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Glacial Geomorphological Observations in Naradu Glacier Valley, Kinnaur, Himachal Pradesh

Surendar Singh
Lecturer,
Deptt.of Geography,
Govt.College College for Women,
Kathua, Jammu

Abstract

The Himalayan glaciers, presently confined above the altitude of 4000m, have existed at the lower altitude levels in the geological past. Glaciers of Quaternary period in Himalaya have retreated continuously with punctuations of minor advances. The evidences of glacial extent and its subsequent retreat can be observed in the form of various landforms in the glacial landscape attributing their origin to glacial and glacio-fluvial geomorphic processes that operated in the geological past.

Keywords: Himalayan Glacier, Geomorphology Features, Glacialland Scape, Naradu Glacier

Introduction

There has been a general retreat of Himalayan Glaciers, more prominently in the present century. The retreat of these snow giants has resulted in the alteration of landforms and production of different geomorphological features. Glacial ice and melt water are the two important agents producing glacial landforms and deposits. The glacier ice has tremendous ability to modify landforms, over which it moves. It has a great impact on the physical landscape. The glacio-fluvial processes are more significant during the period of glacier retreat than during the periods of glacier advance. The study of the landforms produced by glacial and fluvial action is an important tool in understanding the poly-genetic origin of the glacier valley.

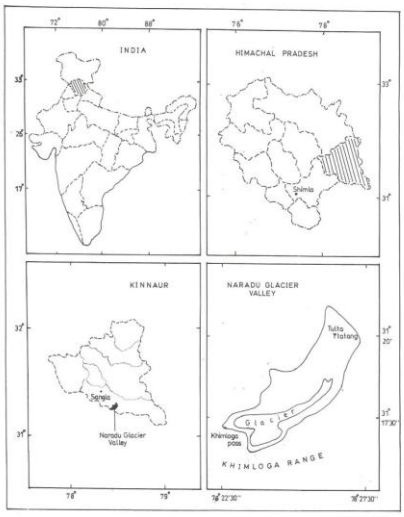
The paper deals with the study of geomorphic expression and features in Naradu glacier valley, situated in Kinnaur Himalaya in Himachal Pradesh. They are recorded in the form of moraines, kame terraces and eskers. Glacial erosional features are present in the form of U-shape valley, striations and polished surfaces. The large number of glacial features suggests that the valley has been under effect of glacial activity for a long period of time. Retreat of Naradu glacier has also been responsible for partly modifying or obliterating the glacial geomorphological features by subsequent glacio-fluvial and/or fluvial activities.

Area of Study

Naradu glacier valley is situated in the Sangla Tehsil of Kinnaur District of Himachal Pradesh. It is located near the remotest village Chittkul, an offshoot of Hindustan–Tibet Highway–22. The glacier snout located at an altitude of 4392 m is almost at a distance of 6 km trek from Chittkul village. Naradu glacier is one of the 89 glaciers of Baspa basin (Glacier inventory prepared by Glaciology Division of Survey of India). Baspa basin is the 5th order Basin of Sutlej River and forms one of the largest ice fences of Sutlej. The Naradu glacier is housed in the upper part of the valley commencing from Khimloga range head wall at an altitude of 5600m. It comprises of two lobes in southwest and southeast direction and descends to merge at an altitude of 5000m. It flows down a distance of 740m in north east direction and then descends down into main valley of the glacier. Extensive crevasses, in the form longitudinal and chevron, occupy this part of the glacier. Icefalls are common in the upper part of the glacier as there is sharp change in gradient and variation in litho logy of the valley. The snout is marked by numerous transverse crevasses and is predominated by supra glacier debris. Below the snout the valley as whole is one of the steepest valleys having a relative relief of 2100m.

Naradu basin is fenced in the south by two peaks of Khimloga range of Himalaya, which happens to be water divide between Sutlej and

Ganga.The basin is connected with Uttarakhand State through Khimloga pass. The glacier proper commences from Khimloga range head wall at an altitude of 5600m from a common ice front and descends in two branches in a cirque trough. The two branches merge at an altitude of 4900m at the vicinity of ice-fall, and flow down in northeast direction and terminate at an altitude of 4392m. The glacier has length of 5.15km and covers an area of 4.56km². The longitudinal profile of the Naradu Glacier is parabolic in outline with convexity at trough head and body of glacier has four treads with steps in between. The first tread commences from snout and extends to the altitude of 4520m.It has gentle gradient and covers area of 19.6%. The second tread extends between the altitude 4560m and 4920m and covers area of 27.84% area of glacier. From the equilibrium line at 4920m to the altitude of 5080m, there is another tread of moderate gradient extending between the altitude 5080m and 5200m covering an area of 12.6% of the glacier. Above 5200m there is steep trough with serrated ridges having an area of 9.7%.



Objective of the Study

The present study is aimed to investigate the fluvial and glacial geomorphological characteristics of Naradu Glacier valley. The valley is poly-genetic in nature and has been produced due to retreat of the Naradu Glacier. The surface features bear a testimony to operation of mutually complementary processes of deposition and erosion. The objective is thus to identify the landform features and study their morphology, character, chronology and mechanism of their interaction.

Review of Literature

The systematic studies on modern lines on Himalayan glaciology were started in the second half of the 20th century. Glaciology Division was established in Geological Survey of India in 1974. Gangotri glacier was the first glacier on which glacial geomorphology, lichenometry, till fabrics, micro climate and other studies were carried out. Considerable amount of work has been done on glacial, hydrology, palaeoglaciation and glacial geomorphology in Himalaya during past three decades. Singh and Agarwal in 1976 investigated the deglaciation of northwestern Himalaya from radiocarbon evidences. Raina, Koul and Singh conducted mass balance studies of Gara glacier in 1977. Gupta (1980) analyzed raised pavements (moraines) which demarcated the limits of glaciers in Baspa valley. Bassi and Chopra (1981) gave a note on morphology of Baspa glaciers. Devendra Pal (1987) accounted glaciations vis-à-vis landforms evolution in northwestern Himalaya. Kaul (1990) discussed the Glacial and Fluvial Geomorphology of Western Himalaya. Kaul (1990) discussed the Glacial and Fluvial Geomorphology of Western Himalaya. Verma (2001) briefly reviewed the mode of glaciation duration and extent of glacial episodes in Kangra valley on the basis of chronological history of Quaternary events such as climatic changes and post-glacial geomorphological features. Sangewar, Singh and Siddiqui (2001) described the basin characteristics of Baspa basin on the basis of morphometric analysis and prepared a glacio-geomorphic map of the valley. Singh and Kumar (2001) worked on textural discrimination between glacial and pre-glacial sediments of Baspa valley.

Observations

Valley Morphology

A major part of Naradu Glacier Valley has a 'U'- shape with 'V'- shape notch at the lower part. The Naradu glacier housed in the upper part of the valley commences from Khimloga range head wall at an altitude of 5600m from a common ice front and descends in two branches in a cirque trough. The two branches merge at an altitude of 4900m at the vicinity of ice-fall, and flow down in northeast direction and terminate at an altitude of 4392m. The Naradu valley profile shows three series of treads separated by stairways at elevations of 4390m and 4850m. The hanging valleys have developed a convex form at the middle and slight concave at the valley head. Overall the profile is comparatively less steep at the upper part than the valley terminus.

Nearly 17% of the valley is covered by the glacier and rest by glacial landscape. The floor of the valley is narrow and bordered by steep slopes, a mixture of rock faces and high angled scree slopes. Nearly 37% of the valley sides are covered with scree. Eastern side has a greater cover of scree as compared to the west due to valley orientation with eastern side experiencing longer daily periods of sunshine and resulting in greater degree of weathering as compared to the western side.

Glacial Geomorphology

The Naradu Garang Valley is characteristically glaciated having typical U-shaped and other features such as hanging valley, polished rock surface and glacier drift deposits. The polished surfaces with striation markings are preserved along the valley head, valley wall as well as along hanging valleys. The polished surfaces are plentiful in valley at an altitude of 3800m along the north east margin. These are preserved on granite and slate. The striations are preserved prominently on Quartzite boulders. The quartzite boulders are frequently striated whereas Phyllites are rarely so. The general direction of striation in the valley is N25ºW. Roche moutonnees are observed at few sites, majority of

them at two elevations 3680m and 3900m. The moutonnees are 50m-60m long, 10m wide and 15m-20m high from valley floor. Their stoss side slope ranges between 30º to 40º and lee side 60º to 70º.

The glacial depositional landforms in Naradu valley vary in morphology and have complex evolution. These are produced due to deposition of debris through different processes related to their location at or inside the glacier margins in active or stagnant ice. Moraines are the most eminent depositional features that can be seen in the valley. Major part of the valley is covered by moraines arranged in ridges parallel to the sides of the valley. These ridges stretch from an altitude of 4800 m to 3600 m in the valley. There is large tract of fluted ground moraines in the vicinity of Tulathang (3580m). It covers an area of 425m².In this morphological division there are well developed 3m high linear furrows. The surface is covered with rounded boulders of crystalline, sandstone and phyllites. The crystalline are prominent in proportion (40%).The outline of this feature is rolling in nature and it is attributed to pressing of debris in channel cavities under ice and presently the area is covered by vegetation and is stabilized.

Polished Surfaces and Striations

Striations and polished rock surfaces are preserved along the valley head and valley walls as well as along the hanging valleys. The polished surfaces are plentiful in the valley at an altitude of 3700m and 4000m along the northeastern margin. These are preserved on granite and slates. The striations can be prominently seen on quartzite boulders. The general direction of the striations in Naradu valley is N25ºW.

Cirque

Five cirques have been observed in the Naradu valley. Two large cirques are located at higher altitude (upper section of valley) between 5400m and 5100m.These two cirques house the two accumulation lobes of Naradu glacier from where the glacier proper commences. Cirque stairway has been identified in the right lobe cirque of the glacier. The cirques in this section of the valley have southwest-northeast orientation. Two cirques are located in the middle section of the valley between the altitude zone of 5000m and 4640m along the western margin of the main glacier. One out of these two cirques, one is occupied by ice and other is ice free. The ice-free cirque in this section has southwest-northeast orientation and is covered with rocks and scree.

Lateral Moraines

Lateral moraines in the valley extend from an altitude of 4900 m to an altitude of 3600 m. They exist as elongated ridges along western side of glacier valley. Only a small section from an altitude of 4560 m to 4510 m along eastern side of the valley preserves lateral moraines. Moraines are breached at several places by scree cones or fluvial regimes and cover an area of 6.9km². They show distinct gradation in height and width from the valley head to valley bottom. Three levels of lateral moraines have been observed in the Naradu valley. The low lateral moraines extend from an altitude of 4900m to 4510m along the western margins of the Naradu glacier. In the vicinity of 4900m, their height is about 20m and it gains to 38m at 4510m altitude. They have slope of 40^0 to 60^0. Medium-high lateral moraines are present between altitudes of 4580m to 4020m.

Their height is 40m to 80m and have slope of 25^0 to 35^0. The high lateral moraines are nearly 80m to 115m high from the valley floor and have a slope of about 15^0 to 30^0.Similarly the width varies between 35m and 68m.In the vicinity of first hanging valley, the lateral moraines forms arcade loop having box like pattern. From 4900m to 4510m, the lateral moraines have developed lobately pattern, abutting young moraine having height 25m and comprising loose angular fragments as compared to consolidated material of older moraines. The lateral moraines of study region primarily comprise rock fragments of crystalline rocks of Vaikrita group (sandstone phyllite, schist and sandstone) and moraine material ranging in size clay to boulder. The highest moraine ridges are stabilized and have 40% by weight of coarser material with silt and clay than young low moraines containing nearly 90% weight by coarser material along with coarse sand. The old moraines are confined in prominence in the middle and lower section of the valley. The older moraines have more proportion of finer sediments and are stabilized. They have vegetation growth on them. The uniformity of large coarse fraction in soil matrix of high, medium, and low moraine ridges of crystalline rocks indicate its origin to single advance .However, the extent of medium moraine ridges with low concentration of crystalline rocks having moderate height and high stabilized moraine ridges indicate three phases retreat of glacier.

Medial Moraines

Three well developed medial moraines run parallel to each other, first one is between an altitude of 4920m asl and 4840m asl with average length of 700m and height of 6m.The medial moraines comprise of fresh rock fragments with ice cored material at the base suggestive of young age moraines. The second one lies between an altitude of4750m asl and 4580m asl and is 900m long with an average height of 9.7m.A third medial is on the east of the glacier between an altitude of 4660m asl and4400m asl with an average height of 9.85m and length of 850m.The extreme end of medial moraine, in the vicinity of altitude of 4900m asl, coincide with present equilibrium-line of the glacier. The medial moraine, between an altitude of 4510m asl and 4920m asl is situated below the hanging valley revealing the thickness of hanging glacier could be 50m or more. A lateral moraine of medium height fuses with the extreme end of the medial moraine in the vicinity of 4580m.

End Moraines

End moraines are important geomorphologic feature of glacial deposition form transverse to the ice front. Their formation depends on a precise balance between glacier advance and the rate of marginal wasting. The end moraines are formed by dumping of debris by retreating glaciers. In Naradu valley, the dumped moraine material can be seen in the pro-glacial area from the altitude of 3500m to the snout (4392m). They are marked by heaps of rounded and sub-rounded boulders embedded in sand-silt matrix. The glacier melt channel has cut through them. The

stony mounds in the vicinity of snout (4390 m) are about 15 m to 20 m high and primarily comprise of angular fragments. The dumped end moraines have been formed due to deposition of glacial drift moving outwards through shear planes at the retreating margins of glacier. These shear planes extend up to bottom of the thin sheet of active glacier near the terminus and as the debris reaches the surface it dumped along the margin of the ice mass, these moraine are formed from altitude of 3580m to the glacier snout. Between the altitudinal sections 4150m and4210m asl, two end moraines ridges of arcade shape(60m high) parallel in pattern for a distance of 450m covering an area of 0.7 km²are observed .Their origin is to thrusting. Further from 4210m altitude to present day snout position (4392m-4395.10m) a series of five moraine ridges have been observed .These moraine are covered by ablation moraine of thin material with ice wedge at depth 1m to 1.5m.Their origin is attributed to strong push of glacier against a narrow and concave topography resulting in increase in thickness of ice that otherwise is thin. The concavity in bedrock is the result of push and pull factor caused by body of the glacier. Three well developed end moraine are seen in the valley at 3750m, 4100m and 4200m asl suggestive of three recessions.

Near Chitkul,in the vicinity of Rhimdarang and Shilpaya Garang (3450m to 3650m), terminal recessional moraines are observed. These moraines have joined with right loop of Shilpaya and left lateral moraine of Naradu Garang that resulted in blocking of Baspa river near Mujiling (3520m).

Debris Landforms of Deglaciation Processes

Kame Terrace

The kame terrace in the Naradu valley occurs between the altitude of 4050 m and 4070 m in the middle section the valley. It is 300 m long and has a width of 55 m to 70 m forming an arcade shape. It slopes 25^0 towards the valley trend, 45^0 to esker ridge and 40^0 towards the lateral moraine. The orientation of Kame is 20^0 NE-25ºSW and it lies parallel to the lateral moraine. Hence it shows close correspondence with the direction of the ice movement. The fabrics of sediments are fine towards the top. There are several kettle holes within a flat patterned ground. The lowest horizon of the Kame terrace is silt-clay to clay in nature suggesting the stagnant conditions of deposition of sediments. It is overlain by bolder conglomerate bed having lenses of fine sand and silt. The top deposit is gravely in nature. The matrix of gravely deposits sediments comprise of coarse sand. The surface of the Kame terrace is covered by grasses. The stratigraphy sequence of the Kame terrace suggests its origin by the deposition of material released from stagnant ice mass.

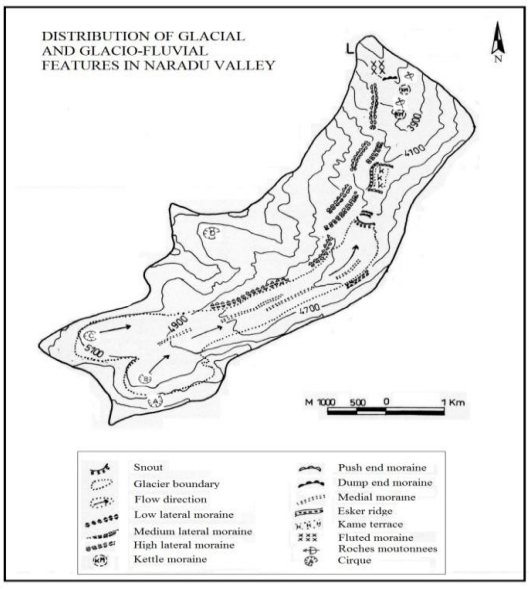
Esker

The esker identified in the study area stretches in a curved form from the altitude of 4150m to 4260m. The upper and lower limit of the esker is buried under the terminal moraines at these altitudes. It is nearly 30m wide and 3m to 10m high from the valley floor. The ridge has rounded crest and slope of 35^0, the maximum angle of repose of coarser material. The origin of the esker in the Naradu glacier valley is attributed to the glacio-fluvial material released by melt water which has been gradually laid down by thinning of glacier ice laterally in sub-glacial part. The melt- water channels under hydrostatic pressure move upslope explaining the ternd of eskers that are against the topographic slopes opposed to general direction of melt-water flow.

Kettle Moraine

Two kettle moraines have been observed in the vicinity of 3680m and 3900m confined between two hummocky ridges having a height of 50m to 60m, separated by low relief central axis. The kettle moraines cover an area of 0.12km^2 at 3680m and 0.06km^2 at 3900m.The hummocky ridges have a width of 170m to 215m and length of 210m to 350m. The low relief central axis is underlain by rolling diamict (2m to 4m thick). The dia-micton is compact and similar to basal till. The outwash is fine grained, mainly silts to silty-sand and contains few clasts of less than 20cm .

The low elevation lacks high relief topography but is having undulated surfaces with pebble and boulders. At an altitude of 3695m, a large conical Moulin kame rises to the height of 25m and rests directly on the top of basal till. The sides of the Moulin kame are at the angle of repose. Exposures in Moulin kame reveals well sorted to poorly sort sand, gravel and laminated clays. The maximum clast diameter is 1m. The long hummocky ridges border both sides of the depression up to the height of 15m to 30m. A narrow valley having a depression of 20m abuts the rocky exposures of valley walls. At an altitude of 3800m, the steeply sided hummocky ridges have moderate height of 10m to 15m and in-between these hummocky ridges, there is a low relief central axis located at the north-eastern side of the valley in comparison of large kettle moraine located at eastern side near the entry point of the Naradu valley.



Discussion and Conclusion

The glacial erosion landscape of the valley is characterized by high concentration of erosional features in the middle section of valley. The striations and polished surfaces are well preserved between the altitudes of 3700m and 4000m. Roche Moutonnee at an altitude of 3680m and 3900m in the vicinity of

kettle moraines provides undisputed information regarding the prolonged and vigorous glacial action. The size and shape attributes their origin to combined processes of abrasion and plucking.

The landforms of glacial deposition in Naradu Valley vary in morphology and are complex in evolution. An examination of landscape reveals a close relationship between the landscape orientation and ice flow direction. A majority of moraines have lineated topography and their tills show significant preferred pebble orientation parallel to the moraine crest. Three sets of lateral moraines in the form of linear ridges are observed between an altitude of 4900m and 3600m. The uniformity of large coarse fractions in tills of these moraines is largely attributed to single glacial advance. However, existence of moraines at three different altitudinal levels indicates three phases of glacial retreat. The genesis of end moraines is attributed to both, thrusting and dumping. The distinctive location of end moraines at different altitudinal levels documents the phases of recessions that have followed in Naradu glacier valley.

The distribution of sediments in kettle moraines and undulated land form in central axis dotted with roche moutonnees having two sets of striation reflect that Naradu glacier, after maximum extent of 3400m, retreated leaving behind two sets of medial moraines after thinning of glacier and these two medial moraines turned into two lateral moraine of medium height along the left at 3600m. Similarly at 3800m, it left two subdued lateral moraines. After retreat, the glacier advanced in phases upto altitude of 3800m and 3600m reworked the lateral moraines and produced complex kettle moraines along with well developed roche moutonnees along the edges of hummocky surfaces.

Kame terrace, at an altitude of 4050m, reveals a polygenetic sedimentary association. The sedimentary sequence comprising sand, assorted rock fragments and debris reveals intermittent lacustrine, glacial and fluvial regimes. Esker ridge occurring at an altitude of 4200m along the western margin of the valley is attributed to the glacio-fluvial origin caused by the release of melt water. The esker ridges are laid down by thinning of glacier ice laterally at ice contact margin through longitudinal crevasses developed in sub-glacial part.

Subsequent to the maximum glacial advance of Naradu glacier up to an altitude of 3350m, when Naradu glacier joined the main Baspa glacier near Chittkul, two phases of glacier advances are reported as envisaged from the evidences of lateral and kettle moraines at an altitude of 3680m and 3900m. The occurrence of Roches Moutonnees corroborate to these glacial advances. Correspondingly three phases of retreat are well documented by way of presence of terminal moraine complexes including the fresh one.

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