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# Morphology of Hazards of High Himalaya: A Case Study of Baspa Valley, Himachal Pradesh

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**Abstract:** Hazards in Himalaya are by and large atmospheric in origin related to climatic morphogenesis phenomenon that has resulted in steeper unstable slopes. The extremes of most of meteorological variables like snowfall, winds, solar radiation, ambient temperature and rainfall can cause a hazard. In addition variables (elements) often combine in a way which greatly increases threat when low temperature combines with high winds to create a wind chill, snow storms, avalanche etc. The nature and intensity of hazards vary considerably through length and breadth of NW Himalaya. In the southeast the intensity of monsoon winds triggers the mass movement and cloud burst processes resulting in flash flood in mid mountain region. In the northwest Himalaya, the western disturbances invade the region with a chilly winds followed by heavy snowfall resulting in bridging of crevasses resulting in glacier fluctuation and activation of ice slab avalanches in higher reaches and blizzards, snow avalanches, activation of mass movement processes etc. in the mid mountain regions (4000m to 2500 m).

**Key words:** Hazards; climatic morphogenesis; meteorological variable; Baspa Valley.

## 1. Introduction

Himalayas have a dramatic landscape of formidable mountain ranges with snow, glaciers and surging river system for about 1600 km between Indus in the NW and Brahmaputra in the NE. The Himalayan ranges are result of geological events that goes back to 60 million years. The Himalaya attained its present elevation about 15 million years back that led to the initiation and establishment of monsoon system in Asia. Pleistocene has been the time period when pulsating uplifts resulted in pushing Himalaya further up snow line that resulted precipitation in the form of snow around the year and ultimately the formation of large glaciers (Valdiya, 1993a, b). Topographic and chronological evidences indicate that glaciation is strongly controlled by southwest monsoon (summer) and Westerly's (winter and spring). These two circulation systems, combined with local high altitude atmospheric circulation exert climatic controls on the distribution of existing glaciers and fluvial system.

The Himalayan Glaciers as we see today is a shrunken phase in context of their large extension during Pleistocene. The Himalayan Glaciers comprise nearly 30 percent of all the glaciers outside Polar region and cover the area 20 times of the glaciers of Alps (Wissman, 1959). According to the Inventory on Himalayan glaciers prepared by Geological Survey of India, there are altogether 9575 glaciers extending from Kashmir in the west and Sikkim in the east, of which 7997 glaciers are confined to higher reaches of Himachal, Kashmir and Ladakh Himalaya along the major watersheds of Indus (Sutlej, Beas, Ravi, Chenab, Jehlum, Upper Indus-Leh and Kargil). Glaciers are dynamic bodies of ice that in Himalaya move under the influence of variable temperature gradient. The temperature of ice plays a fundamental role in its movement and morphological activity. The glaciers in Himalaya are both warm and cold type. The warm type of glaciers are confined to narrow valleys of Himachal and Kashmir Himalaya where ice temperature is close to melting point throughout its thickness except for upper accumulation part where temperature is low to chilling conditions. The melt water exists at the base of debris covered glacier. The cold glaciers are found in cold desert of Ladakh. They are characterized by temperature below melting point throughout their thickness. The surface and basal melting occurs in short summer ablation season and supra glacial streams temporarily appear in the lower ablation zone. The glaciers are by and large clean and are confined to broad valleys.

The snow and ice covered higher peaks and ridges descend precipitously, to glacier basins and steep relief is a cause for numerous ice falls, heavy crevassing, and massive debris load. As a consequence, some glaciers surge and move at times by block schooled motion, whereas majority of glaciers show gradual fluctuation. Some glaciers, particularly avalanche type, behave erratic and fluctuate rapidly causing temporary damming of rivers and thereby threatening the safety of recently built highway and reservoirs such as that of Sutlej basins. Further, the high relief, steepness of slope and debris accumulation provide an overwhelming sense of instability, mass movement and catastrophic events

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that could lead to widespread slope failures leading to temporary blockade rivers and land sliding. Thus, natural hazards leading to catastrophes have power to exert a substantial and consistent on pressure on society

**2. Study area**

Baspa an elongated glacial valley of Kinnar Himalaya is situated in Sangla Tehsil of Himachal Pradesh and is accessible by Hindustan-Tibetan Highway 22 (Figure, 1). The Valley is 72 kms long and 15 km wide with NW trending orientation. River Baspa flows through the valley and joins Sutlej at Karcham The valley is girdled by High Himalaya that houses 89 glaciers. The valley commences from the main ice-field situated in southeast, from where two main glaciers Arsamang (6159m) and Baspa Bamak (5760m) commence and have westerly orientation. The valley is fenced in south by Whoming (5215m), Khomsingh (5746m) and Khimloga (5712m) peaks and that also is water divide between Sutlej and Ganga drainage basin. The valley has an area of 1100 sq. km out of which 22.4% is covered by glaciers among which Baspa Bamak is the largest, extending from the altitude of 5760m to 4400m for a length of 18.4km. The other major glaciers are Hania, Janpa, Jorya, Saro and Shusha. Most of the glaciers are north facing and range in length from 5.5km to 17km.The evidence of glacial activity is well preserved in the landforms produced by erosional and depositional processes. Lakes near Sangla, Rakcham in lower altitude (2500m and 3100m) and Chitkul, Rimdrang (3400m and 3900m) in higher altitude are result of damming of river by mass-movement processes.

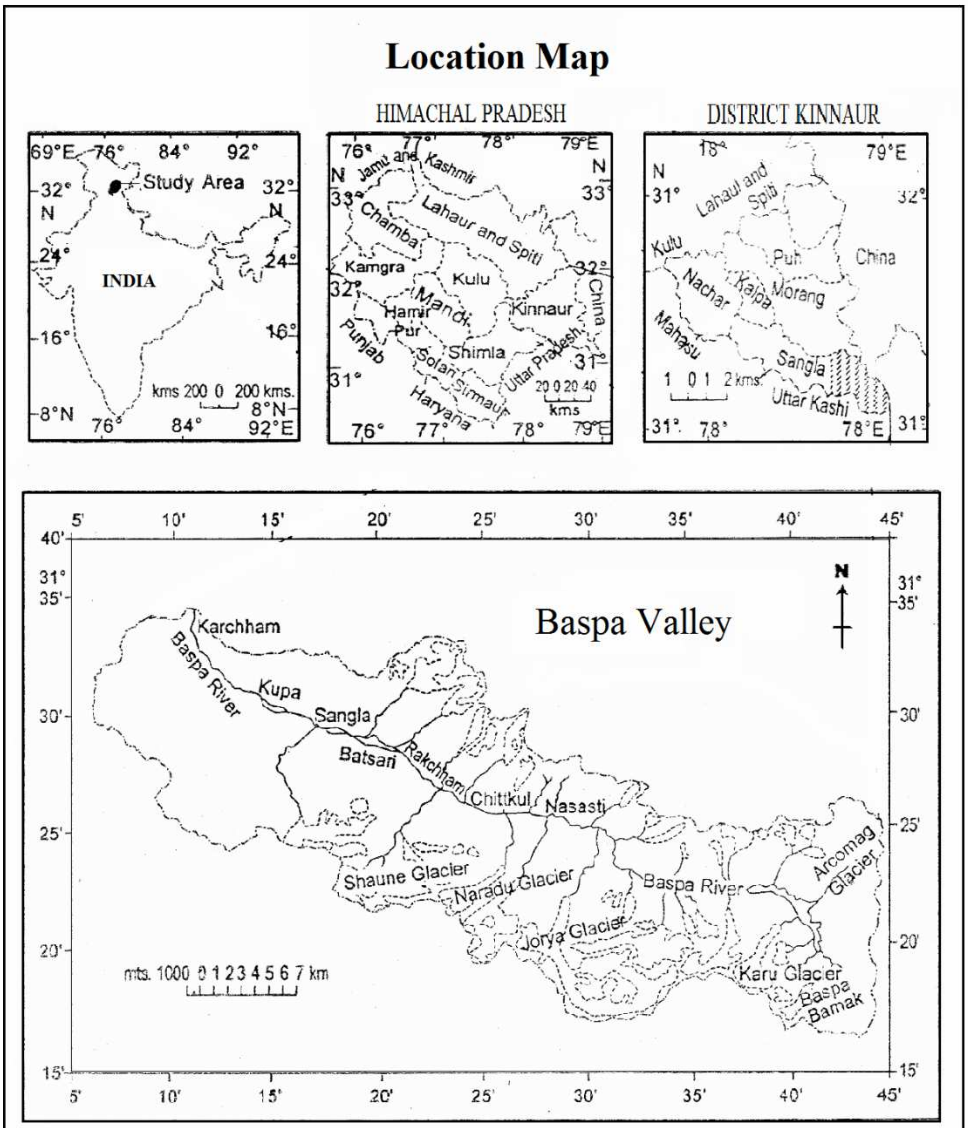


**Figure No 1**

The granite is intruding into Phyllites/ Slates and sandstone country with sharp disconformities contact. Structurally the basin proper presents two fold stratigraphy dominated by sandstone and slates. Due to buoyant rise of granite the overlying sedimentary and meta-sedimentary rocks form an anticline structure with moderate dip of 25˚-35˚ to east west. A considerable thickness of 700m is confined on eastern limb of basin whereas in western limb more granite is exposed due to erosion of loose sedimentary and meta-sedimentary cover.

The topographic development in Baspa valley is inherently polygenetic nature with glacial and fluvial processes, playing important role in different times. At present, glacier activity is confined in the higher reaches (4300m-6200m) of Himalaya. The geomorphic hazards in glacier landscape are mainly related to climate morphogenesis particularly to snow, glacier and peri-glacier environment. In the higher reaches of Baspa valley, a rapid change in atmospheric conditions is because of steady decrease in thickness of atmosphere. The decreased concentration of water vapour and carbon dioxide in turn heats and cools ground surface rapidly and leads to acute cold condition.

The higher Himalaya is intrinsically linked to atmospheric circulation caused due to western disturbances that cause maximum deterioration of weather resulting in abundant snowfall and extreme cold condition in higher mountains resulting in growth and sustenance of glaciers. The western disturbance is caused through thermo-dynamic effect of Himalaya on the periodicity and incidence of depression. The depression usually takes 8 to 10 days from its source to reach Himachal Himalaya and the life of each depression is barely 5 days. During the winter season temperature ranges between -1 ºC and -25 ºC. During the summer season (July to September) the mean temperature ranges between 10 ºC and 15 ºC, July being the hottest (25 ºC) and solar radiation peaks to 600 watt/m$^2$. During summer season monsoonal winds do penetrate up to the altitude of 3500 m all along the high Himachal Himalaya. The study region is located in convergent zone of warm moist monsoonal circulation and cold semiarid Northwesters. During monsoon season, the convergence of monsoonal air mass and Northwesters in upper atmosphere leads to plenty of rain in the form cloud burst and point rainfall that causes flash floods in mountain regions of Baspa valley.

## 3. Results

### *3.1 Hazards Induced by Rock fall and Catastrophic Slides*

The rock fall activities have been observed throughout the Baspa valley from village Chitkul (remotest village near China border) to Karchham. The valley is covered by huge rock fragments along the foot hill as well as valley head. However, recent rock fall processes are limited to few distinct locations in the altitude zone of 3400m to 5000m where permafrost conditions prevail. The left side of the Naradu Garang and Baspa valley is characterized by unstable rock formation up to 700m above the river bed. Other sites in Baspa valley are found near Rakcham, Sangla and Batseri area. In these areas the rock break down occurs in the valley slopes due to frost shattering and unloading of rock material by glacial excavation. The large amount of supra glacial material produced by weathering due to albedo effect caused on dark and light rock help in creeping the scree along the valley slopes. The temperature of blackish color slates and brown colored weathered granite absorb large amount of heat during the day time. The temperature measured in rock cavities and rock cracks indicates that they generally have higher temperature by above 4° C and 1.5° C higher than the air temperature during the peak hours of the day. This has far reaching consequence in production of rock fall along the valley wall. The unloading of rock debris in the lower altitudes is carried by high intensity rain fall during summer monsoon particularly during the months of July and August. The high intensity point rainfall episodes cause catastrophic rock slides followed by landslide slips along the Sutlej River in Baspa section near Sangla-Wangtoo section. Such catastrophic slides were observed during 1996, 2000, 2002 and 2009, that resulted in damming of river at Sangla, Wangtoo and Tapri sites. The damming of the river followed by floods caused a great loss to men and machinery of hydro-power, property of the villagers and huge loss of life. Scree slopes and rock falls are conspicuous elements of Baspa valley landscape (Plate 1, 2).

Plate- 1: Scree cone

Plate- 2: Scree slopes formed by reduction of rocks

**Modification of scree in Baspa Valley**

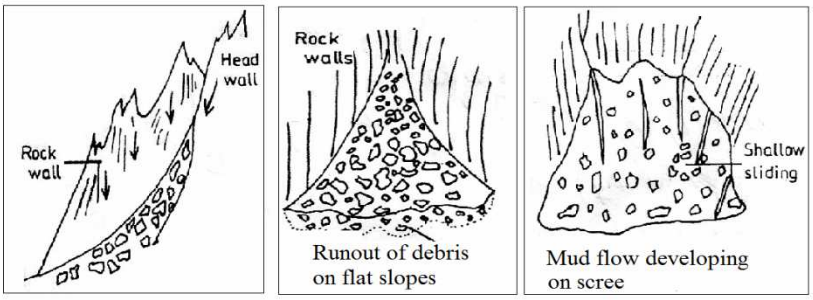


**Figure No. 2**

They vary in form from small rock scree cone to huge compound debris accumulation (Figure, 2) with the slope length up to 1500m and relative height up to 500m with a slope angle range up to 35°. Such sort of a rock debris scenario is very common of higher reaches of the valley thereby indicating the extreme events of freeze and thaw activity created by pen-glacial environment. The valley walls and valley slopes of the region are highly fragile due to the influence of solifluction and nivalfluction activities favored due to frost action. The displacement of material is up to 2m due ice rind action. The talus moves down the steep slopes with the average creep velocity of 3m per year. Such a grandeur of wide spread sign of slope failure leads to usually high frequency and large magnitude mass movement activity. Such mass movement activity is a great risk and hazardous to the travelers as well as to the inhabitants of the region.

*3.2 Cloud Burst*

The Baspa valley is a classic domain of cloud burst as its topography has a high relief along with close basin morphology. The basin morphology is broad at the top with a downward depression resembling Y shaped outline. The region is vulnerable to monsoonal winds that induces high temperature gradient and creates a localized cumulonimbus clouds at the top, a part of which slips into the bottom of the basin. The top of the cumulonimbus clouds has a positive charge whereas the bottom has a negative charge, resulting in the formation of convectional winds. The cumulonimbus clouds get electrically charged and burst the clouds spontaneously into a huge sheet of water. Such phenomenon is also observed in the geomorphic landscape of Kulu and Chamba (H.P.). The high frequency cloud burst usually takes place between July and September. There frequency is more in July and August when monsoon fully sets in this part of the region. During last 20 years (1993-2013) nearly 40 major cloud burst caused flash floods resulted in nearly 800 deaths and loss of property worth crores and huge loss of forest wealth and livestock.

*3.3 Flash Floods*

The head waters of Sutlej are confined in Tibetan plateau where bursting of glacial lake have been reported due to increase in temperature by 0.3 ºC during last one decade (Shang *et al.*, 2003; Feng *et al.*, 2001). It has been instrumental in causing flash floods in Sutlej and Chenab rivers. Due to these outbursts Sutlej river rose to about 15m and 20m above the flood level at Khab on 31st July 2000 and 26 June 2005 respectively (Gupta and Sah, 2007). They caused huge damage to national highway 22 and washed away 20kms of road, 7 bridges and 250 houses and nearly 200 lives were lost. The total loss due to these flash floods in India amounted to rupees 100 crores. The Himalayan head waters contribute nearly 60% of discharge of river Ravi, Sutlej, Beas and Chenab due to snow and ice melt. The extreme rainfall events during monsoon season result in flash floods and sleek water formation along the river course in high and middle mountain regions and in lower altitudes, leads to floods and shifting of meanders. During last one decade nearly one thousand people have lost their lives and large chunk of land has been subjected to erosion and nearly 500 crores have been lost due to the flash floods (Tribune and daily excelsior).

*3.4 Glacier Fluctuation*

The process of advance and recession of glacier results in the occupation and evacuation of area by glaciers, depending up on phase of glacier through which it is passing through time and space. This process creates a hazardous moraine dammed lake. These lakes developed behind unstable ice cored moraine have a potential burst floods. Secondly when the movement of the glaciers is confined too much higher scale for years and decades such as glaciers volume decreases appreciably leading to water resource problem. The glaciers in northwest Himalaya exhibit accumulation area ratio ranging between 55% and 65% and indicating that majority of the glaciers are receding and depleting (Sangewar, 1995). The rate of retreat is quite variable depending up on the location and aspect of glacier basin. The general dimension of the glacier on the southern flanks of Himalaya, according to Pascoe (1964) has been oscillating, some seemingly stationary and few others even advancing, but majority of them show evidence of secular retreat. Similarly present day snout of main Baspa group with respect to one in 1965 topographic sheet confirms the horizontal retreat of 320m in 33 years and remnant moraine about 5m to 6 m higher than the present glacier snout suggest vertical retreat of ice (Sangewar *et al.*, 1996). The glaciers retreat at variable scale from southeast to northwest of northwest Himalaya ranging at the rate between 4m to 12m and 2.5m to 8m respectively. Naradu glacier in Baspa retreats at the rate of 4.5m per year during last one decade and Durung Drung glacier in Zanskar retreats at the rate of 2.7m per year (2005 to 2007). The snout of the glaciers is very irregular in outline thereby showing variable rate of fluctuation. In front of the glacier there are series of terminal moraines in the form of crevasse fill ridges and ice cored moraines. These moraines are neither blocking the melt water channel nor producing the moraine dammed lakes. As such the glaciers in this region are behaving in normal way and showing secular retreat.

**4. Discussion**

The field observations reveal preservation of abundant drift material in Baspa valley in the form of moraines, tills, bare rock faces scarred with avalanche chutes gullies, mud flow channel and massive scree slopes along main valley as well in tributary valleys. The magnitude of relief, overall steepness of slope and scale of debris accumulations provide overwhelming sense of instability, mass movement and catastrophic events. Thus, wide spread sign of slope features tend to mask overall slow rate of operation of small scale geomorphologic processes and emphasize usually the high frequency and large magnitude of mass movement.

The nappies formation in higher Himalaya has produced different of folds in sedimentary structures having large number of cracks and joints. The cracks in the folds have been exploited by different weather elements particularly by freeze and thaw action leading to disintegration and dilation of joints and cracks resulting in providing basic raw material of angular rock fragments to glacier valley from catchment area and along valley walls to different agencies like glaciers and rivers to perform the process of erosion as well deposition leading fill process in valley depression.

The relative relief of the main valley is rarely less 2800m and even the tributaries contain elevation difference of 1700m in horizontal distance of 3km to 5km. Nearly everywhere the higher peaks and ridges descend precipitously in snow and ice covered avalanche slopes to glacier basin below, in a jagged aiguilles and bare rock faces scarred with avalanche chutes.

The ambient temperature in the narrow valleys exceed 24˚C in shady portion, while that on exposed surfaces particularly in the vicinity of rocky cliff, the temperature of 32˚C to 34˚C was observed during field season. During winter season particularly in January to March freezing condition persist in lower altitude of the valley whereas in higher attitude (4000m to 5200m) freezing condition prolong to nearly six months leading to permafrost condition. At high elevation in the vicinity of 4500m to 5000m, snowfall on exceedingly followed by turbulent winds result in avalanching with an individual fall having displacement of 2000m along the eastern margin of mountain slope.

The Baspa valley, though provides evidence of glaciations in the Kinnar Himalaya, yet the preservation is poor and have undergone (to some extent) by fluvial and mass movement processes that are caused by convergent air masses of warm moist monsoonal circulation and semiarid Northwesters influenced by westerly disturbances that led to plenty of rain during July-August caused by cloud burst and point rainfall.

The studies carried out on 175 glaciers in Miyar valley of Chenab basin (H.P.) by satellite data show that large number of glaciers have a negative balance whereas a very few small glaciers show positive balance and large number of niche glaciers does not show any accumulation (Bahuguna *et al*., 2008). The glaciers in the region are retreating in a normal rate in view of climate change. This is also collaborated with the mean daily discharge in Sutlej and Chenab which whose head waters contribute 60% of their total flow from about 18% of glacier catchment area. According to Kaul and Mubarki (1989), runoff ratio factor is 2:1 whereas peak discharge during two decade due to catastrophic rains and cloud burst that caused flooding and damming of river due to catastrophic slips, were triggered by point rainfall episodes.

The studies carried on the glaciers of Ladakh and Zanskar basin reveals that glaciers are receding at comparatively slow rate with net reduction of 4.23% in glacier area and 3% in peri-glacier area in last 35 years (Kaul *et al.,* 2007). In Alps, the glaciers have been reduced by 26 percent during the last century (Muller et al. 1976). This has resulted in perturbation of natural processes like moraine dam failure and excessive retreat of glaciers in alpine region (Evan *et al*., 1994; Taylor, 1997). Similarly in Tibetan Plateau, the temperature has been rising at rate of 0.3 ºC per ten year (Zhang and Tang, 2000) that resulted in formation and bursting of Paranchu glacial lake in Tibet. Such phenomenon has not been observed in northwest Himalaya during last 20 years. As such impact of climatic change on catastrophic geomorphic process validation for Europe does not hold well with Himalayan glaciers.

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