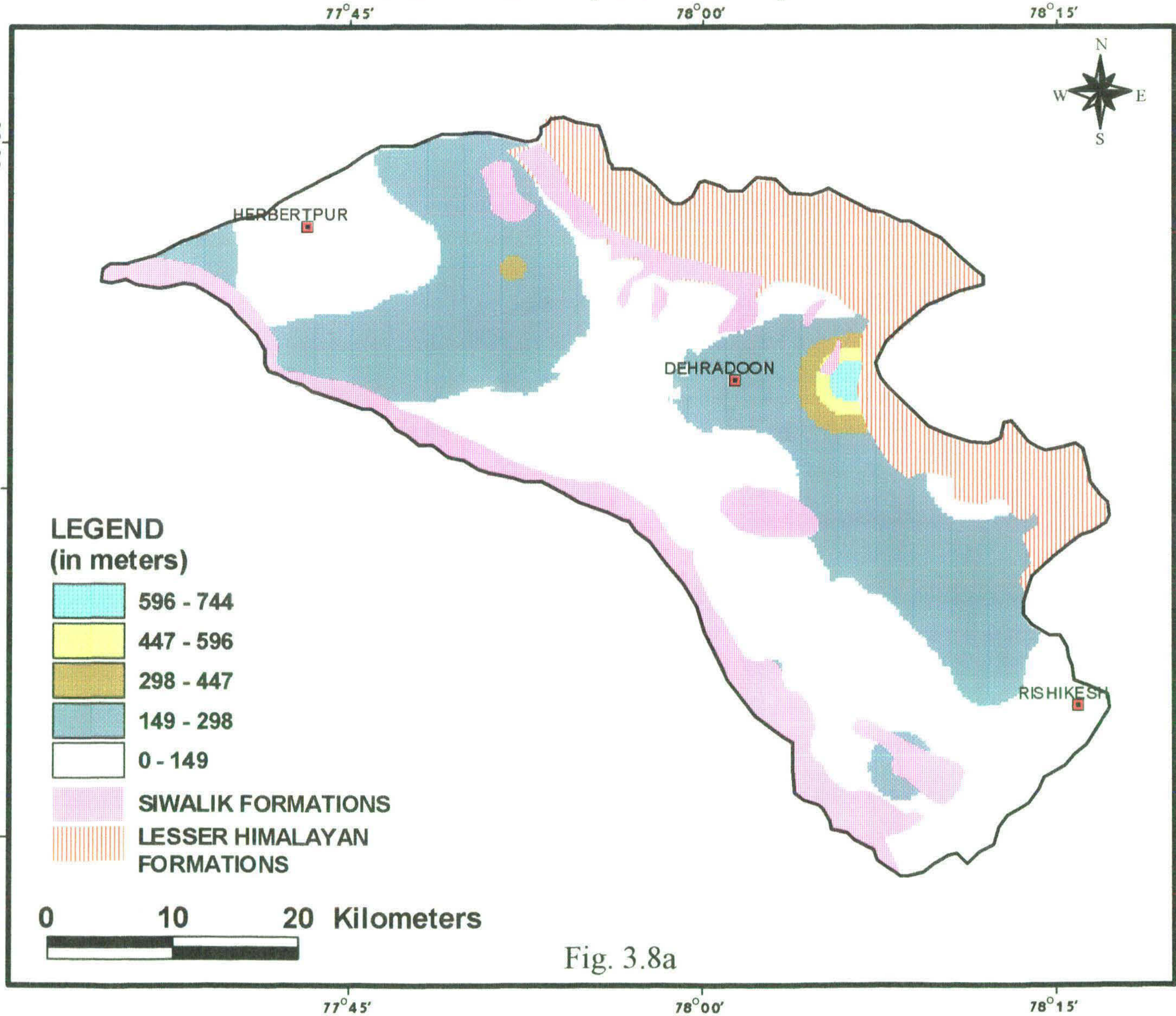


Fig. 3.8a

RELATIVE RELIEF			
S.N.	CLASSES	FREQUENCY CLASSES	% OF AREA OCCUPIED
1	Very high	596 - 744	3
2	High	447 - 596	
3	Moderate	298 - 447	8
4	Low	149 - 298	32
5	Very low	0 - 149	58
TOTAL			100

Table 3.7

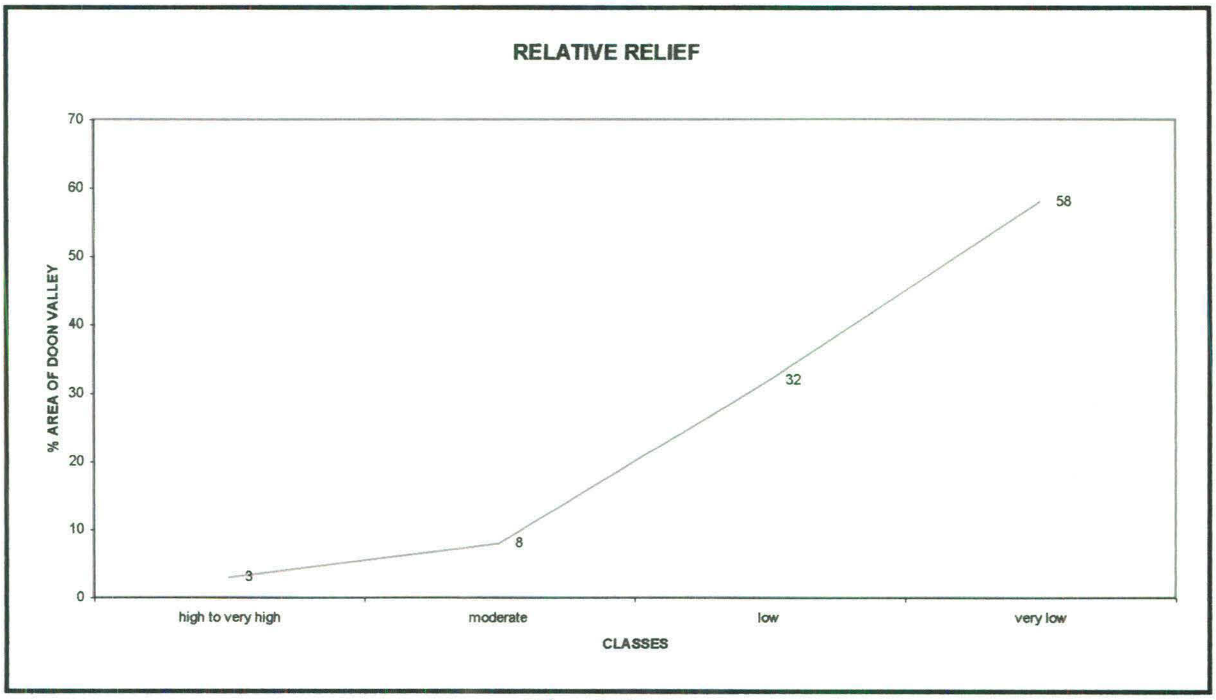


Fig. 3.8

As shown in Fig. 3.8a, high relative relief is only in a small patch in the northern part towards the Siwalik Hills, high and very high-class covers only 3 percent of the area. The low and very low frequency classes have maximum occurrence. Zero relative relief is not found anywhere in the region. The values and the figure clearly indicate that it is more or less a flat valley.

3.1.4.3 Dissection index:

Dissection index deals with the relationship of real area to the projected area between the contours. It clearly indicates the stages in the cycle of erosion. High value shows young stage and low value the old stage (Deen, 1982). Dissection index expresses the ratio of relative relief to the absolute relief. It is calculated by the following formula:

Dissection index (DI) = Relative relief (RR)/ Absolute relief (AR).

The value of dissection varies from zero (complete absence of dissection) to one (vertical cliff).

DISSECTION INDEX			
S.N.	CLASSES	FREQUENCY CLASSES	% OF AREA OCCUPIED
1	Very high	0.74 - 0.92	8
2	High	0.55 - 0.74	
3	Moderate	0.37 - 0.55	
4	Low	0.18 - 0.37	53
5	Very low	0 - 0.18	39
TOTAL			100

Table 3.8

DISSECTION INDEX

DOON VALLEY (DEHRA DOON)

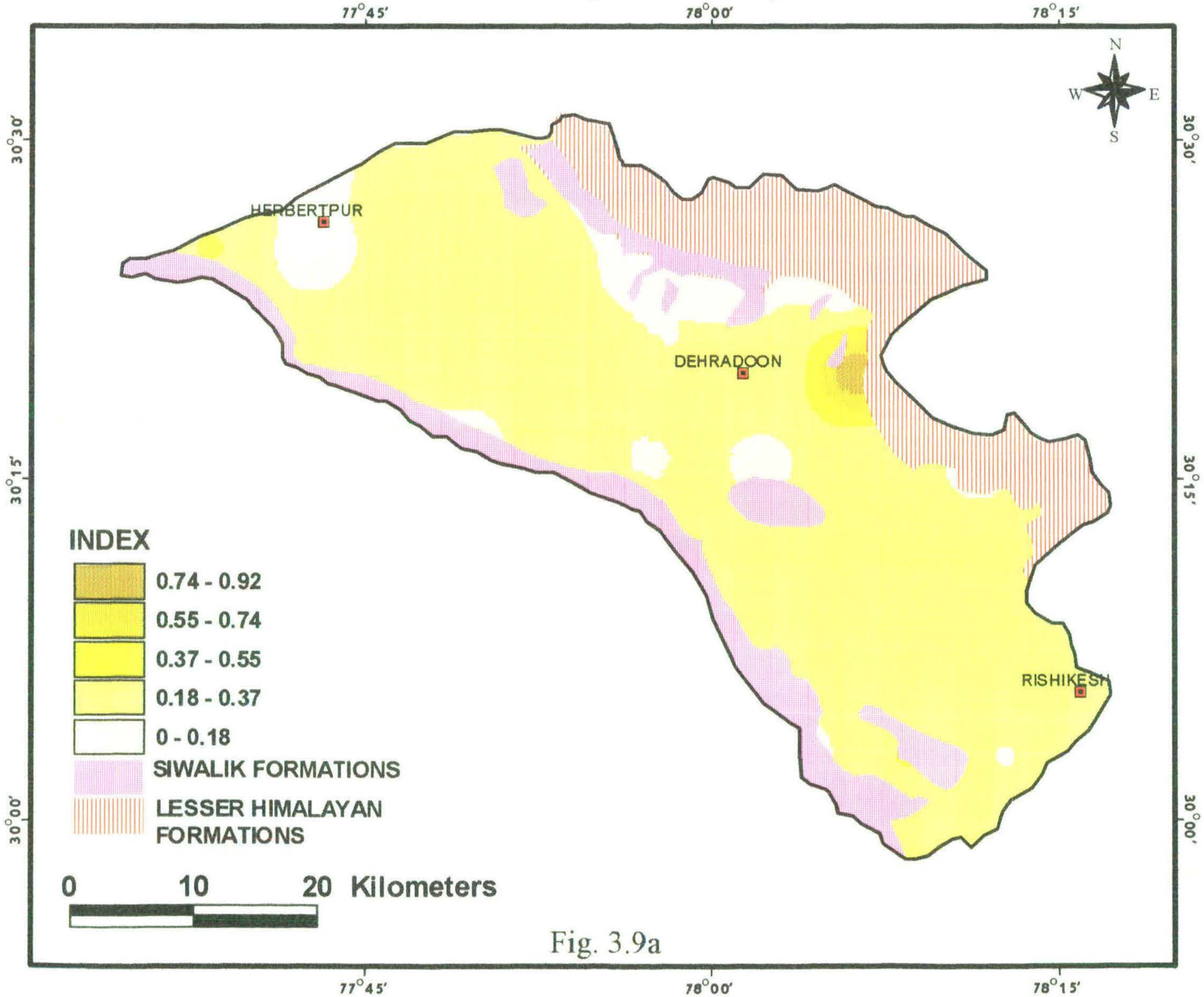


Fig. 3.9a

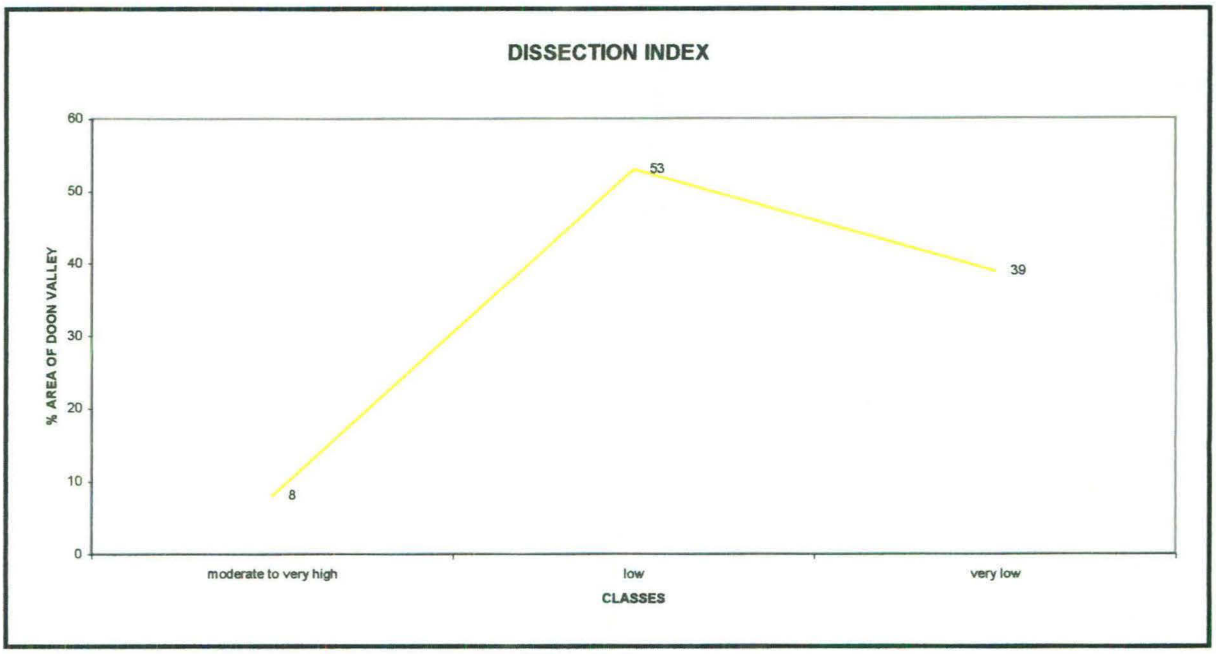


Fig. 3.9

Fig. 3.9a shows that moderate to very high frequency class of dissection index occurs only in a small patch in north-central part of the valley, adjacent to the lesser Himalaya formations and it is only 8 percent of the total area. Rest of the valley has very low-to-low frequency class of dissection index. The reason behind it is that it is having low relative relief.

3.1.4.4 Ruggedness index:

Ruggedness index is a measure of surface unevenness. It is derivative of long standing interaction between available sharpness of local relief and the amplitude of available drainage density and other environmental parameters such as slope precipitation, weathering, soil texture, natural vegetation etc. The ruggedness or number is measured by taking into account both relief and drainage (Chorley, 1971). It is calculated by the following formula:

Ruggedness index (RI) = relative relief (RR) * drainage density / 1000(constant)

RUGGEDNESS INDEX			
S.N.	CLASSES	FREQUENCY CLASSES	% OF AREA OCCUPIED
1	Very high	0.63 - 0.79	3
2	High	0.47 - 0.63	
3	Moderate	0.32 - 0.47	
4	Low	0.16 - 0.32	18
5	Very low	0 - 0.16	79
TOTAL			100

Table 3.9

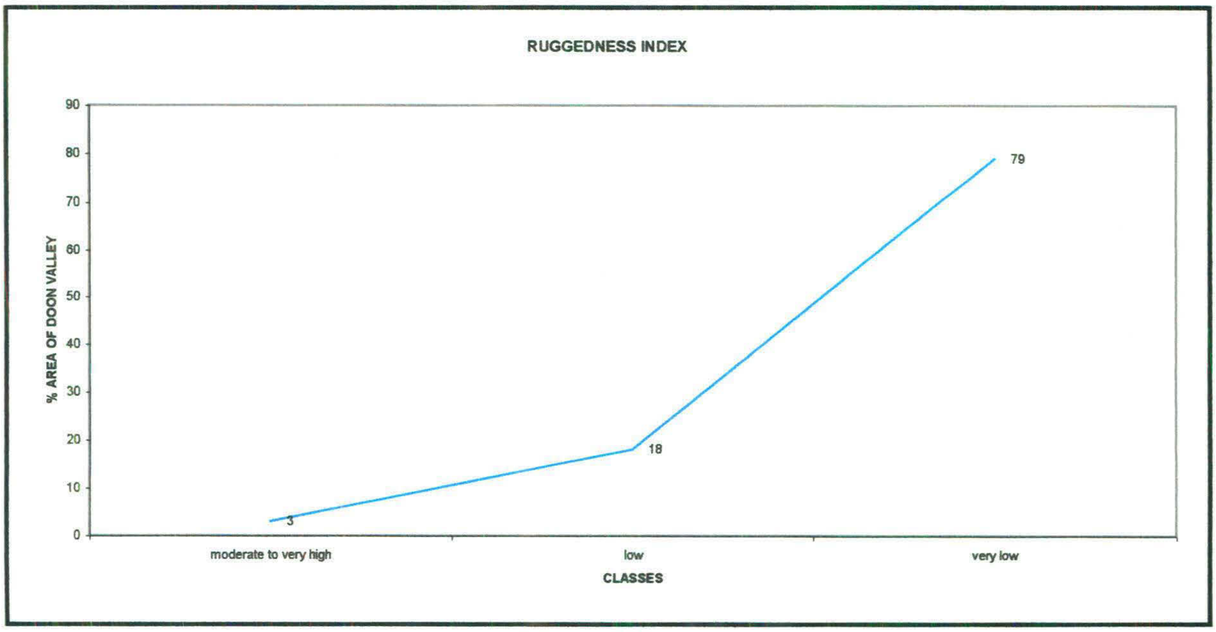


Fig. 3.10

RUGGEDNESS INDEX

DOON VALLEY (DEHRA DOON)

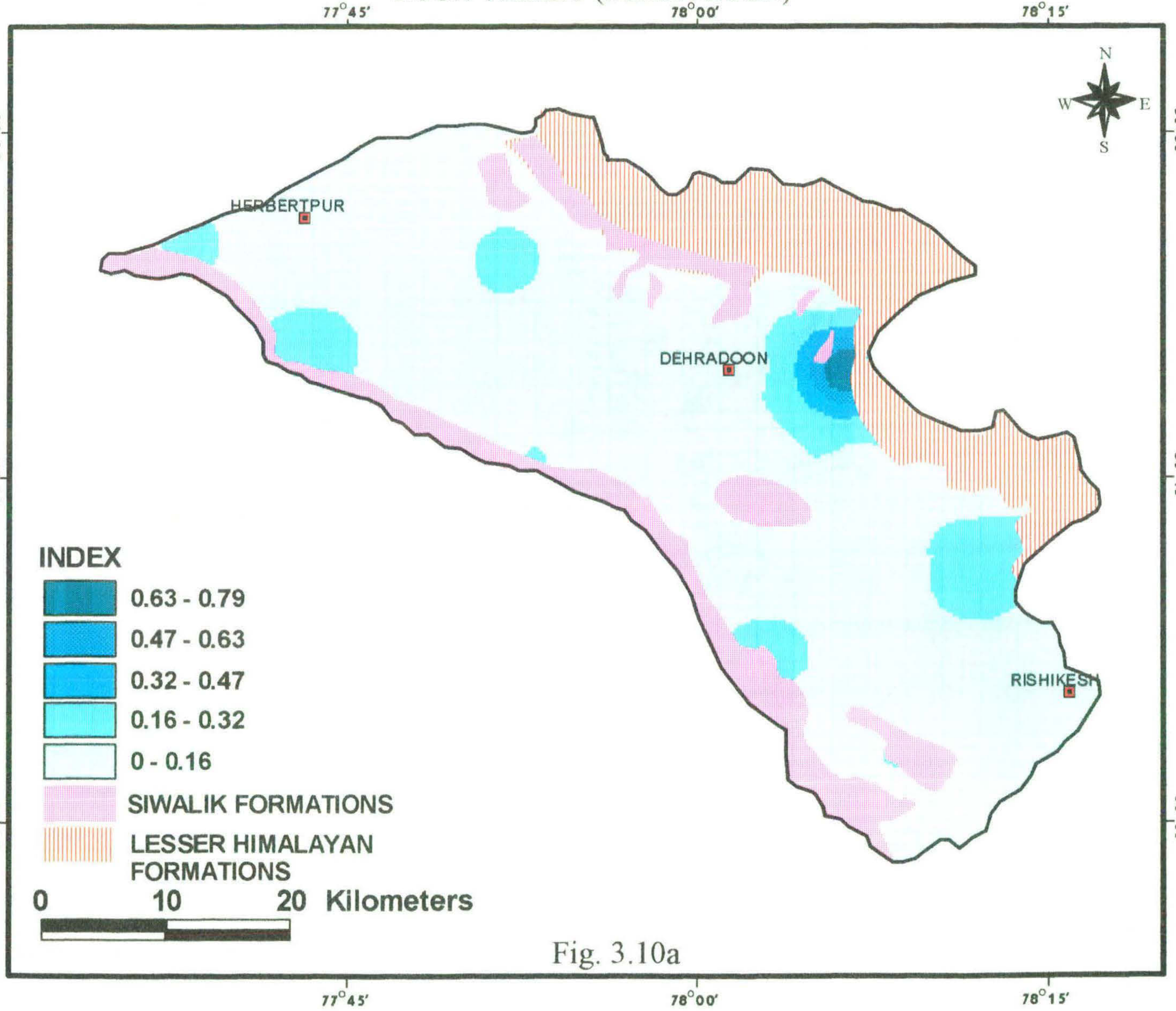


Fig. 3.10a

Fig. 3.10a shows that the moderate to very high frequency classes of ruggedness index is at the areas where it is has high relative relief and dissection index but the moderate value of frequency classes also occur towards the Siwalik hills and also towards the north western and eastern part which shows that it is also dependent on drainage density. But as the value of relative relief is very high compared to the value of drainage density that is why the figure of ruggedness index is more like to the figure of relative relief etc. It clearly shows that high values of dissection index are found towards the lesser Himalaya and the Siwalik hills. Very low value frequency classes of dissection index is found in almost whole valley (Fig. 3.10)

The significance of morphometric analysis has already been explained in beginning of this chapter. All the morphometric parameters addressed here have the direct relationship with the intensity of geomorphic processes acting on the region, which tends to modify physiography of the region.

The term physiography is a term for the combined study of geomorphology, pedology and biogeography (Whittow, 2000).

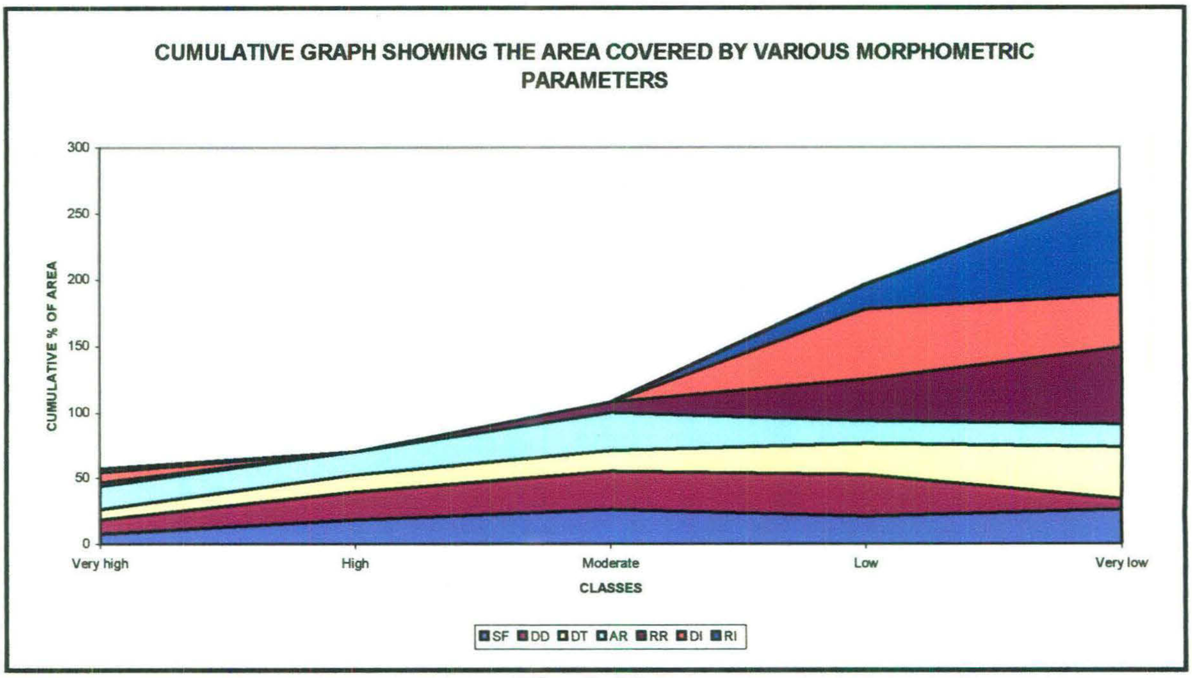


Fig. 3.11

Fig. 3.11 clearly shows that the maximum cumulative percentage area of the Doon valley falls under the class of moderate to very low morphometric parameters as a result of low geomorphic activity in the Doon valley. The surface modifications of the Doon valley due to morphometric parameters have less effect. The Doon valley is entirely formed out of fan deposits and is termed as the dead fans (Mukerji, 1988).

3.2 THE TECTONIC SETTING OF DOON VALLEY:

The Doon valley is bound to north by the Main Boundary Thrust that separates the Precambrian rocks of the Krol belt of Lesser Himalaya to the Cenozoic sediments of the outer Himalaya (Thakur, 1992). The topography suddenly rises in the south in the form of Siwalik Hills and it separated from the recent alluvial sediments by the Himalayan Frontal Thrust (HFT), which is commonly known as Mohand thrust. Fig. 3.12

TECTONIC SETTING OF DOON VALLEY

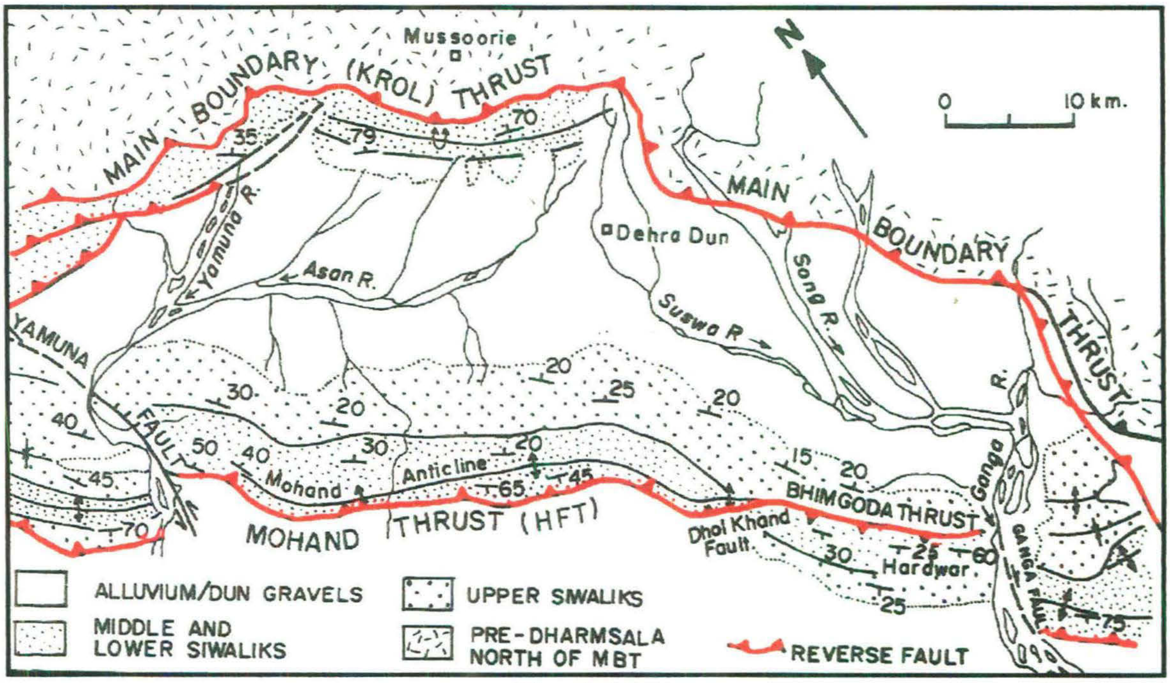


Fig. 3.12

modified after Raiverman et al., 1983

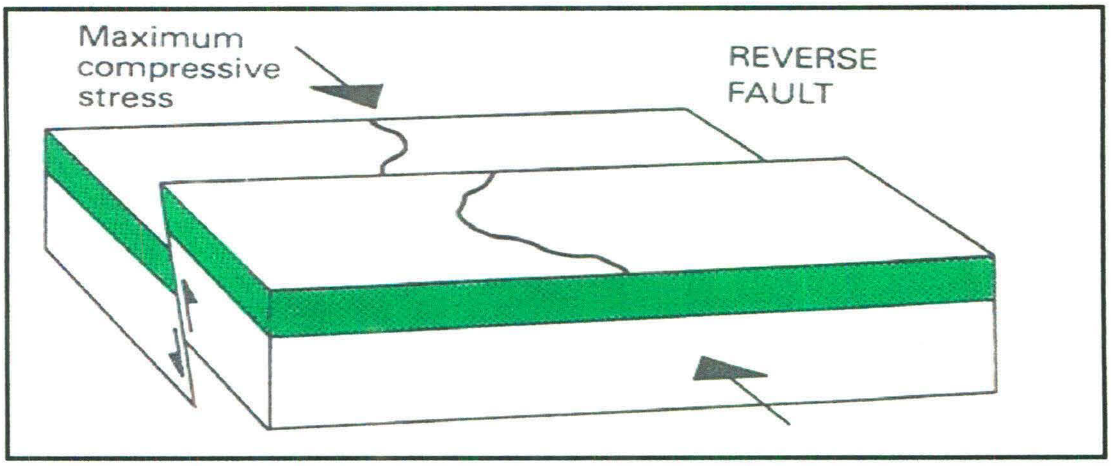


Fig. 3.13

The MBT was initiated before 10 Ma (Meigs et. el, 1995) and is neo-tectonically active (Valdiya, 1992). The Doon valley is made up of broad synclinal valley, to its south within Siwalik strata lies Mohand anticline and to the north the Doon syncline, a tight overturned fold called the Santokgarh anticline is developed folding the Lower and Middle Siwalik in the core of the fold (Thakur, 1995). Himalayan Frontal Thrust dip towards NE and its seismic section extends below the Doon valley (Raiverman et al, 1993) (fig 3.14) The Bhimgoda thrust exists in the eastern part of the Siwalik range dip towards south at low angle (25 degree) bringing the upper Siwalik to override the upper Siwalik (Rao et el., 1974). The Bhimgoda represent a break-back thrust that was developed over Mohand anticline in the southward propogating Himalayan Frontal Thrust (Thakur, 1995).

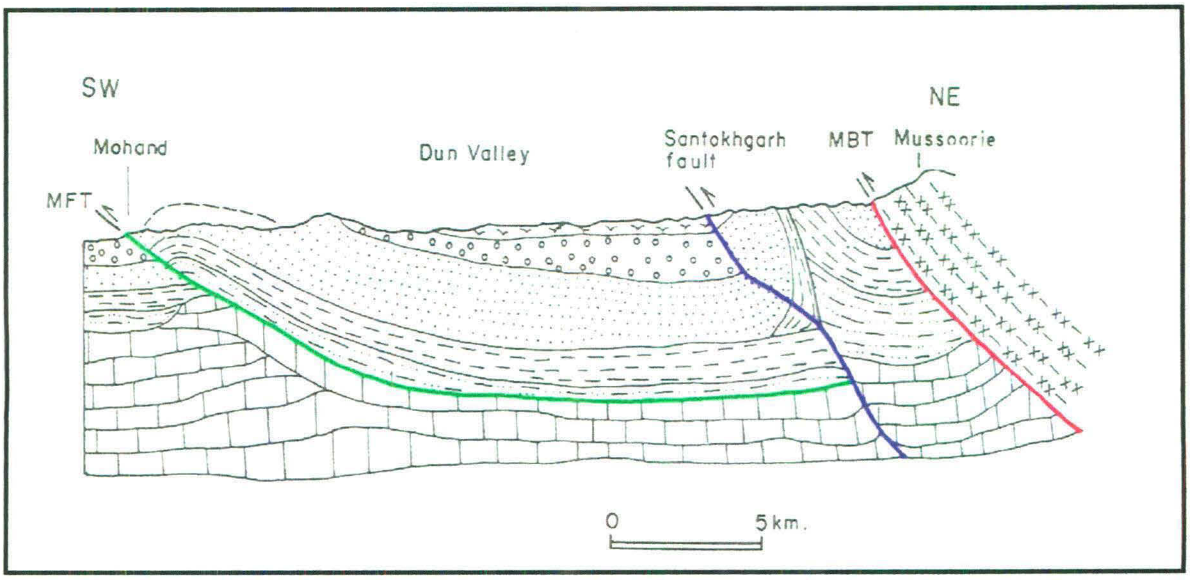


Fig. 3.14 modified after Raiverman et al., 1983

The Doon valley comes under the tectonically active zone. Reactivated faults lead to the dislocation of many streams, alluvial fans, and river terraces etc. The Doon valley, which experienced severe tremors of the Kangra Earthquake in 1905 and the Uttarkashi Earthquake in 1991, has drawn the attention for the recent crustal movement in this area (Philip, 1995). The Siwalik sediments exposed in the sub- Himalayas typically become coarser upward in the section with fan conglomerate (Doon gravels) occurring at the top. This evidence is often interpreted as evidence for progressive rise of the Himalayas and the recent onset of tectonism along the MBT. The MBT cuts the post Siwalik sand gravel and is still active (Mahindra et. el, 1997). In the northwestern part of the Doon valley Rao (1977) mentioned the occurrence of tilted post Siwalik boulder bed. It is Langha Boulder bed, which rests unconformably on upturned Siwalik sediments in Doon valley. Two parallel faults, well within the piedmont fan deposit have been identified, recognized and reported as Donga and Bhelonwala fault. (Fig.3.15)

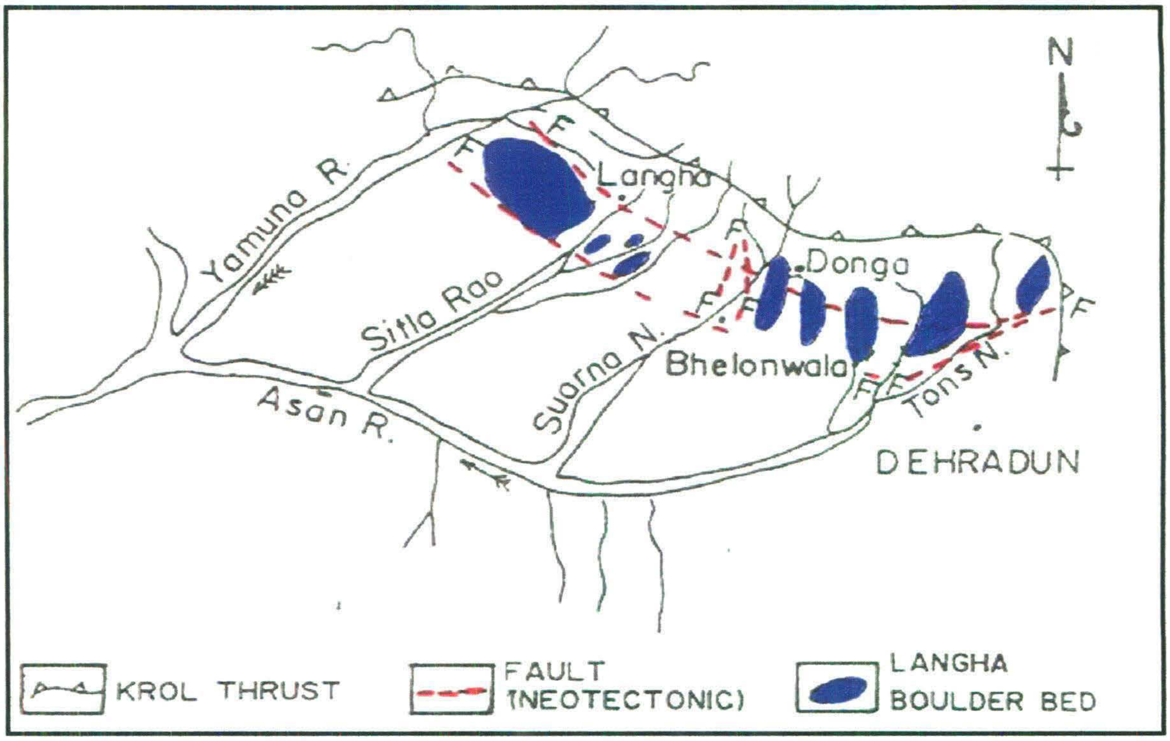


Fig. 3.15 After Rao, 1977

Philip (1996) also pointed out in the shift in courses of river channels of Sitla and Suarna Rao in the western Doon.(Fig.3.16)

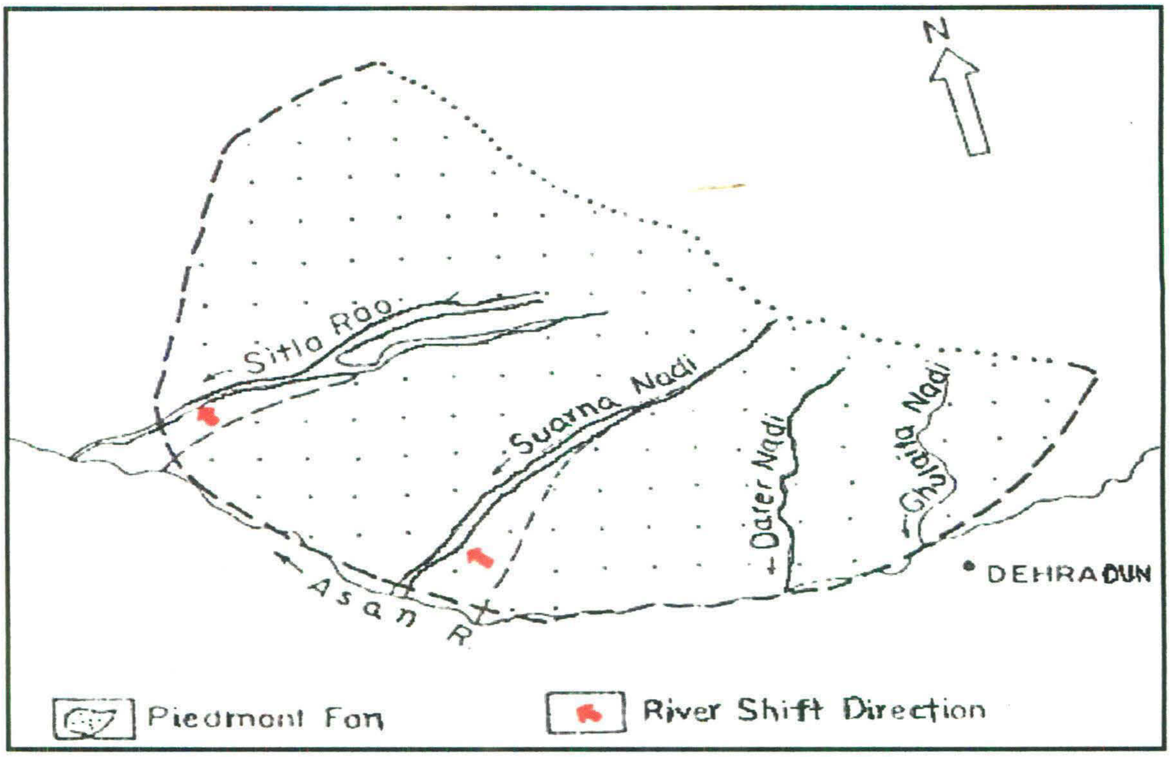


Fig. 3.16 after Philip, (1966)

Near Dhol Khand Fault (Fig.3.12) in the Siwalik Hills, south of Doon valley, river bed upliftment of Gaj Rao has been reported by local people and proved to be correct by various researchers (Mazari, 1996). This shows the active character of the HFT.

Landforms of the Doon valley are not only representative of prevailing or past climate but continued tectonism played a very important role in the evolution of landforms of the Doon valley. So any model of evolution or projection for future landforms or land utilization of the Doon valley should integrate all major responsible factors.

Chapter four

Environment and Landform Evolution

4.1 INTRODUCTION:

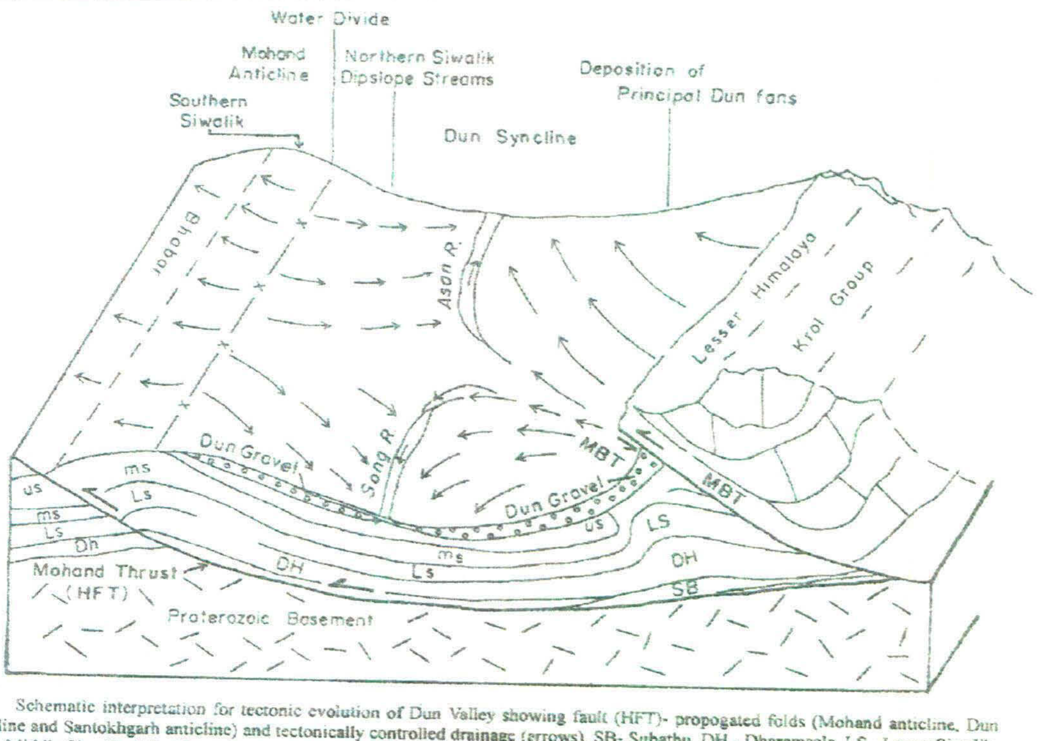
Landform is a function of spatial and temporal distribution of resisting and disturbing forces. For any set of environmental conditions, through the operation of constant set of processes, there will be a tendency over time to produce a set of characteristic features (Appendix. 1). Landforms are continually subjected to perturbations that may arise from change in the environmental conditions of the system or from structural instabilities within them.

The spatial distribution of landforms is shown with the help of distribution of geomorphological features over the space, whereas temporal characteristics can be shown by facies association and their interrelationship would be adjusted. Facies is a unit or group of units that exhibit lithological, sedimentological or faunal characteristics, which enable them to be distinguished from unit or groups of units adjacent to it. The units are homogenous in any characteristic. Facies association study can be brought forward by taking any of the distinctive characteristics exhibited by the units of study. The facies analysis can vary from simple to very complex methods that are from visual observation to the structural, chemical etc. properties of units. Stratigraphy is also a vertical arrangement of different facies, usually referring to chronological building up.

4.2 THE FORMATION OF DOON VALLEY:

In geological context the Doon valley landforms essentially comprises of two components. These components are formations and faults. Formations reflect the lithology and stratigraphy of the Doon valley. Faults also played an important role in the initiation and deposition of the Doon valley sediments. The faults have played an effective role in the initiation of the fan formation, fan-head entrenchment and the segmentation of the fan (Mukerji, 1988) The fans have developed on underlying upper Siwalik.

Fig. 4.1 shows the arrangement of different layers in the Doon area, proceeding upwards we finds Proterozoic basement, Sabathu formation, Dharmshala formation (Appendix -V), lower Siwalik, middle Siwalik, upper Siwalik and upper Siwalik and on top lies the Doon gravel.



Schematic interpretation for tectonic evolution of Dun Valley showing fault (HFT)- propogated folds (Mohand anticline, Dun syncline and Santokhgarh anticline) and tectonically controlled drainage (arrows). SB- Subathu, DH - Dharamsala, LS - Lower Siwalik, MS - Middle Siwalik, US - Upper Siwalik

Fig. 4.1 After Thakur, (1995)

4.2.1 Stratigraphic base:

The sedimentation history of the Mohand area shows two overlapping alluvial fan systems. In the first alluvial fan system, sheet floods developed the lower sandy alluvial fan in braided trunk river system with proximal river flood plain deposits and deposition which occurred in radial alluvial fan setting with lower rate of subsidence and supply of detritus from the inner lesser Himalaya. In the second alluvial fan system, MBT became active and the source lithology changed from inner to outer lesser Himalaya (i.e. Krol belt) and the continued advancement of the thrust sheet along MBT, increase in gravel influx from the north causing transformation of braided river to alluvial fan system (Kumar, et al., 1994)

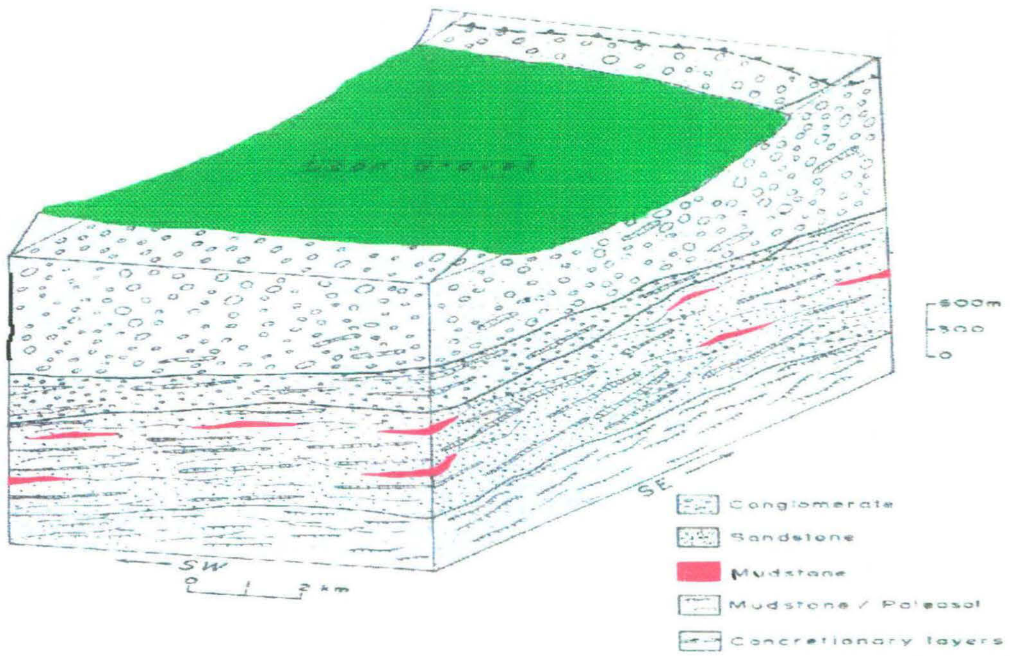
The sratigraphical records of the Doon valley can be summerised in the table given below:

STRATGRAPHY OF DOON VALLEY

AGE	FORMATION	LITHOLOGY
Recent	River alluvium	Sand, silt and clay
Late Pleistocene to early Holocene	Doon fan gravels	Pebbles, sand and clay
Late Pleistocene	Old Doon gravels	Boulders, pebbles, sand and clay
	Unconformity	
Pliocene to Pleistocene	Upper Siwalik	Conglomerate and clay bed
Miocene to Pliocene	Middle Siwalik	Micaceous with intercolation of clay

Miocene	Lower Siwalik	Sand stone and interbedded clay
	Unconformity	
Paleocene to middle Eocene	Sabathu series	Shale, sandstone and limestone
	Unconformity	
Permian to Triassic	Krol	Limestone, slate and shales
Carboniferous	Infra krol	Slates boulders beds and quartzite
Permian	Nagthats	Quartzite with minor shales
Lower Paleozoic to Pre Cambrian	Chandpurs	Slates, phyllites thin quartzites
Pre Cambrian	Mandhali	Slate, limestone

Table 4.1 Ref. in Appendix II, III, IV, and chapter one



Three-dimensional fluvial architecture around Mohand area showing the vertical and lateral facies variation

Fig. 4.2 Modified after Kumar, 1994

Here one is concerned with the lower, middle and upper Siwalik and the Doon gravels. If the Table 4.1 and Fig. 4.2 are interpreted together the stratigraphic of Doon valley would show that litho logically, the lower Shiwaliks are made up of sandstones and interbedded mudstones, with thickness of about 2000 meters and age of about 14 Ma to 18 Ma.The middle Shiwalik shows multistoried sandstone with pebble and mudstone siltstone with planner stratification with thickness of about 1800 meters and age as about 10 Ma to 6.7 Ma. The upper Shiwalik having thickly bedded massive conglomerate in sandy matrix and interbedded sandstone with thickness of about 2000 meters have ages from 0.5 Ma to 5 Ma (Appendix III and IV and Plate 6) above which lies the Doon gravel. Old Doon gravels and Doon fan gravels constitutes thickly bedded massive conglomerate embedded in sandy silty matrix with thickness of about 600 meters and age from recent to 0.5 Ma, (Thakur, 1995).

4.2.2 Geomorphological base:

Geomorphology is the science concerned with the form of land surface and the processes that create it (Summerfield, 1991). Processes that operate on the surface are directly related to the environment of that region. Nossin (1971) had prepared first detailed geomorphic map of the Doon valley by using aerial photographs. He determined that this synclinal valley is of post Upper Siwalik age and that the regional uplift of the valley since Upper Siwalik times is about 950 ft. to 1250 ft. Nakata (1972) also studied the geomorphic surfaces of the valley and described some recent movements. He suggested that the Doon valley evolved by the intricate superimposition of alternate depositional phases, caused by climatic changes and crustal movements

Area occupied by the Doon valley, Siwalik range and fluvial features is 27.50, 24.26 and 3.20 percent, respectively. The other features occupy 45.04 percent area, out of which majority is of the lesser Himalayas.

The above study confirms that the main Doon valley is entirely a fan deposit, a result of successive sedimentation and upliftment. The Shiwalik is a result of folding of foreland deposits of lesser Himalaya. The Siwalik range what we see today is an anticline. And the synclinal part is buried beneath the Doon gravels.

4.3 STAGES IN THE EVOLUTION OF DOON VALLEY:

Here the evolution of Doon valley is discussed in different stages. Possible diagrams are shown. In the diagrams only direction and dehradoon tehsil boundary are true to scale.

4.3.1 Stage I:

Slope of the streams was not steep enough to bring down to the plains any coarse debris. This stage was prior to the Pleistocene period. It was only towards the commencement of Pliocene, that the Himalayas attained their height comparable to the present. Earlier the source of sediment was inner Himalayas. The sediments of the lower Siwalik are probably of this time. There was no barrier in the south. which can confine the material brought from the inner Himalaya. Occurrence of sand stones and

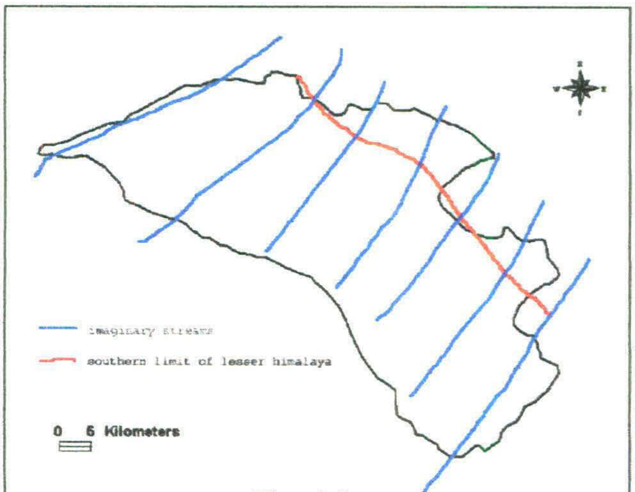


Fig. 4.9

over the past hundred thousand years. His suggestions are seems to be more compatible with present theme. Nossin (1971) divided map into three main geomorphic divisions:

- Siwalik range
- Doon valley
- Other various fluvial features

These are subdivided further given below with some modifications:

Siwalik range:

Sn - northern Siwalik

Ss - southern Siwalik

Sol - outlier of Siwalik

Doon valley:

Dfl - lower realm of principal fans

Dfd - dissected parts of principal fans

Dfp - principal Doon fans

Dfh - high level fan terraces

Dt - fan terraces below principal fans

Fluvial features:

Ftl - lower level fluvial terraces

Ftm - intermediate level fluvial terraces

Fth - highest-level fluvial terraces

Others:

Es - erosional scarp

Lho - outlier of lesser Himalaya

Lh - lesser Himalaya

Rb - broad rivers

Rn - normal rivers

CROSS SECTION OF the DOON VALLEY

(Above and below are west and east section respectively)

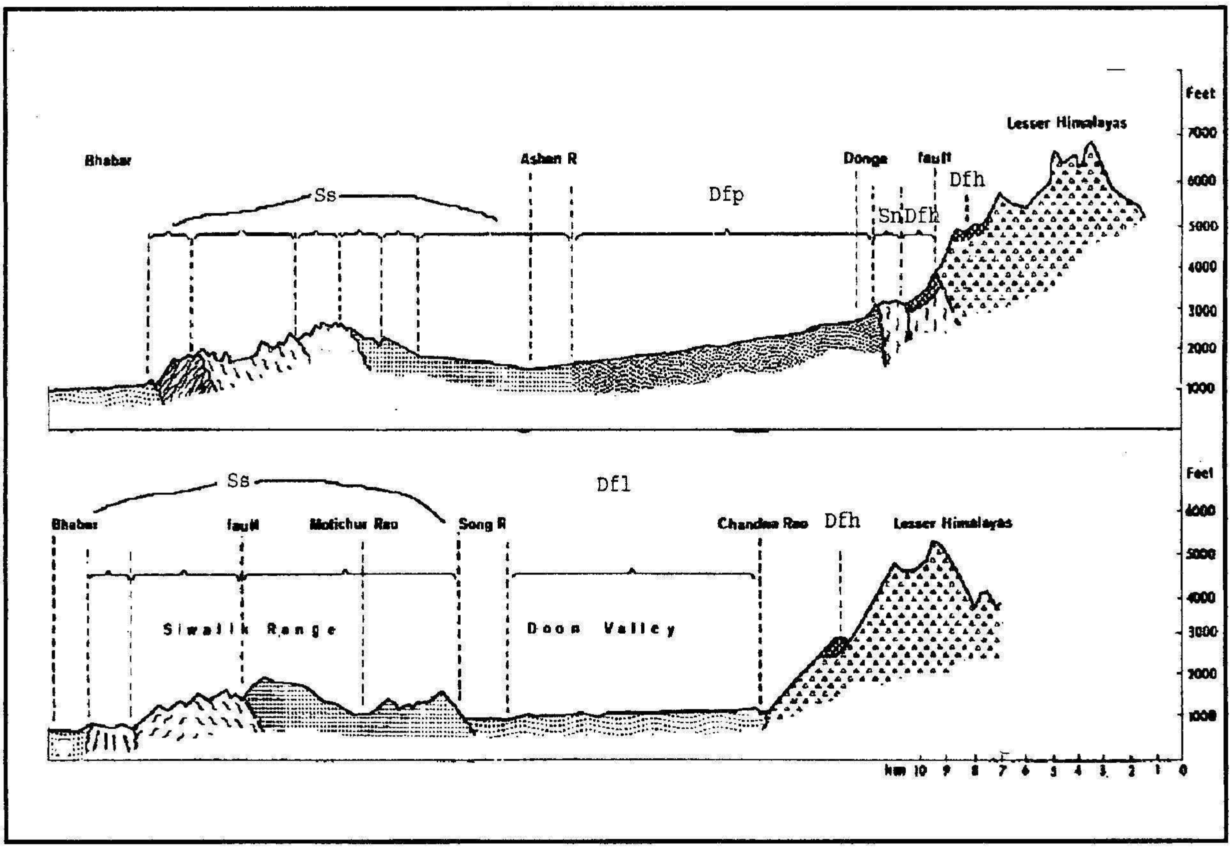


Fig. 4.3, Modified after Nossin, 1971

GEOMORPHOLOGICAL MAP OF THE DOON VALLEY

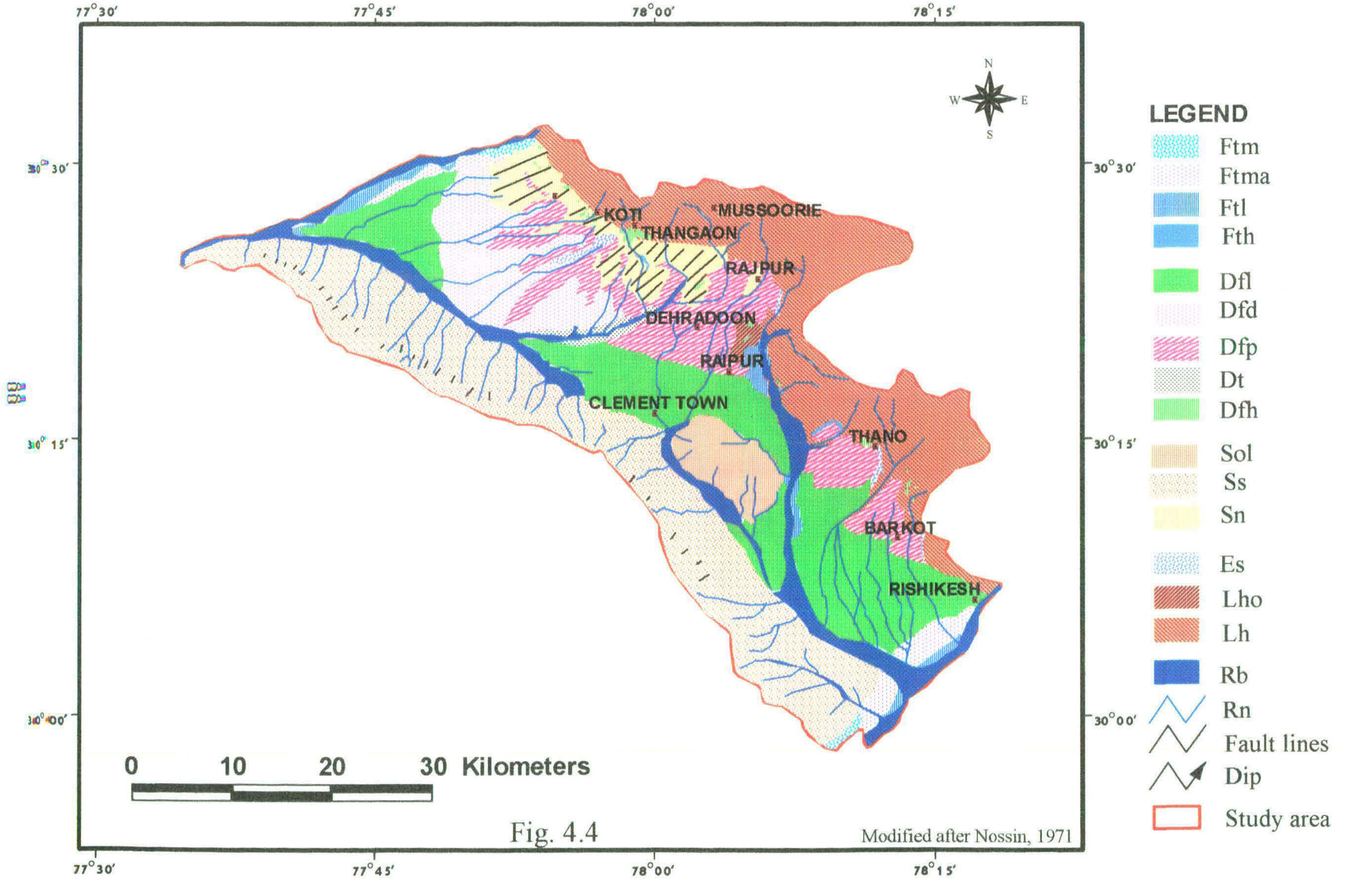


Fig. 4.4

4.2.2.1 Geomorphic landforms, their composition and evolution:

4.2.2.1.a Siwalik range:

Sn: Northern Siwalik is found in the northwestern part of the valley. It is tectonically very active. It lies south of the Main Boundary Fault. The middle Shiwalik sediments are exposed here. It shows the records of fluvial origin of the Siwalik Hills and forms nappe along the Santokgarh fault, (Fig.3.14). It consists of upper Siwalik conglomerate and middle Siwalik sandstone. It formed of channel and over bank deposits in the Miocene period. It also shows the evidences of single major flood deposits.

Ss: Its north slopes consists of the upper Shiwalik conglomerate and boulder beds. Its northern portion dips towards the Doon valley, gentle in slope, and shows parallel drainage pattern. Its southern portion shows escarpment, coincides at most places with present boundary of water divide and is steep in the south facing slope. Its deposition occurred due to high-density stream flows and there is also change in the flow regime. They evolved in the Pliocene to Pleistocene periods.

Sol: Its name is Nagsidh hills and is in the east central part of the valley. It is detached part of the Shiwalik Hills. River Suswa seem to might be responsible for its detachment.

4.2.2.1.b Doon valley:

Dfl: It is in the lower portion of the principal fans, and is less elevated above the main river. Its upper part has steeper gradient then lower part. It is composed of small size boulder cobble and pebble as compared to principal Doon fans. It is low energy river deposits.

Dfd: It is detached part of principal fan by the numerous streams and in between re-exposed Siwalik part is shown. The cause of evolution is headward erosion by the streams.

Dfp: Very coarse boulder beds with sandy and silty matrix characterize these fans. These are the large sized fans developed along the lesser Himalayan front, out of the streams coming from it. Its evolution shows high-level river discharge. It has a smooth gradient. It is separated in the north by the Santokgarh fault. Numerous small streams emerge out of these fans. Dehradoon city is situated on this sub-division.

Dfh: These are high-level fan terraces lying above in the lesser Himalaya, and above the Siwalik hills (Plate 2 and 3), These indicate a clear break in gradient. They are relatively flat surfaces and steeper at their fan-head. These are formed due to the movement along the MBT and Santokgarh fault. These are the good example of tectonic upliftment and movement along the boundary. These terraces are found near Rajpur.

Dt: It is terrace itself in the fan surface along the river. It is formed by the seasonal change in the discharge of the river.

Overall composition of the fan deposits consists of coarse gravel, pebble and cobble, and are well rounded except in the upper reaches. At few places, large boulders and blocks are also found. At lower levels of fans, finer components are significant. These are mainly composed of quartzite or quartzitic-sandstone. Wherever Siwalik are exposed pebbles are mixed with the Doon gravels. Such large fans definitely mark the Pleistocene inter-glaciations.

4.2.2.1.c Fluvial features:

The fluvial terraces are sub divided into high, intermediate and lower level fluvial terraces. Pebble dominates these terraces with sandy layers. These are found along the presently flowing rivers. These are sub- divided according to height and found along the rivers. These are normal depositional features of the rivers. The high level terraces show their origin from braided streams that must have had large scale lateral shifting.

4.2.2.1.d Other features:

The other features are erosional scarps visible in a small patch in the northern Siwalik region. It is along the western bank of Suarna nadi. It might have formed due to the cutting by river of the Siwalik. The outlier of lesser Himalaya is found in the north central part of the valley. Between the lesser Himalaya and outlier the Song River flows, and may be the cause.Numerous big and small streams are flowing in this region. There are numerous small seasonal streams known as Raos, too. Streams are deeply entrenched and have less effect in modifying the surface of the valley.

4.2.2.2 Percentage of area occupied by various geomorphic features:

The total area of study area is 2492.42 sq. km

4.2.2.2.a Siwalik range:

To the south Siwalik range makes boundary of study area. It is exposed in the NW part of the Doon valley and SE part as Nagsidh hills. Area covered by its various subdivisions is shown in the Fig. 4.5.

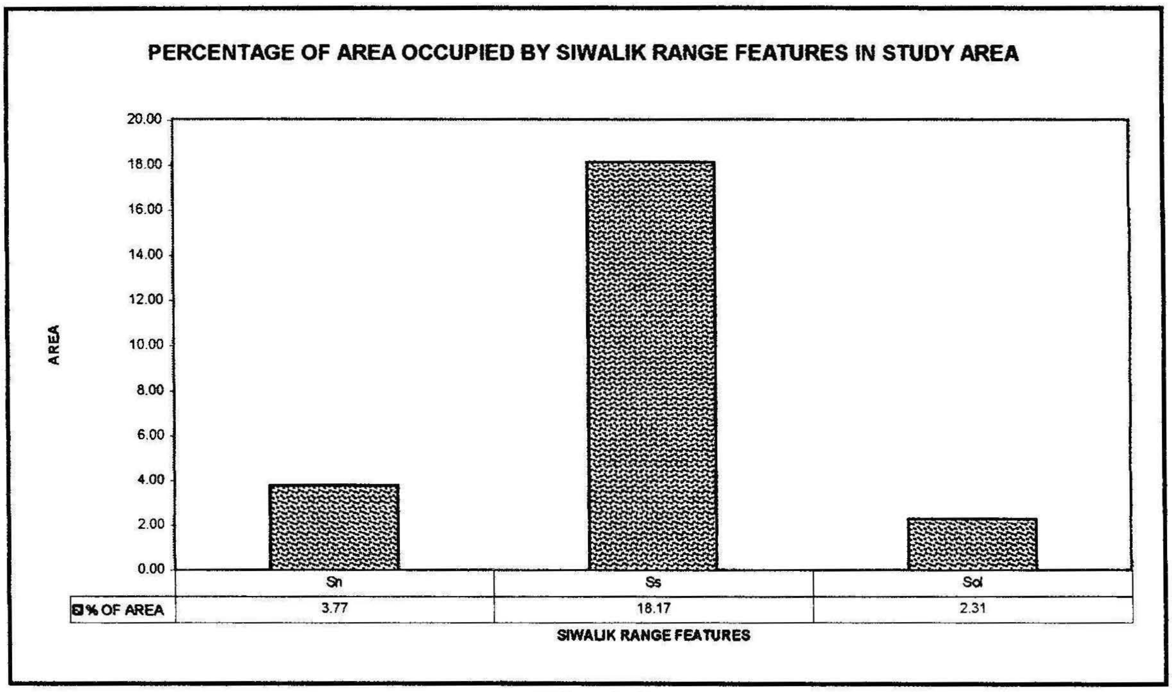


Fig. 4.5

Area covered by southern Siwalik (Ss), northern Siwalik (Sn) and Siwalik outlier (Sol) is 18.17, 3.77 and 2.31 percents respectively. The location and area together shows that the Doon valley is filled from the debris brought by rivers from northern portion of the study area or from the lesser Himalayan zone. Siwaliks in the northern portion are buried under the Doon gravels. In the southern Siwaliks there is no such source of debris. The outlier of Siwalik Hills shows the combined effect of upliftment and erosion.

4.2.2.2.b Doon valley:

The Doon valley features are confined in the main Doon valley. It is bounded both sides by Siwalik Hills and lesser Himalayan features. The area occupied by various Doon valley features is presented in Fig. 4.6

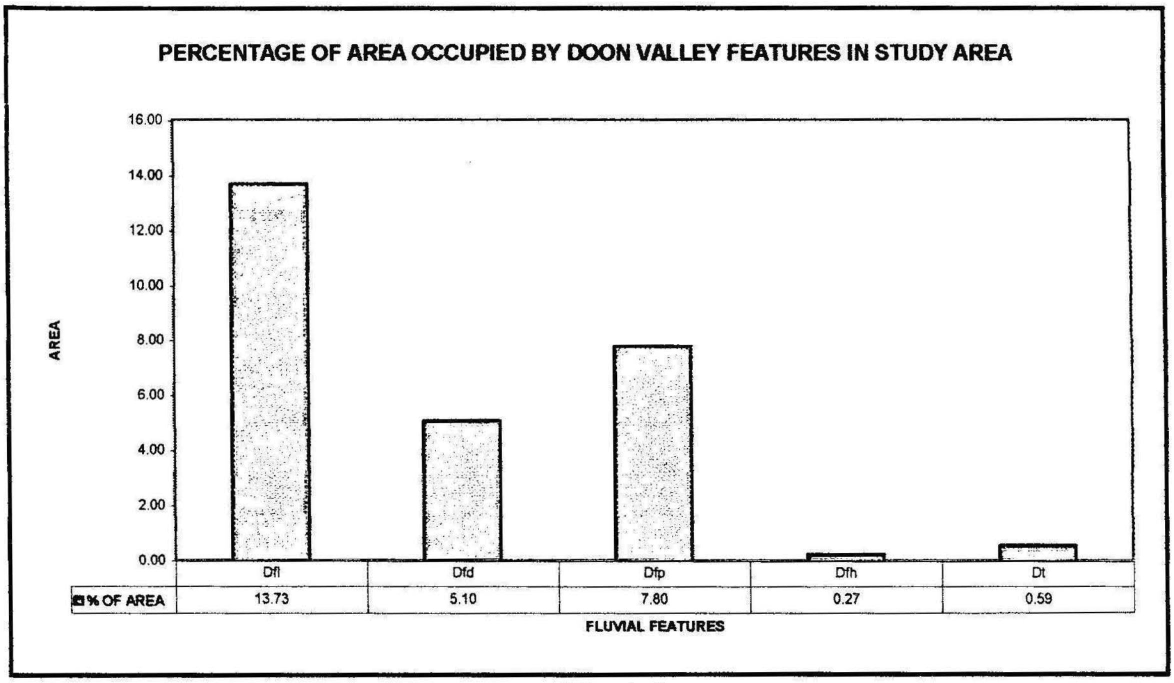


Fig.4.6

Area covered by lower realm of principal fans (Dfl), principal Doon fans (Dfp), dissected parts of principal fans (Dfd), fan terraces below principal fans (Dt) and high-level fan terraces (Dfh) is 13.73, 7.80, 5.10, 0.59 and 0.27 percent respectively. The fan deposits covers almost the entire area of the Doon valley (Fig. 4.4). This shows that the entire Doon valley is a fan deposit. The various sub-divisions are according to their composition, which is guided by their location of deposition. The overall factor responsible for it is the energy of the flow responsible for deposition. The maximum interbedded clay shows no drastic environmental disturbances.

4.3.2 Stage II:

It was around 10 Ma in the late Miocene period that the MBT was evolved. The initiation of MBT caused the increase in gradient, which led to the drastic change in the bed load and the source lithology changed from inner lesser Himalaya to outer lesser Himalaya (Kumar, 1994). Continued thrusting along MBT and increase in gradient is reflected in the gravel size and depositional setup. This is the period of middle and upper Siwalik sedimentation. This is from of late Miocene to early Pleistocene. The depositional environment constitutes mainly sheet flood braided streams on distal sandy alluvial fans in the middle Siwalik sedimentation and mainly gravel load braided streams and sheet flood on distal alluvial fan in the upper Siwalik sediments. The thrusting along MBT and advancement of source area towards southern side led to the transformation of braided river system to a gravelly alluvial fan. All these activities happened up to 0.5Ma till the initiation of HFT. The force was in the specified direction and can be assumed by looking at the arrangement of the river Ganges and Yamuna tear

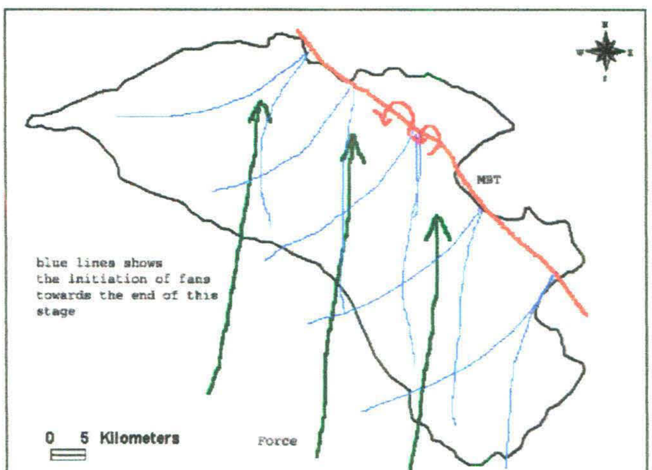


Fig. 4.10

area occupied by lower realm of principal fan shows distal fan deposits spread in the vast area of the valley.

4.2.2.2.c Fluvial features:

Of fluvial features are mainly found along the main rivers i.e. river Ganges and river Yamuna (Plate 5). If we analyse Fig.4.4 together with contour map of the valley, it is interpreted that sub divisions are according to height along the rivers. In this sub division absolute height of individual fan features is not taken into account. That is the reason Ftl terraces can be seen at various heights along the rivers. The area of Ftma and Ftm is grouped into Ftm due to scale factor and they both represent intermediate level fluvial terraces (Fig. 4.4). The area of various subgroups of fluvial terraces such as lower level fluvial terraces (Ftl), intermediate level fluvial terraces (Ftm) and highest-level fluvial terraces (Fth) is 1.23, 1.90 and 0.07 respectively as shown in Fig. 4.7

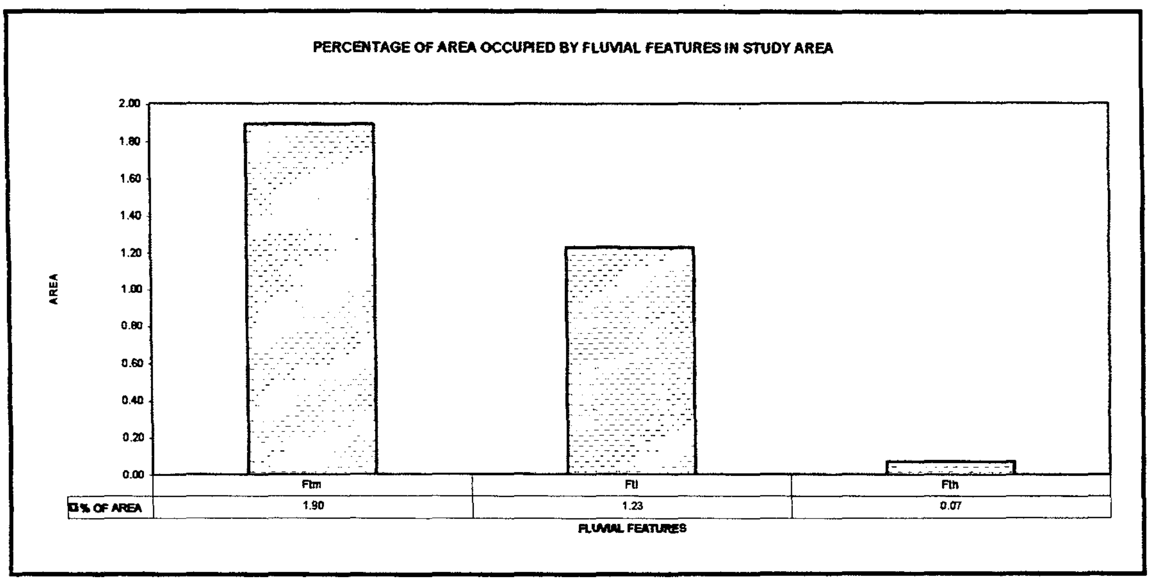


Fig. 4.7

These terraces are the example of continuous down cutting and upliftment. The largest area of intermediate level terraces shows the deposition of longer time with the same weather conditions and continued gradual upliftment.

4.2.2.2.d Relation among various geomorphic divisions in study area:

Every unit contributs in various degrees in the formation of the Doon valley.The lesser Himalaya is in the north of the valley and acted as a source of deposits for the Doon valley.

The Siwalik range helped in confining the deposits in the Doon valley. The area occupied by various geomorphic divisions help in assessing surface configuration and dominance of activity. Area occupied by the various geomorphic divisions in study area is given in Fig. 4.8

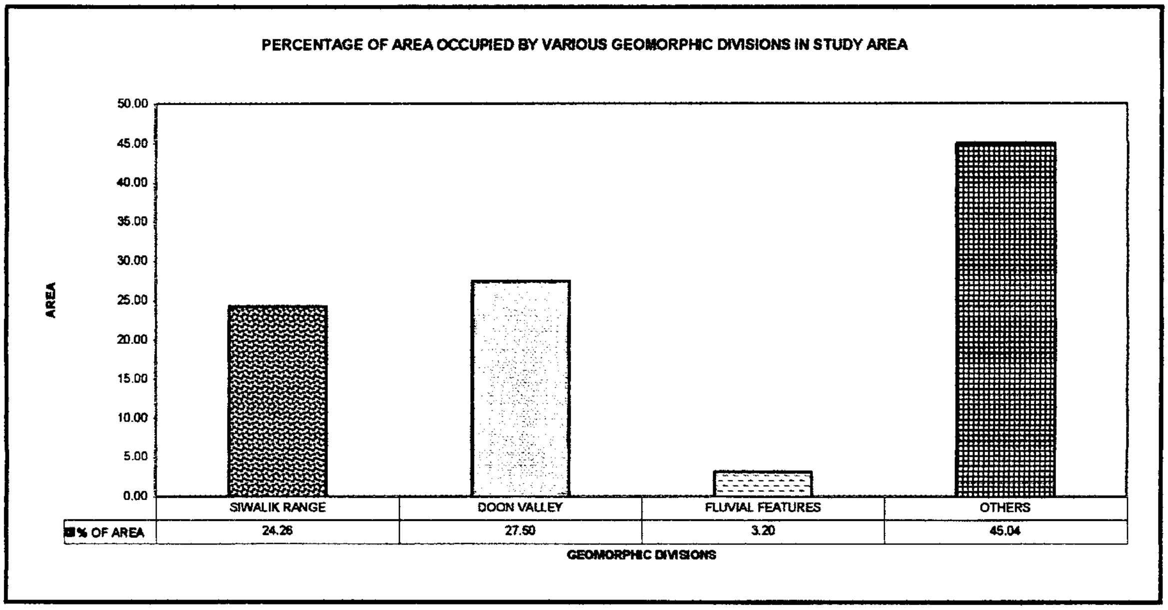


Fig. 4.8

faults, and exposed the northern Siwalik in NW part of the valley and the direction of water divide between Asan and Song river systems.

4.3.3 Stage III:

This stage is directly linked with the formation of the main Doon valley. Filling started just after creation of syncline, earlier debris brought by rivers used to spread in the foreland of lesser Himalaya. The development of the HFT initiated the formation of the Doon valley and coeval deposition of Doon gravels. Upper age limit of upper Siwalik is estimated at 0.5 Ma, which is also lower age limit of Doon gravels (Nossin, 1971). In this stage answer of following questions is as development of Doon fan gravel.

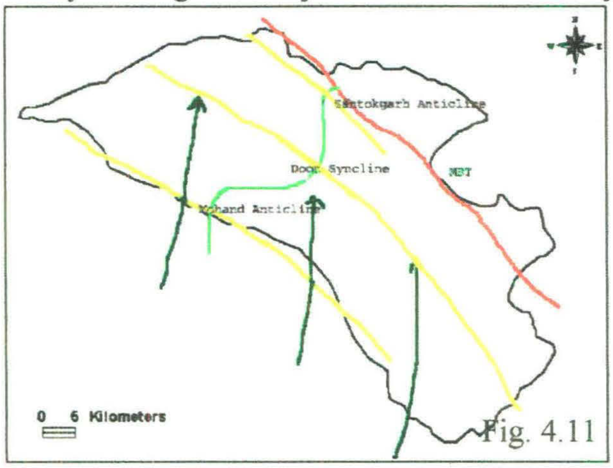
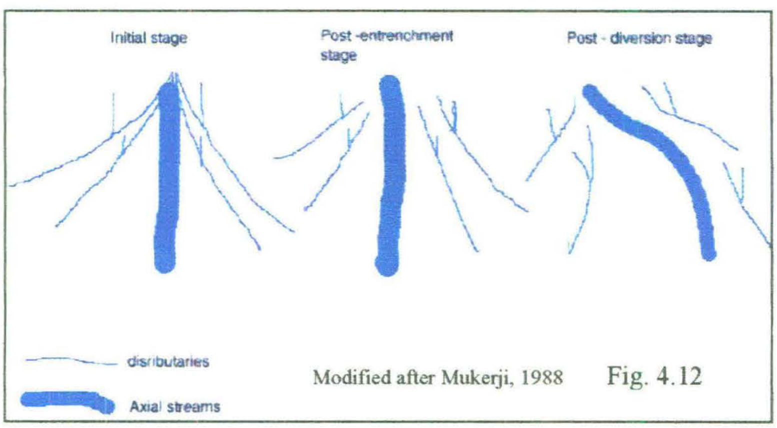


Fig. 4.11

- Development of Rajpur - Mohand as water divide.

It has been already discussed that fan debris are brought from north as a continued uplift of Mussoorie range due to activity along the MBT. But this alone could not answer the entire question.The Doon fan gravels consist of boulder conglomerates that consist of Pebbles, Cobbles and boulders of sandstone, limestone, quartzite and schist. The presence of lime shows that they are derived from the pre-Siwalik formations as the upper Siwalik (see Plate 4). Very little has been picked from upper Siwalik boulder conglomerate. These fan depositions is related to continuing semi-arid climatic conditions, more a variant of Koppen's Cwg, characterized by high energy rainfall, thunderstorms, thundershowers and bursting floods (Mukerji, 1988). The factors responsible for the development of the Doon fan gravels can be summarized as below:

- River coming out of the lesser Himalayas forms fans as they leave mountain. The Capacity of rivers to carry load increased by increase in steepness along the MBT. This was due to fault movement. The fault created break of slope which this led to the decrease in capacity of rivers to carry load that caused the deposition to occur at the break of slope.
- These fans developed from the upper Pleistocene to early Holocene periods and was the period of Pleistocene glaciations and inters-glaciations. During inter-glacial and coupled with the tectonic activities, led to the development of such large fans.
- The evolution of the Santokgarh fault (which seems to be younger then HFT) also added to the influx of debris from the upper reaches.



Modified after Mukerji, 1988 Fig. 4.12

Mukerji, (1988) persented two models for the development of Doon fan systems. The models were about post-entrenchment and post-diversion pattern of rivers. He said that due to the tectonic movement or increased discharge, the axial got deeply entrenched forming the fan head trench and dismembered the distributaries from

SKETCHES SHOWING POSSIBILITY FOR THE EVOLUTION OF DOON VALLEY

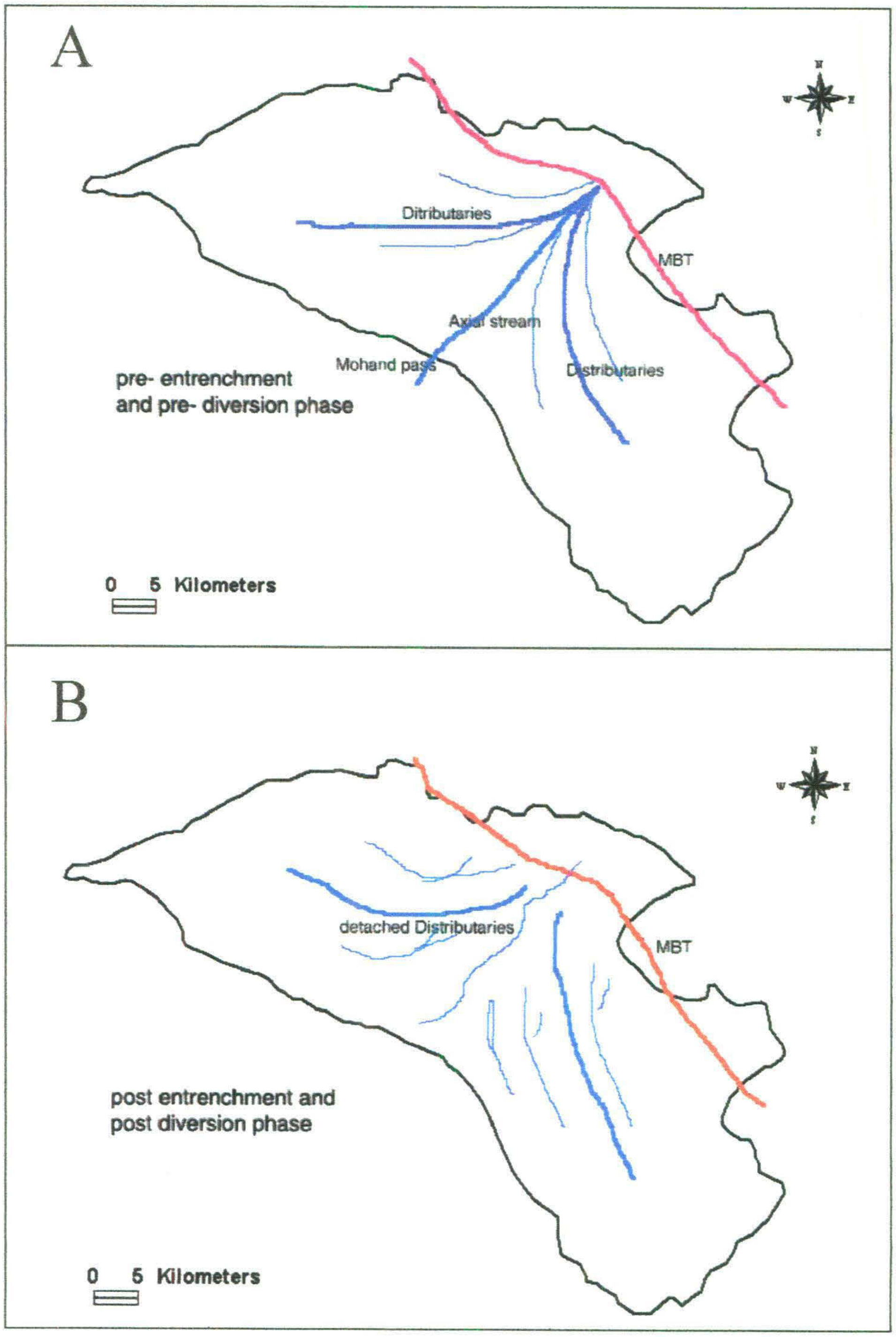


Fig. 4.13A and 4.13B

axial streams. As a result the upper parts of the streams were filled with fan detritus and completely plugged and now are at various stages of decay and filling. The stream in another model not only experienced entrenchment but also inversion in thalweg, which led to the breaching of bank and encompassing the radiating distributaries. The detached streams come to the inert stage and enlargement of the fan stops. This could be incorporated as one of the reason for the development of Doon fans in this region. This can be proved by the fact that many first order streams are lengthy then their second order streams. It may be possible that a large stream might descent from lesser Himalaya over the present day Dehradoon city (Fig. 4.13A and 4.13B). Following are the evidences in this support:

- The valley deeply entrenched in the center, north of dehradoon city.
- Mohand pass is just opposite to entrenchment in the same line, which might be an exit for assumed stream during the uplift of Siwalik and later on more uplift could easily stand against the weak power of the stream at the distal end.

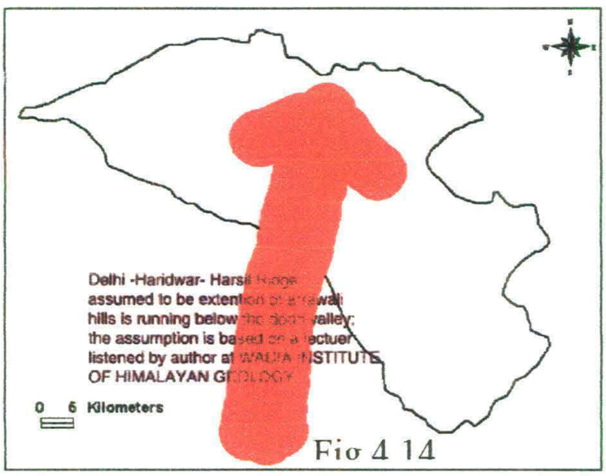


Fig 4.14

- Rivers to the both sides of this segment (Fig. 4.13A) are in accordence models in initial stage(Fig.4.2). As a result of diversion and entrenchment in later stage, the segment from Mussoorie, Rajpur, dehradoon, clement town and Mohand acted as water divide between the Asan and Song rivers.

Although these proofs are insufficient in explaining present day water divide,other possibilities may be the presence of Delhi- Haridwar- Harsil ridge extending below the Doon valley (Fig. 4.14). Rajal et al., (1986) quoted that the water divide may also be due to active tectonic in this region.

The above discussion shows that the Doon valley formed in sequential stages of evolution. It is made up of Doon gravel, a fan deposit. The tectonic movements and presence of interglacial phase (early Mindel- Riss interglacial (referred by Mukerji, 1988) initiated the fan formation. Koppen's Cwg climate brought monsoon rainfall, also established by this time. The establishment of Cwg climate is related to the upliftment of Himalaya. There was a continued change in the climate en episodic manner from arid, semi- arid to humid, favorable for fan formation. Tectonic movement and climatic oscillations coupled together might have led to the formation of such large fans. Axial stream entrenchment (Fig. 4.12) caused by recent tectonic movements led to the termination of fan forming processes. Due to the entrenchment even the high discharge of water could not reach to surface and the fans turned to the inert state, probably same as what we see today.

Chapter Five

Summary and Conclusion

The Doon valley, the green valley running NW to SE lies between the lesser Himalaya in the NE and Siwalik hills in the SW. It is a synclinal trough between two consecutive anticlines. These anticlines are the Mohand anticline in SW and the Santokgarh anticline in the NE. The valley is bounded by the river Yamuna and river Ganges in the NW and SE, respectively. It is 80 km. in length and 20 km wide within Siwalik and lesser Himalaya. The Mohand anticline is growing fold structure, uplifted the Siwalik range and restricted the drainage within the Doon valley. The uplift of Siwalik created a water-divide separating the NE flowing streams into the Doon valley from the SW flowing streams across the Siwalik range into the Bhabar plains. The Doon gravel, the post Siwalik sediments, were deposited as coeval sediments with the growth of fold structures and neotectonic activity along the Main Boundary Thrust. It is inferred that tectonic evolution of Doon valley began around 0.5 Ma.

This region falls in the category of neo-tectonic movement zone. It contains diverse flora and fauna and is also a region of growing civilization; hence needed to be studied in its totality. Recent political development such as creation of Dehra Doon as capital of Uttaranchal, also pose a great threat to the fragile ecosystem of the valley in the near future. For any study to be conducted in the Doon valley, it becomes essential to know about the evolution of Doon valley, existing landform and their development. This will help in the management of resources in the valley.

The average height of the valley lies between 300 to 600 meters above sea level. It bounded on both sides with relatively high relief. This causes to restrict the flow of rivers within the Doon valley. Rivers Asan and Suswa are flowing longitudinally and joining river Yamuna or river Ganges respectively. Mussoorie- Rajpur- Dehra Doon- Mohand act as water divide between the Asan and Suswa river systems.

Doon valley is composed of Doon gravels consist of boulder conglomerates that consist of Pebbles, Cobbles and boulders of sandstone, limestone, quartzite and schist. Sediments are largely derived from the lesser Himalayan formations and partly from the weathering of Siwalik formations, mainly the upper Siwalik. The climate of this region is similar to those in the plains. Locally, the temperature varies according to the elevations. In general climate is temperate and the year may be divided into four seasons viz. cold, hot, monsoon and post monsoon season. Geohydrologcal condition of the Doon valley shows that the main productive aquifer is found in the synclinal zone, along river the Asan and Song, and also along the Ganges and Yamuna. The water table contou,r that is the depth of water table below ground surface, shows variations from 340 feet to 600 feet. Water table contours are shallowest towards river Ganges in Song catchment area and is deepest close to the water divide of the Asan and Song River, north of Dehra Doon. In general, water table occurs at a shallow depth towards the distal parts of the fans, towards the Asan and Song River and at higher levels towards the proximal parts of the fan. Groundwater flow pattern is locally modified by fractures, faults, colluvial and fluvial deposits.

Natural vegetation of the region includes the vast range, varying from tropical to alpine species owing to the variation in altitude and aspects. Sal is the most dominant species found in this region and covers the maximum area among the tree vegetation. Mixed forest species include Chir Pine, Oak, Dhaula, Sisaru, Kala Bansa etc. Agriculture is mainly confined in the main valley in the west and east sides. Terraces are also cultivated as some patches are traceable in the mountainous region. Orchards are mainly confined around settlements and the easy modes of transport lines.

Morphometric analysis provides a clear picture of the physiography and the intensity of processes operating to modify the surface. The whole region is taken as one complete basin because the boundaries are either coincide with water divide or by the rivers Yamuna and Ganges. Basin morphometry constitutes three types of properties of areal, linear and relief. Linear properties are stream ordering, bifurcation ratio. Stream numbers, stream length etc; areal properties are stream frequency, drainage texture, drainage density and relief properties are average relief, relative relief dissection index and ruggedness index. The values of all these morphometric parameters are categorized into five classes such as very high, high, moderate, low and very low. The cumulative area occupied by all these morphometric parameters falls in low to very low category, which suggests that geomorphic activities are acting weakly in the valley.

The other factor that is operating in this region is continued tectonic activities. These are termed as neotectonic activities. Various active faults are located in this region such as Donga fault, Bhelonwala fault, Dholkhand fault, HFT, MBT etc. Reactivated faults lead to the dislocation of many streams, alluvial fans, and river terraces etc. The Doon valley experienced severe tremors of the Kangra Earthquake in 1905 and Uttarkashi Earthquake in 1991. MBT and HFT are reverse fault while Ganges and Yamuna faults are tear fault. Landforms of Doon valley are not only representative of prevailing or past climate but Tectonism played a very important role in the evolution of landforms of the Doon valley.

Landform is a function of spatial and temporal distribution of resisting and disturbing forces. For any set of environmental conditions, through the operation of constant set of processes, there will be tendency over time to produce a set of characteristic features. The spatial distribution of landforms is shown with the help of distribution of geomorphological features over the space where as temporal characteristics is adjusted by stratigraphic analysis. The Stratigraphy of Doon valley shows that lithologically lower Siwalik are made up of sandstones and interbedded mudstones with thickness of about 2000 meters and age is about 14 Ma to 18 Ma, middle Siwalik shows multistoried sandstone with pebble and mudstone siltstone with planner stratification with thickness of about 1800 meters and age as about 10 Ma to 6.7 Ma, the upper Siwalik having thickly bedded massive conglomerate in sandy matrix and interbedded sandstone with thickness of about 2000 meters and age is from 0.5 Ma to 5 Ma and above which lies doon gravel. Old Doon gravels and Doon fan gravels constitutes thickly bedded massive conglomerate embedded in sandy silty matrix with thickness of about 600 meters and age is from recent to 0.5 Ma. The spatial distribution of geomorphological features is divided into three broad categories; these are Siwalik range, Doon valley and other fluvial features. Doon valley features are mainly fan deposits and covers the maximum area among other features as a result it becomes important to study Doon valley features and their evolution. Visual interpretation shows that these features are mainly occur in main Doon valley.

There are three stages in the development of Doon valley. In first stage the slope of the streams was not steep enough to bring down to the plains any course debris. This stage was prior to the Pleistocene period. It was only towards the commencement of Pliocene Himalayas attained their height comparable to present. Earlier the source of sediments was inner Himalaya. The sediments of the lower Siwalik are probably of this time. The second stage was around 10 Ma in the late Miocene period the MBT was initiated. The initiation of MBT caused the increase in gradient, which led to the drastic change in the bed load and the source lithology changed from inner lesser Himalaya to outer lesser Himalaya. This is the period of middle and upper Siwalik sedimentation. This is from the period of late Miocene to early Pleistocene. The depositional environment constitutes mainly sheet flood braided streams on distal sandy alluvial fans in the middle Siwalik sedimentation and mainly gravel load braided streams and sheet flood on distal alluvial fan in upper Siwalik sediments. All these activities happened up to 0.5Ma till the initiation of HFT. The third stage is directly linked with the formation of the main Doon valley. Filling started just after creation of syncline, earlier debris brought by rivers used to spread in the foreland of the lesser Himalayas. The development of HFT initiated the formation of the Doon valley and coeval deposition of Doon gravels. Upper age limit of the upper Siwalik is estimated at 0.5 Ma, which is also lower age limit of the Doon gravels. Doon fan deposition is directly linked with neotectonic movements and changes in the climatic conditions. There are still many queries, which are not yet known correctly, such as the formation of large fans evolution and present pattern of drainage system etc. But the facts and figures presented here to find out the solution and other finding of environment and landform evolution of the Doon valley can be concised as follows:

- The Doon valley evolved as a result of intricate superimposition of alternate depositional phases, caused by climatic changes and crustal movements over the past hundred thousand years.
- Intensity of morphometric parameters in modifying the surface are operating very weakly. Tectonic movements gain importance in such times.
- The Doon valley fans evolved from the upper Pleistocene to early Holocene periods and a time of glaciations and inters-glaciations, coupled with active tectonic activities.
- The Mussoorie- Rajpur- Dehra Doon- Mohand water divide is probably formed as a result of entrenchment and diversion of axial streams, or due to the sub-surface Delhi- Haridwar- Harsil ridge movements.

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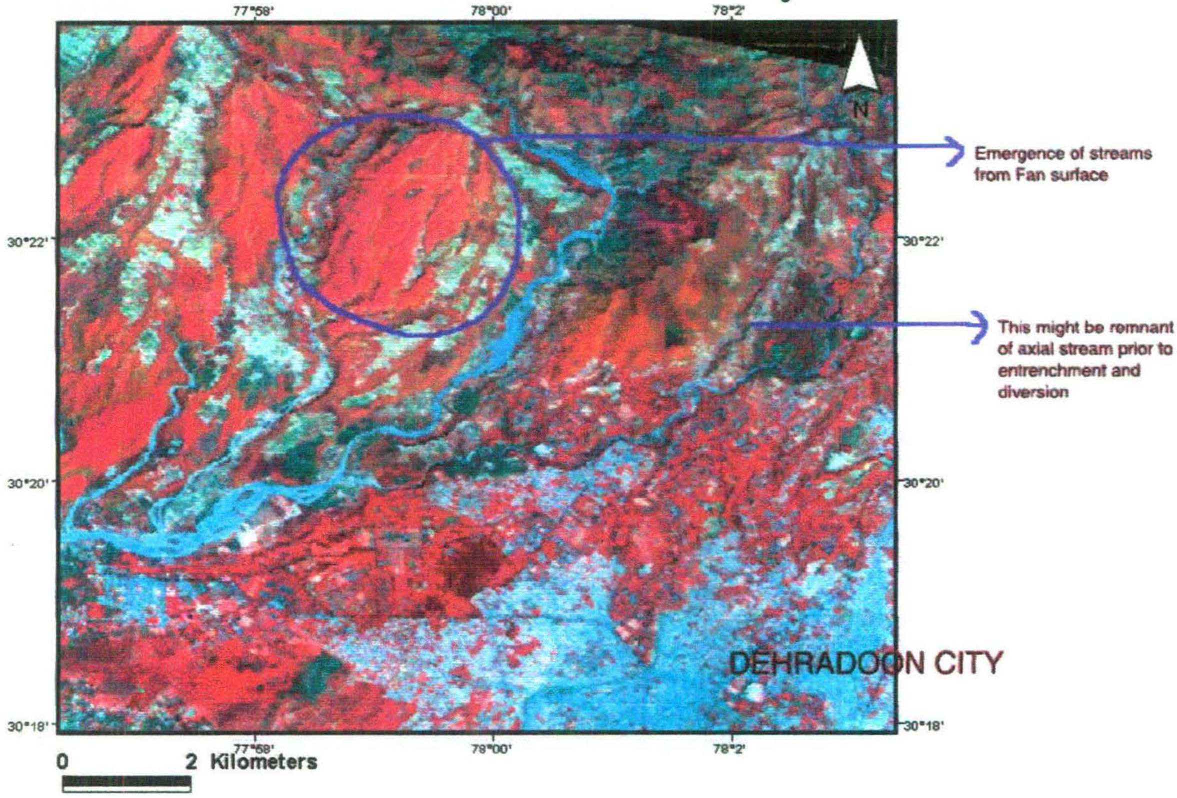
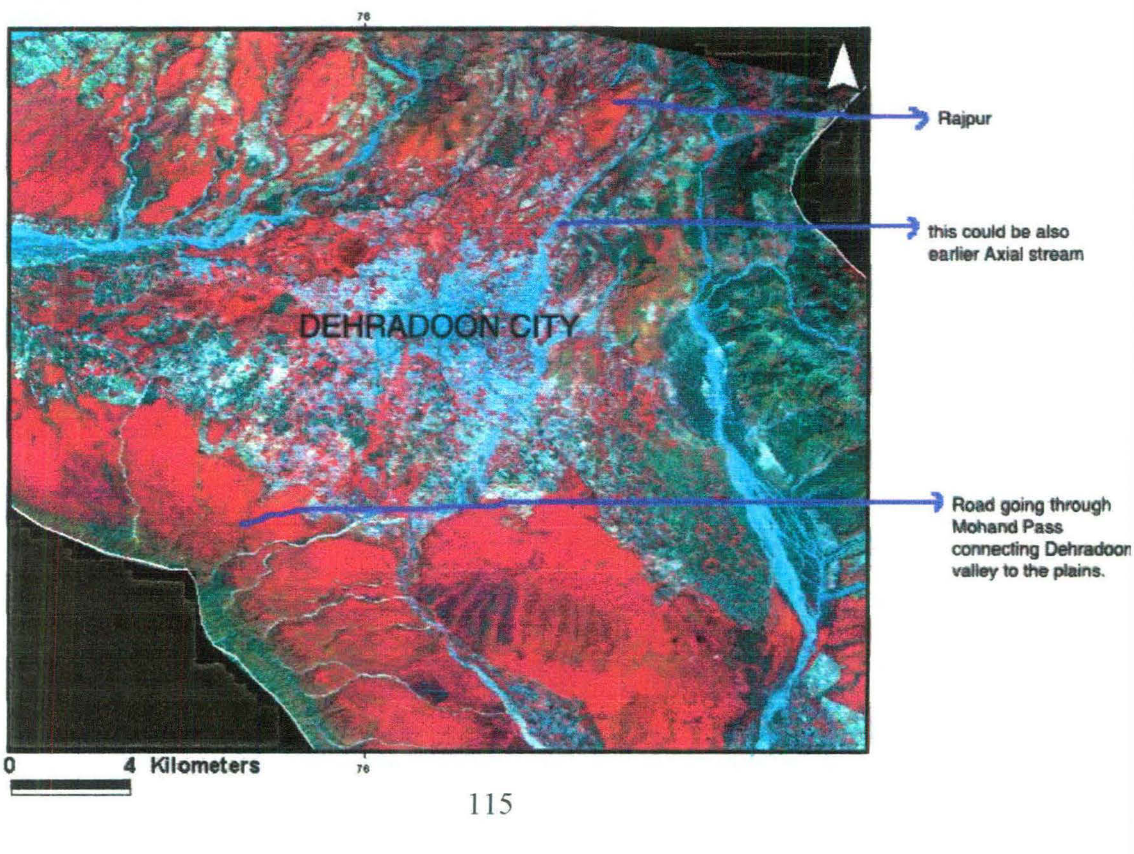
Plate: 1

Satellite imagery showing the evidences of evolution of Doon Valley





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plates

Plate:2 and Plate:3

Modified after Nossin, 1971

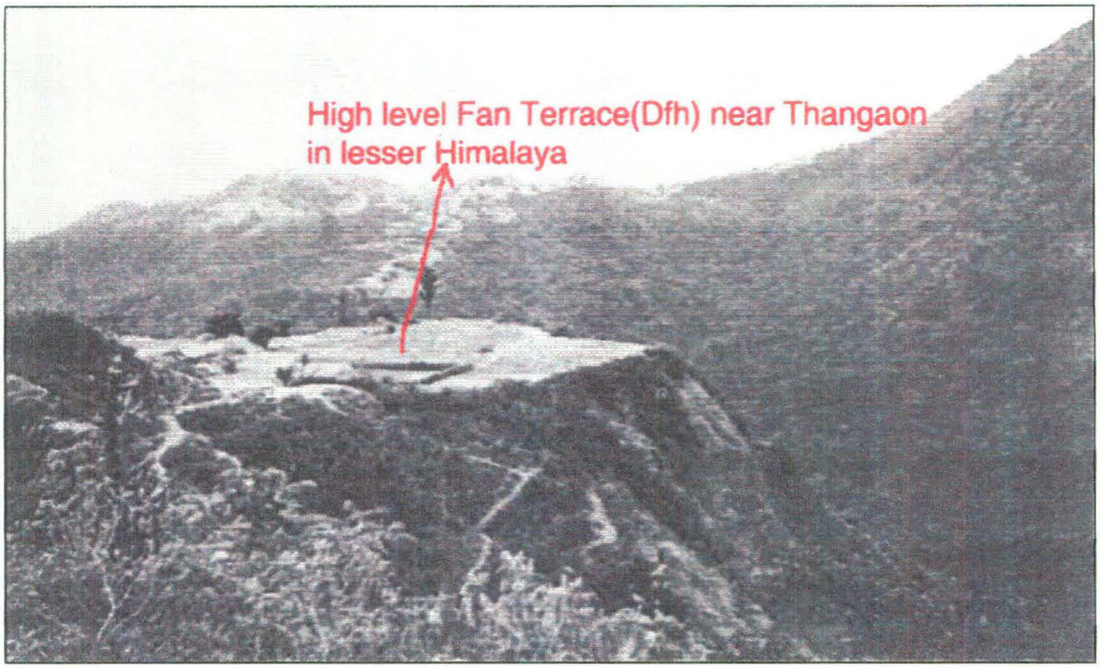


Plate:2, showing high level fan terraces

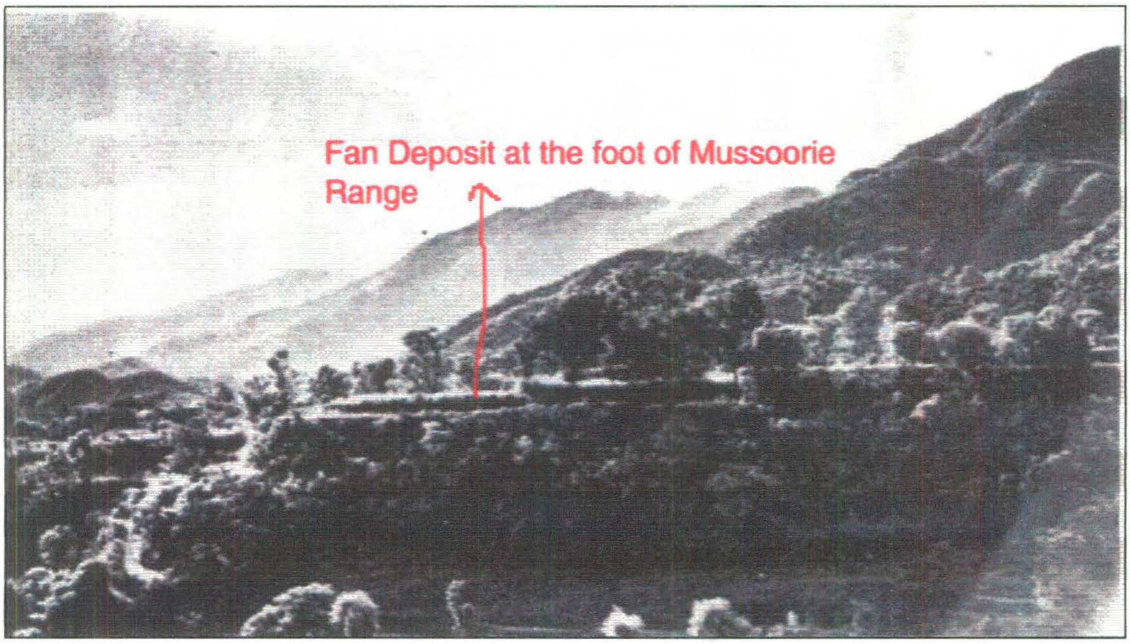


Plate: 3, high level Fan Terrace at the foot of Mussoorie Range

Plate: 4 and Plate: 5

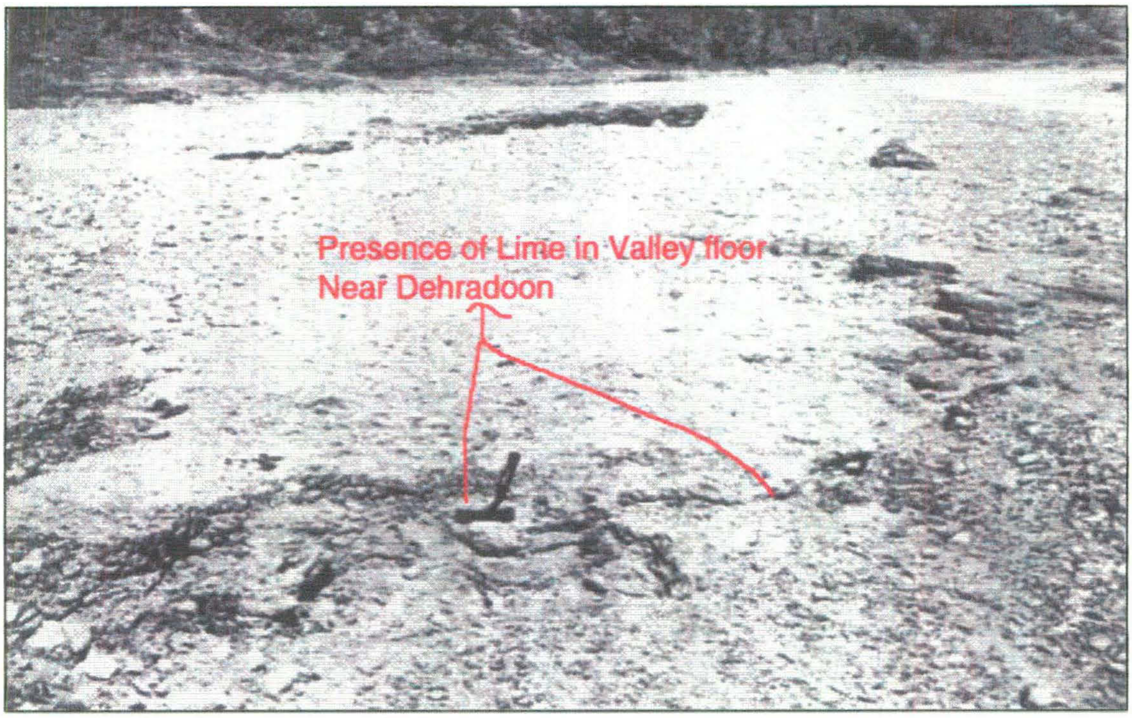


Plate: 4. showing presence of Lime in valley floor, Adopted from Nossin, 1971

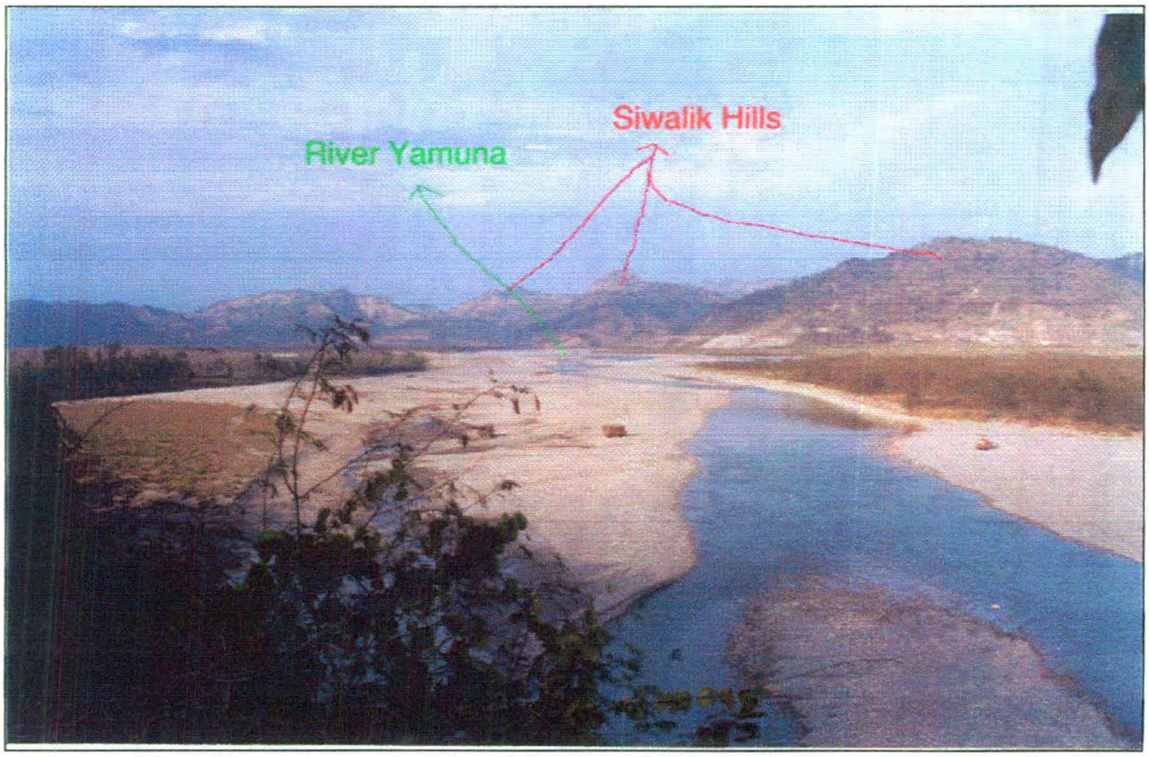


Plate: 5, River Yamuna entering the plain viewed from Kalesar, from west bank of river, Siwalik Hills are in the background

Plate: 6

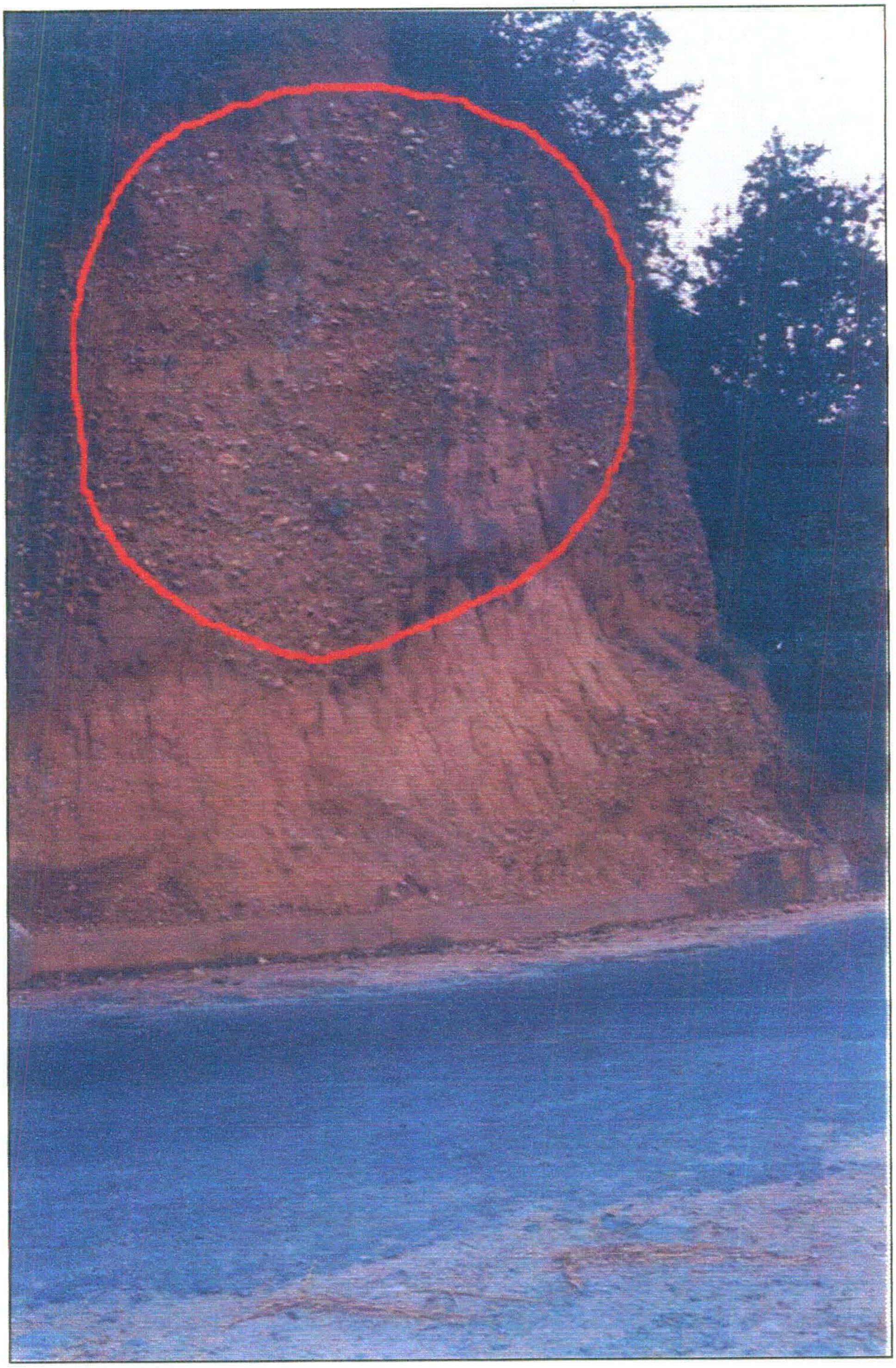


Plate: 6, Upper Siwalik formations exposed along road in western Doon Valley in Southern Siwalik, conglomerate are seen in side circle

Appendices

Appendix – I

Hierarchy of Spatial and Temporal scale in Geomorphology

Hierarchy of spatial and temporal scales in geomorphology

SPATIAL SCALE	DIMENSIONS		EXAMPLES OF LANDFORMS				MAJOR CONTROLLING FACTORS		TEMPORAL DURATION SCALE	
	Linear (km)	Areal (km^2)	Endogenic	Exogenic: Fluvial	Exogenic: Glacial	Exogenic: Aeolian	Endogenic	Exogenic		
Micro	<0.5	<0.25	Minor fault scarps	Pools and riffles in a small river channel	Small moraine ridges	Sand ripples	Individual earthquakes and volcanic eruptions	Microclimates; meteorological events	Steady time	10^1 a
Meso	0.5–10	0.25–10^2	Small volcanoes	Meanders	Small glacial valleys	Dunes	Local and regional isostatic uplift; localized volcanism and seismicity	Local climates; short-term climatic change	Dynamic time	10^3 a
Macro	10–10^3	10^2–10^6	Block-faulted terrain	Floodplains of major rivers	Highland ice caps	Sand seas	Regional uplift and subsidence	Regional climates; long-term climatic change (glacial-inter-glacial cycles)	Cyclic time	10^7 a
Mega	>10^3	>10^6	Major mountain ranges	Major drainage basins	Continental ice sheets	Large sand seas	Long-term patterns of uplift, subsidence and continental motion	Major climatic zones; very long-term climatic change (ice ages)		

Adopted from Summerfield, 1996. Pp.13

Appendix - II

PARTICLE SIZE

Table indicates the main size classes used in the description of sediments. More detailed information can be obtained from any textbook on sedimentology. The phi (φ) scale is widely used in the description of sediments. It is an inverse logarithmic scale where a particle size of 1 mm is given a φ value of zero. The convenience of the φ scale arises from its small numerical range in comparison with the metric equivalent. Grain sizes have traditionally been determined using square-meshed sieves or, for fine particles, pipette and hydrometer techniques. Automated sediment size analyzers employing laser technology are, however, now becoming available.

Table Major class intervals used in description of sediment sizes

mm	φ	SIZE CLASSES	
		Boulder	*Gravel*
256	-8		
64	-6	Cobble	
32	-5		
16	-4	Pebble	
4	-2		
2.83	-1.5	Granule	
2.00	-1.0		
1.41	-0.5	Very coarse sand	*Sand*
1.00	0.0		
0.71	-0.5	Coarse sand	
0.50	1.0		
0.35	1.5	Medium sand	
0.25	2.0		
0.177	2.5	Fine sand	
0.125	3.0		
0.088	3.5	Very fine sand	
0.0625	4.0		
0.031	5.0	Coarse silt	*Silt*
0.0156	6.0		
0.0078	7.0	Fine silt	
0.0039	8.0		
		Clay	*Clay*

Source: Based on F. J. Pettijohn *et al.* (1972) *Sand and Sandstone* Springer-Verlag, New York. Table 3-2, p. 71

Adopted from Summerfield, 1996

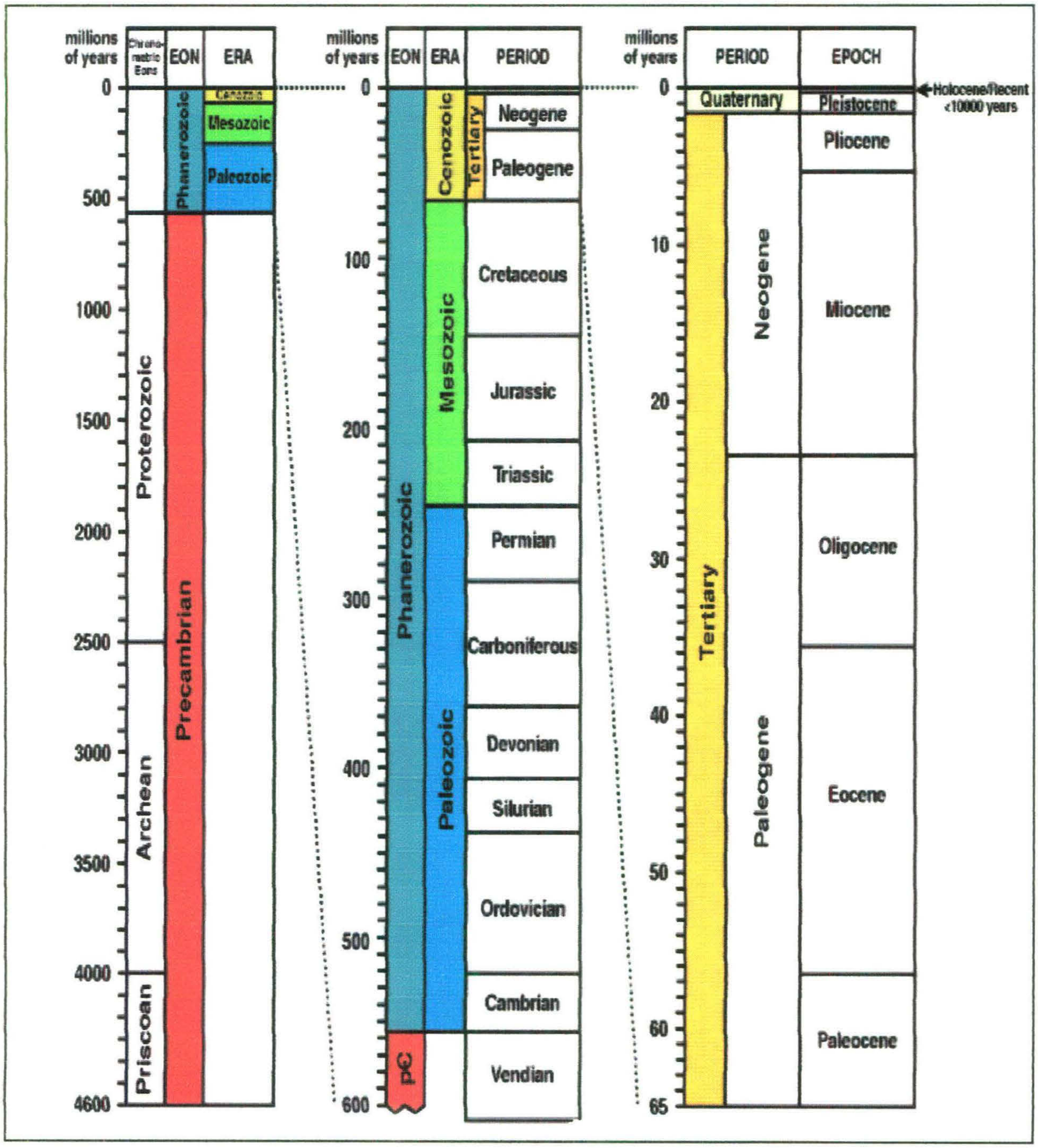
Appendix – III

GEOLOGY OF INDIA

Eras	Epochs	Periods	Major Events	Distribution	Lithology	Speciality
Neozoic	Quaternary	Holocene	Neo-tectonics	Coastal streches	Marine & lagoonal Khadar sand dunes, laterites	Shore zones
	1 my.	Pleistocene	Wurm, Riss, Mindle, Gunz	Coastal areas, Alluvial	Sedimentaries, Fluvio-glacial, conglomerate, silts, lagoons, lakes	Oil bearing, mammalian fossils
Cainozoic	Tertiary (Shiwalik)	Pliocene	–			
		Miocene	–	J & K (Murree series), Assam, Gujarat, Orissa	Tertiary coal, Shale, clay	Marine fossils
		Oligocene	Ganga Trough	Assam		do
		Eocene	Karakoram Folding	Assam, Meghalaya, Pondicherry	Coal bearing (Lignite), Sandstone	do
	60 my. (Deccan Trap)	Palaeocene	Karakoram folding	Kutchh, Surat	do	do
Mesozoic (reptiles)	Secondary	Cretaceous	Deccan Lava eruption	Hima, Meghalaya, Pondicherry, Tiruchirappalli, Raghavan Rada formation	L.St., Shale, S.Stn. Basalt	Marine, lacustrine, Estuarine
		Jurassic	Drifting initiated	Himalayan Area, Marine Transgression in Rann, Raj., H.P.	L.St., Conglomerate, Shale	Reptile fossils
	300 my.	Triassic		Central Him., Nepal, Kumaon	L.St., Shale, Sand St.	
Gondwana		Permian	Permo-Carboniferous glaciation	Damodar, Mahanadi, Godavari valley, Sikkim, Darjeeling	Fluviatile, Lacustrine, conti.	Trilobite (index fossil)
		Carboniferous		Mt. Everest, Ea. Himalaya, Siwaliks	L.St., Shale, dolomite, Quartzite, coal, glacial boulders	Coal formation, glossopteris
Dravidian	350 Primary				Quartzites	Unfossiliferous
Palaeozoic (Dravidian)		Devonian	–	H.P. (Kandhar), J & K		
			–	H.P., U.P., J & K	Sedimentary	Brachiopods, Chain corals
	450	Silurian	–	Lidar valley (J & K), Kumaon	S.St., L.St., Qtzite, grit, conglomerate	
	500	Ordovician	–		Sedi., meta.	Fossiliferous
	600 my.	Cambrian		Spiti valley (HP), Baramula (J & K), Kumaon, Salt Range		
Purana, Proterozoic (Puranic)		Pre-Cambrian	Vindhyan		Diamond horizon, do	Sedimentary marine
	1400 my.		Cuddapah	A.P., Chhattisgarh, Singhbhum, Aravalli, Orissa	Clay, slate, S.St., L.St., quartzites	do
Azoic (Archean)		Archean (when part of Pangea)	Dharwar System	Karnataka, Aravalli, Jharkhand (Hazaribagh)	Igneous, metamorphic	Unfossiliferous
	4000 my.		Archaean Gneisses and schists	Chhattisgarh (Bastar), Orissa (Keonjhar & Sundargarh), Himalayas (J & K, H.P., Uttar.)	crystalline	

Largest metallic mineral; most ancient metamorphosed rocks of India.

Appendix – IV
Chronology of Geological Time Scale



Appendix - V

DEFINITIONS:

Cwg:

This is a climatic classification given by Vladimir Koppan in year 1900. He was a German Botanist and Climatologist. He took temperature and precipitation as the basis for statistical parameters for delineating the various climatic regions. C stands for humid mesothermal middle latitude warm temperate climate, having mild winters, average temperature of warmest and coldest month between 8 to 18 degree and below 18 respectively, w: for winter dry season and g: stands for hottest season preceding precipitation.

Dharamshala formation:

These are the oldest formations among the Siwalik groups.

Paleosol:

An ancient soil horizon or buried fossil in which organic remain provide possibilities of dasting and reconstructing paleoenvironment by the means of radiocarbon dating and pollen analysis. Pleistocene solifluction deposits.

Phyllites:

Cley sediments altered by low-grade regional metamorphism into a metamorphic rock between slate and schist, it is coarser grained less perfectly cleaved then slate.

Stratigraphy:

The branch of geology, which deals with the composition, sequence and spatial distribution, classification and correlation of the stratified rocks.

Subathu formation:

The youngest lithostratigraphic unit of lesser Himalaya occurring uncoformably upon tal as well as the the charkrata. Comprising siltstone and mudstone with intercalation of shelly limestone of Eocene age. Anmed after town Sapathu or Sabathu in Himachal Pradesh.

Unconformity:

Geological term referring to a break in sequence, marked by major break in sedimentation or by structural planner surface separating younger rock above and older rocks below. It generally represent unspecified period of unrecorded time.

Appendix - VI

FEW IMPORTANT PLACESOF DEHRADOON