CHAPTER 1

INTRODUCTION

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I. 1. GLACIER DEFINITION

Glacier is defined as a mass of perrineal ice (with included rock debris and air) produced from recrystallisation of snow and flows down a gradient under the influence of gravity.

I. 2. GLACIER DISTRIBUTION

At present glaciers cover 10% of earth surface and contain 33 $x10^6$ km^3 by volume whereas 14.9 $x10^6$ km^2 by areal extent (Table 1. 1). Of this about 12.5 $x10^6$ km^2 is accounted by the Antarctica Ice sheet and 17.5 $x10^6$ km^2 by Greenland Ice sheet (Flint, 1971). This leaves a mere 700,000 km^2 (or 4% of total area) of glacier ice distributed among other glacierized areas; this is located in many ice caps which rarely exceed 10,000 km^2 in extent (mostly in high latitude) and in many thousands of small glaciers in the upland areas of the world.

Table 1.1. Present day Glacier Extent (Flint, 1971)

Region	Area (Km^2 approximate)	Sub-totals
South Polar region		
Antarctic ice sheet (excluding ice shelves)	12,535,000	
Other Antarctic glaciers	50,000	
Subantarctic islands	3,000	
		12,588,000
North Polar region		
Greenland ice sheet	1,726,400	
Other Greenland glaciers	76,200	
Canadian Arctic archipelago	153,169	
Iceland	12,173	
Spitsbergen and Nordauslandet	58,016	
Other Arctic islands	55,658	
		2,081,616
North American continent		
Alaska	51,476	
Other	25,404	

		76,880
South American Cordillera		26,500
European continent		
Scandinavia	3,810	
Alps	3,600	
Caucasus	1,805	
Other	61	
		9,276
Asian continent		
Himalaya	33,200	
Kun Lun Chains	16,700	
Karakoram and Ghujerab- Khunjerab ranges	16,000	
Other	49,121	
		115,021
African continent		12
Pacific region (including New Zealand)		1,015
	Grand Total	**14,898,320**

Out of 14.9 $x10^6$ km^2 area of world's glacierized area, Himalayas account for 33,200 km^2 glacial extents and even in that Indian Himalayas comprises of 23,000 km^2 area (Kulkarni and Buch, 1991). There are 5000 glaciers presently existing in Himalayas, out of these, 2,550 glaciers are reported in H.P. alone which holds ice reserves of 383.3 km^3 (Srikantia and Bhargava, 1998).

I. 3. PRESENT AND PAST GLACIAL ACTIVITY

The Himalayan glaciers are classified into Alpine type of valley glaciers and are considered to be *treasurehouse* of central Asia. The research carried out by various scientists suggests that Since Pleistocene like other regions of world (Table. 1.2)

Table 1.2. Pleistocene glaciation (Dorothy and Winstanley, 1987)

Age(years BP)	*Britain*	*N.W.Europe*	*Central Alps*
	Flandrian	Holocene	Holocene
10,000 -			
	DEVENSIAN	WEICHSELIAN	WURM

70,000-			
	Ipswichian	Eamian	Riss/Wurm
125,000-			
	WOLSTONIAN	SAALIAN	RISS
175,000-			
	Hoxnian	Holsteinian	Mindel/Riss
320,000-			
	ANGLIAN	ELSTERIAN	MINDEL
480,000-			
	Cromerian Beestonian Pastonian	Cromerian Complex	Gunz/Mindel
820,000-			
	BAVENTIAN	MENAPIAN Waalian EBURONIAN	GUNZ DONAU/GUNZ DONAU
1,700,000-			
	Antian Thurnian Ludhamian	Tiglian	Biber/Donau
2,000,000-			
	WALTONIAN	PRAETIGLIAN	BIBER

Himalayas also have experienced four times glacial and five interglacial phases as shown in (Table 1.3).

Table 1.3. Suggested correlation of glacial stages with the Upper Siwaliks of N.W.India (H. De Terra, 1939)

Period		**Stage**	**Fauna**	**Glacial cycle in Kashmir**
Pleistocene	Upper	Re-deposited silt	Living species.	4th ice advance. Terminal moraine at 2,400 to 3,050 m.
		Erosion		3rd interglacial : erosion
	Middle	*Potwar* : yellow,loess-like silt, and gravel	Narmada fauna in "upper group"	3rd ice advance: 3-4 recessional moraines. Terminal moraines at 2,000 m
		Erosion		Long 2nd Interglacial: Upper Karewa beds
		Boulder-	Narmada fauna. equus,	2nd ice advance :

		conglomerate stage	Buulus, Hippopotamus, Elephas namadicus	boulder clay and gravel in karewa beds
	Lower	Pinjor stage	Equus, El. namadicus, Bos, Sus rhinoceros, Cervus, Felis, Sivatherium	1st Interglacial; Lower Karewa beds, birch, oaks, pine –forest.
		Tatrot stage	Steegodon bombifrons, Hippohyus, Hexaprotodon, Pentalophodon Falc.	1st ice advance. Terminal moraine at 1,675m.
Pliocene		Dhok Pathan stage	Hipparion, Tragocerus, Stegolophodon,Bramtherium	

The latest being the Little Ice Age (LIA) which is believed to last from 1550 A.D. up to recent 1920* A.D., a global cooling occurred where majority of glaciers advanced globally, often on more than one occasion (Lamb,1963;1972; Manley,1971). But the globally accepted time for LIA is from 1550-1850 A.D. Subsequently, until about 1940, glaciers around the world are retreated as climate warmed. Glacier retreat declined and reversed in many cases from 1950 – 1980 as global cooling occurred. Since, 1980 glacier retreat has become increasingly rapid and ubiquitous, so much that it has threatened the existence of glaciers of the world. The process has increased markedly by 1995 (www.nichols.edu). Studied by glaciologists the temporal coincidence of glacial retreat with the measured increase of atmospheric greenhouse gases is often cited as an evidentiary underpinning of anthropogenic global warming. Mid latitude mountain ranges such as Himalayas, Alps, Rocky mountains, Cascade range, and Southern Andes as well as isolated tropical summits such as Mount Kilimanjaro in Africa are showing some of the largest proportionate glacial loss (IPCC, 2001). Excepting the ice caps and ice sheets of the arctic and Antarctic, the total surface area of glaciers worldwide has decreased by 50% since the end of 19th century (www.munichre.com).

*(*From a purely climatic point of view, there seems to be justification from limiting the Ice age to a shorter period than this (see Lamb, 1972); while from glaciological data, Denton and Karlén (1973) argued that the phase lasted from the fourteenth century at least until 1920.)*

Since 1850, the Himalayan Glaciers are in a state of recession (Mayewski and Jeshke, 1979) and the rate of recession is accelerated in recent times (Leet and Judson, 1969). These observations are based on fluctuations of glacial snout (Jangpang and Vohra, 1962; Kurien and Munshi,1972; Srikantia and Pandhi, 1972; Vohra, 1981). Investigations of Baspa basin, a tributary of Sutluj river suggests 19% deglaciation from 1962-2001 (Kulkarni and Alex, 2003).

I. 4. SOCIO-ECONOMIC SIGNIFICANCE OF GLACIERS

The loss of glaciers not only causes landslides, flash floods, glacial lake overflow, but also increase annual variation in water flows in rivers. Hence, glaciers play a vital role in maintaining constant stream flow, governing the climate and it has manifold importance to human life. If these rates continue, power generation, irrigation and other allied benefits from rivers fed by glaciers will start diminishing and even water scarcity will develop at places where river is perennial due to glacial melt. So, glacier study has become a focus of research and attracted scientists from diverse branches all over the world as it has now become very important to know the past and present trend of glaciers. As humans continue to alter the radiation balance of the earth through the burning of fossil fuels and other human activities, understanding past climate variability as a means to predicting future change becomes ever more important, and represents one of the great challenges for modern science. In above perspective, an attempt has been made here to understand the paleoglacial activity of Baspa valley and following *objectives* were selected for the present study.

I. 5. OBJECTIVES

1] *To analyze various Remote Sensing and GIS techniques for glacial geomorphic mapping.*

2] *Delineation of lower limit of glaciation.*

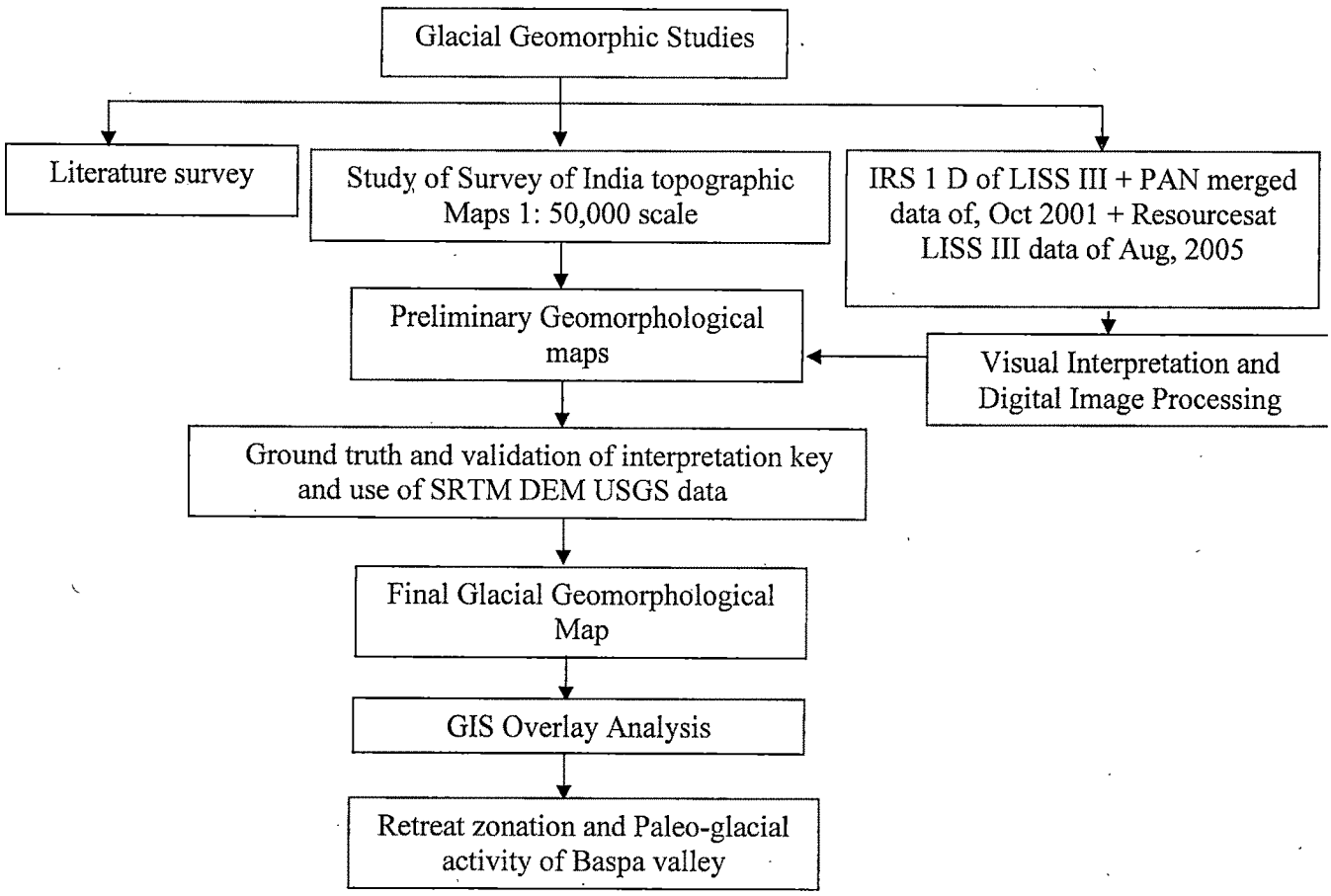
3] *Systematic mapping of glacial geomorphic features and understanding its processes.*

4] *Interpretation of geomorphic features (indicators) for understanding past glacial activity.*

In order to achieve aforementioned *objectives* following *methodology* was adopted.

I. 6. METHODOLOGY

For the present study Survey of India topographic maps of the year 1962 are used as a base map for delineation of glacial geomorphic features of Baspa valley. The preliminary glacial geomorphic map has been prepared from IRS 1D LISS III + PAN merged data of 2001, and Resourcesat, LISS III data of Aug, 2005 using visual interpretation key and is validated in the field. The expedition is completed for four glaciers viz., Shaune, Billare, Shailpya and Jorya garang. After extensive ground truth, literature survey and use of SRTM DEM data for extracting some of the features from satellite data, a final glacial geomorphological map of Baspa valley has been prepared. using GIS overlay analysis of various themes viz; glacial boundaries prepared from topographic maps, satellite data and slope map etc, the glaciers of Baspa valley are categorized into different zones of retreat i.e. Very Low - Very Very High. The *flowchart* of the methodology is as shown below:



With this objective and methodology a study has been carried out for Baspa valley of Himachal Pradesh.

I. 7. STUDY AREA

The Baspa basin (Fig.1.1) is placed between $31^0$30'17.16" N to$31^0$10'01.00" N Lat and 78^0 10' 26.52" E Long to 78^0 52' 41.75" E Long. It is located in south-east corner of Kinnaur district, H.P (Fig 1.1). It occupies 1100 sq. km spread over survey of India toposheet (Nos. 53 I/7, I/8, I/11, I/12, I/15 and I/16) with an elevation ranging from 1770 m asl to 6465m asl. The Baspa river which starts near the Indo-Tibetan border flows through Kinnaur forming an exquisitely beautiful valley inhabited from Chhitkul (3475 m) to the rivers junction with the Sutlej river at Karchham (1770 m asl). A large part of this 75 km long valley is either arable land or covered with forest. The forests lie in middle slopes while cultivated areas lie in lower slopes. Barren ranges covered by snow from the upper half of valley extend almost up to the village Chhitkul and beyond up to the main Baspa Bamak glacier. Baspa valley is characterized is lofty snow peaks, with a total of 35 important north and south facing glaciers exhibiting erosional glacial geomorphic features such as horns, arêtes, hanging valley, empty cirques, and frost shattering in rocks while depositional glacial geomorphic features such as terminal moraines and lateral moraines, which indicate past glacial activity in the valley. Other characteristics are deep gorges, lush green vegetation, fast flowing rivers, flower beadecked meadows, enchanting waterfalls etc.

Field Investigations were carried out for Shaune garang (NE facing glacier), Shailpya garang (S facing glacier), and Jorya garang (NE facing glacier) glaciers in Baspa valley. This and above mentioned geomorphic features made the area more interesting from the point of view of research of reconstruction of paleoglacial history. Sangla, Rakchham and Chhitkul are one of the most famous; not much explored but guaranteed one of the finest tourist spots in the Baspa valley where international as well as national tourists are spotted making expeditions.

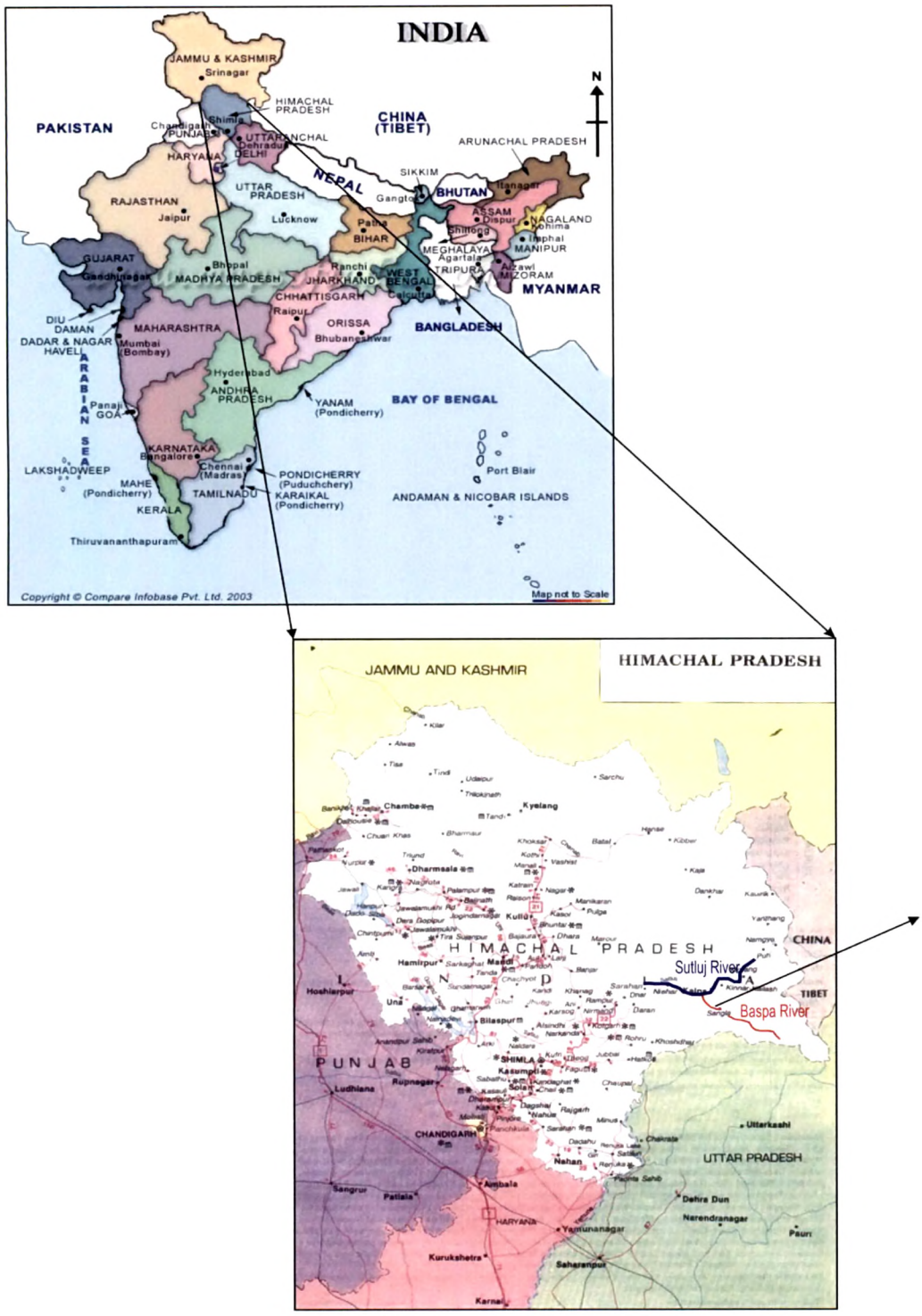


Fig 1.1. Location Map

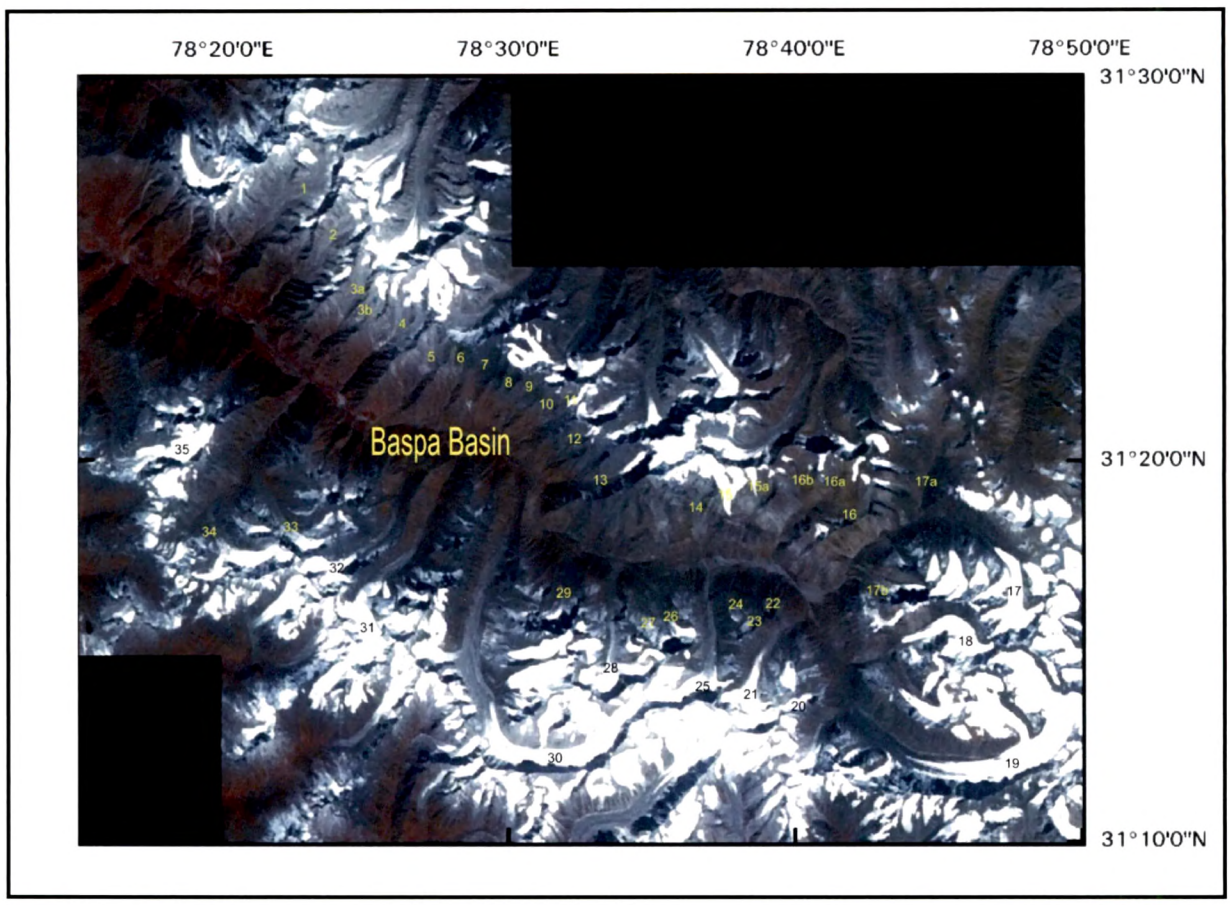


Fig 1.1. Location Map - [IRS LISS III + Pan merged image of study area exhibiting number of glaciers]

I. 8. COMMUNICATION

The Baspa valley is connected by a motor road with the main Indo-Tibet road i.e NH-22.The journey of Baspa valley starts at Karchham which is located 571 km from Delhi and 220 km from Shimla. The route is as follows- NewDelhi-Chandigarh-Shimla-Sangla-Rakchham-Chhitkul. Nearest railheads and airport is Shimla. Taxis are easily available from Delhi, Chandigarh, Shimla, Rampur and Peo. PWD rest house and hotels are also available at Sangla (18km from Karchham), Rakchham 13 km from Sangla and Chhitkul (28 km from Sangla). Chhitkul is the last village in Baspa valley located on right bank of the river at 3475 m asl. Chhitkul onwards only mule track is available in order to reach the glaciers.

I. 9. PHYSIOGRAPHY

Himachal Pradesh comprises of a bundle of hilly and mountainous terrain (Fig. 1.2). Earlier glacial and fluvial activities have shaped the landscape what we see at present day which shows deep gorges and rising mountain peaks with steep slopes and varying relief. There are both longitudinal as well as transverse ranges. Here elevations above mean sea level vary from as low as 300 m in the south, adjacent to the great plain of Indus-Ganga Alluvium, to as high as 6975 m at the peaks of great Himalaya Range in Kinnaur district bordering Tibet. Incerase in altitude is generally observed to rise from south to north and generally from west to east. H.P. is broadly divided into five physiographic zones (i) Alluvial Plain - It is an intermittent and insignificant zone and forms the southern fringe area. It has an average altitude of 500 m. (ii) Sub-Himalaya – This is the outermost and lowest zone of mountainous area which covers roughly a fourth part of Himachal Himalaya to the SW. The outermost range of this zone is known as Siwalik Range. It ranges in altitude from 335 m to 1524 m. (iii) Lower Himalaya – This forms a broad zone between the Sub-Himalaya and Great Himalaya.

It ranges in altitude from 1524 m to 5181 m. The Dhaoladhar and Pir Panjal are the two important mountain Ranges of this zone. (iv) Great Himalaya – The Great Himalaya is the most outstanding physiographic feature of the Himachal Himalaya. It is 25-30 km broad and extends from Lahaul in the northwest to Kinnaur in the southeast and represents a zone of high peaks, rugged slopes and perpetual snowfall. It has an average height of 5791 m with several peaks projecting over 6096 m and mainly concentrated in

Central Lahaul and South Kinnuar areas. (v) Higher Himalaya – The mountainous zone northeast of the Great Himalaya range is grouped under the Higher Himalaya because it is a zone of high ranges (3962 m to 6705 m). In the extreme southeast part of Himachal Himalaya there is an almost N10° W – S10° E trending major transverse ridge of the Zanskar mountains which separates Himachal from Tibet (Srikantia and Bhargava, 1998).

Baspa valley falls within Greater Himalayas and heights within Baspa basin vary between 1770 m asl to 6560 m asl. the altitude increases from W-E and S-N. The Baspa basin falls between Great Himalayan Range (GHR) and Zanskar range. This area lies North of Pir-Panjal and Dhauladhar range which is marked by snow capped peaks, glaciers and old U-shaped valleys. Average elevation of Himalayan peaks in this zone is about 5500m above mean sea level. This geomorphic zone comprises of crystalline rocks, granites and fossilliferous rocks and presents totally rugged terrain of the area. Some mountain passes of the area are Parangla (5548 m), Kangla (5248 m), Pin Parbati (4802 m), Kunzum (4551 m), and Baralacha (4512 m). There are several huge glaciers viz; Baspa Bamak, Sonapani, Chandra, Yonam, Joryagarang, Gara, and Barashigri. This zone is the source of origin for the Chenab, the Ravi, the Beas, the Spiti, the Baspa and the Pabbar rivers which are snowfed rivers (State of environment report, H.P, 2000).

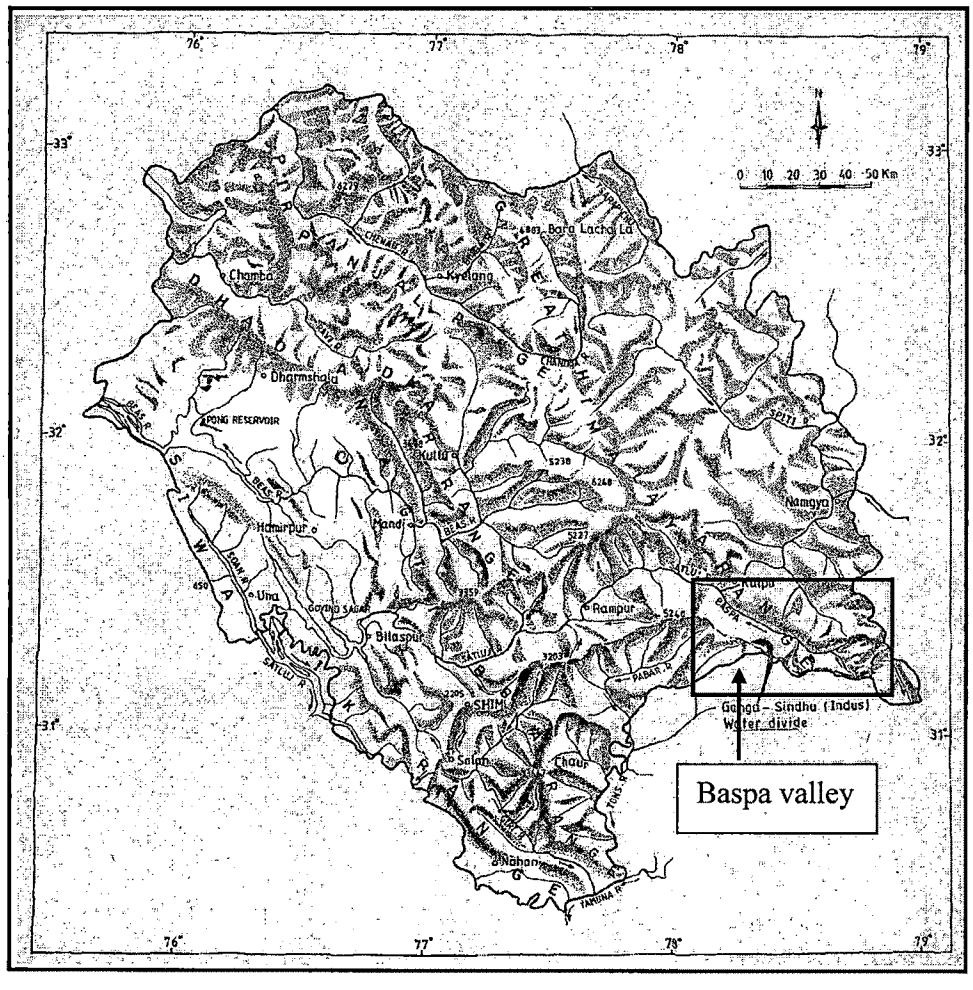


Fig. 1.2. Physiographic map of H.P. (Srikantia and Bhargava, 1998)

I. 10. DRAINAGE

The H.P. is drained by nine major river systems viz; Sutlej, Beas, Chenab, Yamuna, Ravi, Indus, Markanda, Ganga, and Ghaggar. The catchment regions of the state are goverened by several water divides. The two most important are: (a) the central crystalline axis separating Lahaul and Spiti from Chamba, Kullu, Mandi and Rampur, Bushahr in the North and (b) Solan , Kandaghat, Taradevi,Shimla ridge separating the Sutlej (Indus) and Yamuna (Ganga) catchment areas in the South. The lithological structure automatically plays a very important role in the drainage pattern of the state. The rivers of higher Himalayan zone are perennial in nature and are glacial-snowfed (State of environment report, H.P, 2000). The Baspa river which is fifth order drainage basin originates from the Baspa glacier

and flows in WNW direction contributing its drainage to fourth order Sutlej drainage basin (Geological survey of India, 1999).

I. 11. CLIMATE

Baspa valley is known for its *salubrious* climate. It also experiences considerable variation in the distribution of rainfall and temperature due to varying aspects and altitudes. In Himachal Pradesh Precipitation declines from West to East and South to North. Most of Kinnaur experiences temperate climate due to its High elevation, with long winters from October to May and short summers from June to September. January, February and March significant for rainfall. March is the rainiest month. Greater Himalayan region experiences temperature below 15°c. Highest temperature is recorded in the month of June. The relative Humidity is usually high in the months of July, August and September and varies between 76%-95%.Based on regional variations in rainfall, temperature and humidity Baspa valley comprises of three zones (i) Cool temperate zone (1800 m – 2400 m), (ii) cold high mountain zone (2400 m – 4000 m) and (iii) Snowy frigid zone (above 4000 m). The Snowfall data is obtained from the meteorological station placed at Rakchham. The data suggests that maximium snowfall has occurred during the time period of Nov'2001 - April'2002 whereby the amount of precipitation comes to about 574 cm. In the consecutive winter i.e., from Nov'2002 - May'2003 it amounted to 428 cm, again in consecutive winter from Nov'2003-May'2004 it was 319 cm. Hence, indicative of decreasing trend of snowfall.

I. 12. FLORA AND FAUNA

Baspa valley of Kinnaur situated in higher Himalayas consists primarily of hardy grasses. Alpine species such as juniper, pine, fir, cypress and rhododendron can be found at elevation between 3500 m - 5000 m. At lower altitudes, temperate climate trees are found including oak, chestnut, maple, birch, alder, magnolia, apple and apricot. Yaks and dzos are reared by local farmers in higher areas. Scattered population of Himalayan black Bear may also be found and small ponies are common.