Journal of
Geography & Natural Disasters

Lone, J Geogr Nat Disast 2016, S6
DOI: 10.4172/2167-0587.S6-004

Research Article Open Access

Mapping the Glacial-Geomorphological Landforms in East Liddar Valley, NW Himalaya Kashmir India

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Abstract

The paper presents a glacial geomorphological map of landforms produced by different glaciers in East liddar during the past. The map has been created as the necessary precursor for an improved understanding of the glacial history of the region, and to strengthen a program of dating glacial limits in the region. The map was produced using Landsat TM, ASTER DEM, Google Earth™ imagery and field validation. The different landforms which were mapped include: lateral moraines, terminal moraines, proglacial lakes, palaeo-cirques, erratic boulders, outwash plains, whale backs, glacial grooves, rochee mountanee, drumlins, glacial striations, hanging valleys debris/talus cones, subglacial material. Glacial-Geomorphological features are very significant for palaeo-climatic reconstruction, showing variations, temporally and spatially. At the same time these landforms, which are also altered by processes prevailing during interglacial period, helps in geo-environment studies.

Keywords: Hanging valleys; Medial moraines; Terminal moraines; Debris/talus cones; Remote sensing and GIS

Introduction

Glacial geomorphology is the study of landforms produced due to glacial and fluvioglacial processes in the areas of present glaciers as well as in the areas covered by glaciers in the past. Much of the remarkable characters of the present topography in the northern part of east Liddar valley have resulted from the glacial processes in the remote past. Chronological reconstruction of glacial phases in the Himalayas has been attempted since the middle of last century. A study of the glacial processes operating presently can throw light on the landforms that were produced by the similar processes in the past. Therefore it will be helpful in reconstructing the origin of landform features [1]. During the advance movements of glaciers, it creates some erosional and depositional features which remain stationary and act as evidences for the glacial recession. Geomorphological features which acts as indicators of retreat or recession of glaciers includes: Glacial grooves, cirques, moraines, hanging valleys, glacial lakes, whalebacks, rochee mountanee, erratics, outwash plains, debris cones. The present study deals with the extraction of glacial landforms in inaccessible and difficult high altitude areas. East liddar contains some of the best preserved records of past glaciation in Himalayas. Present-day glaciers in this region are restricted to Shishram ice field, However it has been validated that the glaciation has advanced and retreated several times in the past Ahmad and Hashmi [2]. Paleoenvironmental records that exist in east liddar may be used to infer changes in past climate Kaul et al. No comprehensive mapping of glacial landforms at an appropriate scale has yet been done. The aim of the present study is to produce a reliable glacial-geomorphology map of study area and will be used as the foundation for dating glacial limits in the area (Table 1).

Study area

The East Liddar is the Eastern part of Liddar valley, eastern Himalayas, that occupies the south eastern part of the Kashmir Himalayas. The study area (Figure 1) lies between 34° 00'N-34° 12'30" N latitude and 75°07'10"E-75°23'20"E longitude.

The area is covered in the survey of India toposheet no's.43N/4 and 43N/8 and has a catchment of 30 sq. kms. The altitude of study area varies from 2210 metres to 4900 metres above the sea level. The east Liddar drains the large area of in upper reaches of the valley. The east Liddar lows for a maximum length of 14 kms before it merges with east Liddar at famous tourist spot Phalgam. The area reveals variegated topography due to the combined action of glaciers and rivers. The study area is described by sub-Mediterranean type of climate with nearly 70% of the annual precipitation concentrated in winter and spring season. Presently there are number of glaciers in east Liddar. They are concentrated near Shishram Mountains and cover 30 sq. kms. This glacier group is named after Shishram which is largest glacier of the area. The geological formations of the area range from Devonian to Triassic with recent formations along the rivers and glaciers of east Liddar valley (Figures 2 and 3).

Materials and Methodology

Map was produced using a combination of remote sensing analysis

S.No.	Glacial features	Area in Sq kms calculated from Landsat data
01	Glaciers	35.12
02	Lakes	30.54
03	Debris cones	30.07
04	Hanging valleys	28.07
05	Outwash plains	0.25
06	Cirques	1.58
07	Lateral Moraines	7.34
08	Deglaciated area	90.45
09	Sub glacial	0.09
10	End Moraine	0.79
Total Area	----------	224.3

Table 1: Showing the area of different glacio-geomorphological features in west Liddar.

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Received October 26, 2016; **Accepted** November 10, 2016; **Published** November 14, 2016

Citation: Lone S (2016) Mapping the Glacial-Geomorphological Landforms in East Liddar Valley, NW Himalaya Kashmir India. J Geogr Nat Disast S6: 004. doi: 10.4172/2167-0587.S6-004

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and field check with multiple type of imagery consulted to present the most rigorous understanding of glacial geomorphology. Across the region Landsat TM data from the earth explorer of 30 meter resolution, Landsat Imagery was supplemented by Google earth™ imagery consisting of 2014 cnes/SPOT images and 2013 Digital globe images (upto 5-15 m resolution). The satellite imagery was compiled into false-colour composite of bands 5, 4, 3 (30 meter resolution in order to identify and map the landforms formed due to advance and retreat of glaciers in the past. Image processing and mapping was carried out using ESRI Arc Map 10.2. Some image processing, such as layer-stacking and mosaicking, was conducted using ERDAS Imagine 9.3. Base map was prepared by using survey of India topographic map, overlaid by FCC of Landsat TM image. Using standard image characteristics such as tone, texture, pattern, shape, size, location and associated etc. [3] the visual interpretation and on screen digitization was carried out in ESRI Arc Map 10.2 for the extraction of different glaciers and Glacio-geomorphic features. Figure 4 demonstrates the flowchart of this study.

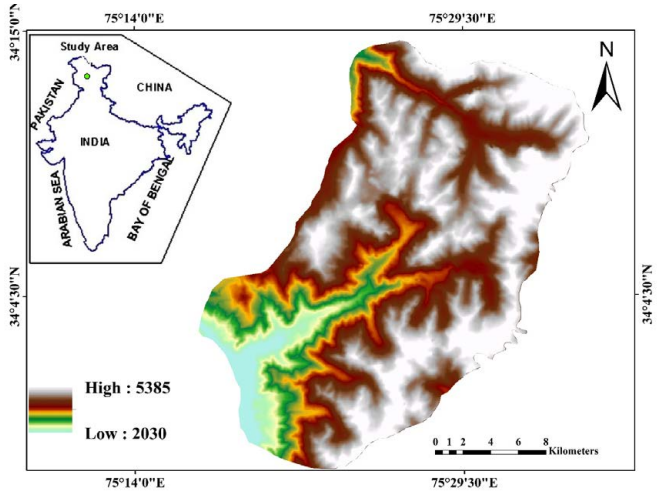

Figure 1: Location map of Study area.

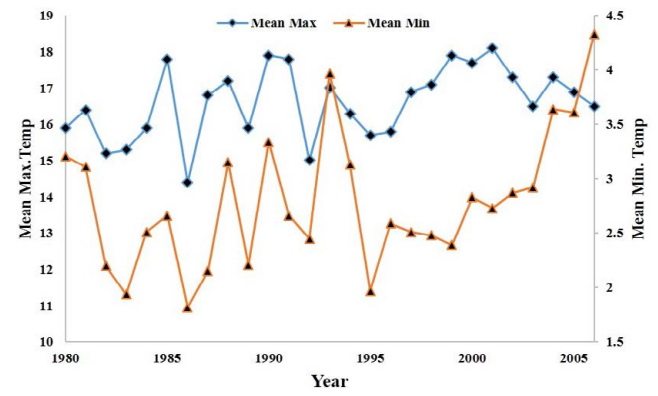

Figure 2: Average Maximum and Minimum temperatures (◦c) from 1980 to 2005.

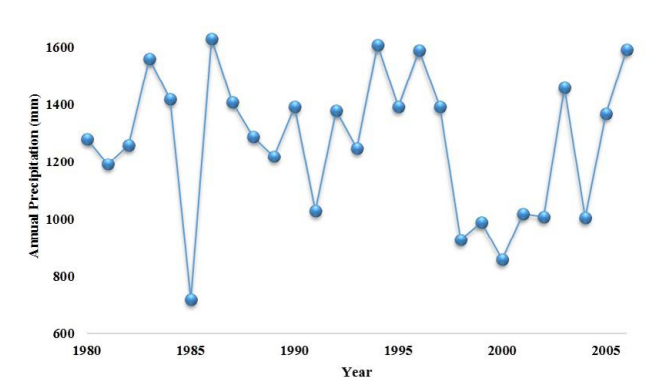

Figure 3: Annual precipitation in mm from 1980 to 2006.

Results

Based on satellite data and field expeditions carried out in east Liddar valley well developed Glacio-geomorphic features were identified like terminal moraines, lateral moraines, cirques, glacial lakes, whalebacks, rochee mountanee, erratics, hanging valleys, debris cones. A Glacial-geomorphological map of east Liddar has been prepared on scale of 1:25,000 (Figure 5). The slope morphometry of the glaciers of the east

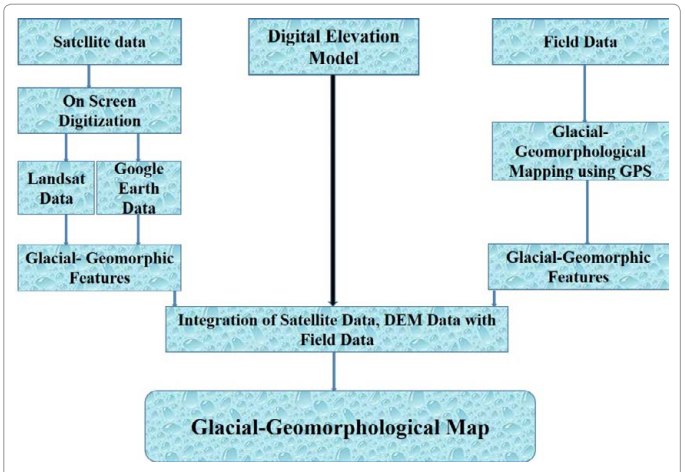

Figure 4: Methodology flowchart for the glacial-geomorphological mapping.

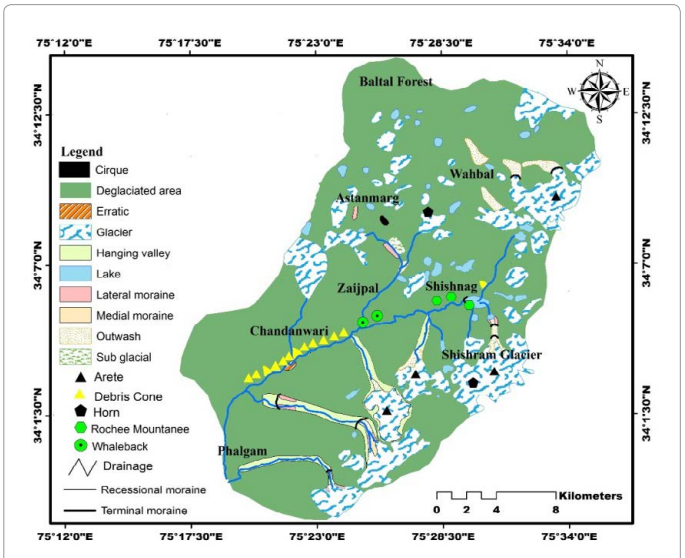

Figure 5: Glacial-geomorphological map of east Liddar.

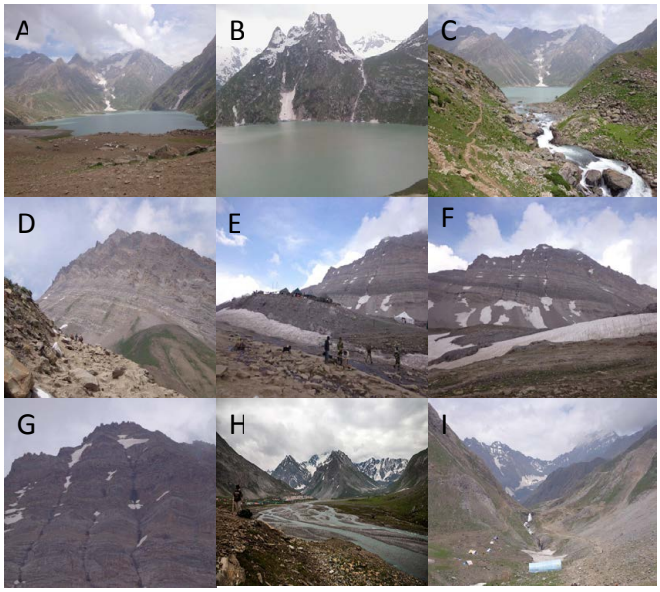

Figure 5a: Field evidences of different glacio-geomorphological features in east Liddar. *(A) Shishnag lake (B) Arêtes and horns (C) Terminal moraine (D) Glacial striations (E) Ground moraine (F) Lateral moraine (G) Glacial grooves (H) outwash plain (I) U-shapped valley.*

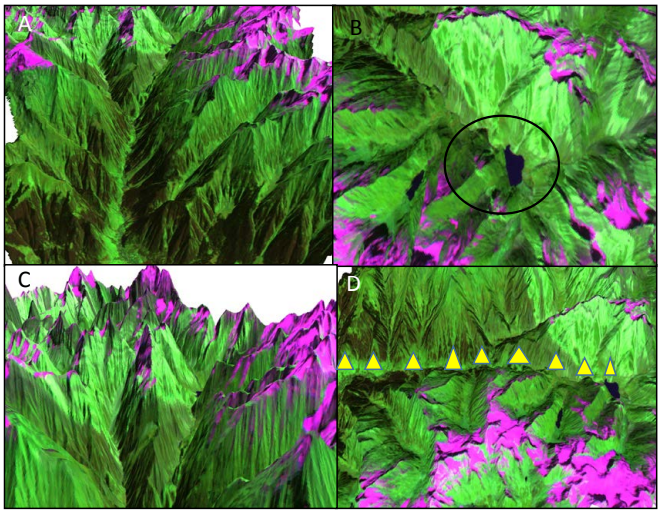

Figure 5b: Landsat images of different features in east Liddar. *(A) U-shapped valley (B) Shishnag lake (C) Arêtes and ridges (D) Debris cones.*

Liddar as well as valley shows that most of Geomorphological features are developed due to glacial activity. The broken fragments have been carried down by either melt water or as a mass flux. The lower ablation zone of Dudhal glacier, one of the glaciers among the east Liddar glaciers is covered by surface moraine [4-6].

The moraine near the snout is spread over 0.5 km and thus the lower part of the glacier is entirely hidden under the ground moraine.

Landform description

Lateral moraines: Lateral moraines are the linear ridges produced from the dumping of till with allied outwash deposits in the trough between the glaciers and valley sides. They are one of the commonest depositional features of the region and are aligned parallel to the margin of east liddar [7-9]. The lateral morainic ridges covers almost entire east liddar valley. They extend from chandawari upto Shishnag Lake. In the hanging valleys of manipal, Duldal, Wokhbal and Tuliyan the morainic ridges are well preserved along both the sides of their tributary channels. The height of lateral moraine near the lake is about 150 metres (Using Google Earth measurements). Lateral moraines appear as linear –curvilinear ridges with brown-grey colour for non-vegetated and red colour for vegetated, with medium to course texture along the sides of the valley glaciers on satellite data these were mapped using Google Earth™ and Landsat data [10-12].

Terminal moraines: A well-developed terminal moraine indicates that the ice remained inactive for a considerable period of time. Terminal moraines are the ridge of till that marks the maximum limit of glacier advance. The series of terminal moraines which marks the recession of the glacier are called recessional moraines. These are crescent-shapped with the convex side extending down the valley and appear as arcuate ridge. In east Liddar valley several moraines were identified and mapped. Near the snout of Shishram glacier, a chain of end moraines have been identified. Other terminal moraines have been identified in front of Shishnag Lake. They are primarily comprised of angular rock fragments. Other terminal moraines were identified and mapped in zaijpal, chandawari, ganshibal areas of east liddar valley. These terminal moraines appear as linear–curvilinear ridges with brown-grey colour for non-vegetated and red colour for vegetated, with medium to course texture along the terminus of the valley glacier on the satellite image. These were mapped using Google Earth™ and Landsat TM data.

Deglaciated valleys: In east Liddar valley a number of deglaciated valleys have been mapped, the most prominent are Shishnag valley, ganshibal valley, chandawari valley and sonsar valley. The deglaciated valley lies below the ablation zone and is formed due to the retreat of a glacier from its maximum extent. It appears as brown colour with medium texture on satellite data. One of the most outstanding characteristics of a well-developed glaciated valley is U-shape of its cross-profile. The side walls are considerably steep, approaching to vertical in place and the valley floor is broad and flat than in the river. Widening and deepening may depend upon the ability of the glacier to erode valley walls and cut into the rock of its bed. This also depends upon the lithology of its bedrocks and glacial plucking of the previously loosened blocks. Apart from the U-shapped cross-profile, other important features of the deglaciated valley are the presence of number of arcuate shaped ridges of terminal moraines, linear to curvilinear lateral moraines and scattered ground moraines, indicative of stages of deglaciation. The valley floors are filled with reworked outwash sediments and exhibits braided stream channels. The deglaciated valley is also marked by series of rock basins, formed probably by plucking in the areas of bed rocks which were shattered or closely jointed. These were mapped using Aster DEM, Landsat and Google Earth data.

Striations, grooves and polished surfaces: Striations, grooves and polished surfaces are the permanent on the surface of bedrocks by glaciers. The strength of marks depends upon the shape and comparative hardness of abrasion tools. The striations and polished surfaces are well-preserved along the valleyhead and valleywalls of east liddar valley. Their distribution is highly unequal. The heavily polished and striated surfaces are noticeable near zaijpal, Dudhal, and Wokhbal. In the polished surfaces there are minute striations and innumerable scratches. These are formed by grains of the sand trapped between the abraded boulders in ice and bedrock. These were mapped using Google earth data.

Whalebacks and Rochee mountanee: Whalebacks are glacially moulded, hard rock surfaces their length is greater than height. They have smooth rock surfaces on all the sides which have been produced by glacial abrasion. Whalebacks in the study area are elongated hillocks. They look like the shells of crocodile. In the study area the whalebacks have been mapped near the zaijpal were these occurs in a field. Rochee mountanee are irregular, rocky hillocks produced by the joint action of abrasion and plucking. The abraded and plucked surfaces are well defined. They expose the thickness of the ice and indicate the side, either stoss or lee. The rochee mountanee have been mapped at various altitudes of the east Liddar. Most of the rochee mountanee were mapped near shishnag, zaijpal, chandanwari areas of east liddar. These were localized above the altitude of 2000 metres.

Cirques: Cirques are universal in occurrence in the glaciated mountain regions and the most recurrent worldwide feature in the glacial landscape. They are restricted to the areas of present or former glaciation. As a result of this broad distribution they have received numerous names. The cirques are most recurrent glacial features in the east Liddar. Most of cirques mapped in the east Liddar are located in inaccessible areas. Several cirques have been mapped in east Liddar among which most of the cirques have been mapped in Shishram mountain range out of which some have developed cirque lakes. Other cirques which have established cirque lakes have been mapped near Wokhbal.In, Tuliyan and chandanwari areas of east liddar. Most of cirques have produced lakes. These cirques were mapped using Landsat and Google Earth data.

Rock fragments and boulders: The great percentage of rock fragments and large boulders are present in the moraines of chandanwari and Shishram. These rock fragments could not have been plucked by glaciers alone, but must have been created from weathered supraglacial rock facies. This is sustained by the identification of large erratic field and perched boulders at shishnag-chandanwari area of east liddar. Most of the erratics, perched boulders and large boulders of moraines are rounded and polished. They have been formed by englacial processes. Their large size and high spericity reflects the enormous power of the transportation of the east Liddar glaciers. These Erratics and boulders were mapped using Google Earth data.

Arêtes and horns: Glacial erosion amends the original form of mountainous regions to a greater extent with the development of valleys and cirques. Further growth of these glacial excavations supported by the mechanical disintegration results in the development of certain peculiar forms, an Arête is a knife edged sharp and narrow crest of a glaciated mountain. The slender shape of an arête is commonly due to removal of most of the material from in between two cirques, due to their advanced growth. Their sharp edges are attributed to wedging by frost action. A horn is a pyramidal multi-facetted projection form in the mountainous region. Several arêtes and horns have been mapped in east Liddar, most of which are located near Shishram, zaijpal, chandanwari, Tuliyan areas of east liddar.

Debris/Talus cones: The deglaciated area of east Liddar is marked with several debris/talus cones. These talus cones are formed by several processes working independently or in combination. These include avalanches; mass wasting, hill slope evolution etc. The loose debris formed due to glacial deposition provides the soft target for the movement of the large boulders during these processes. In east Liddar valley, particularly the left valley wall is totally obliterated with the talus cones. These debris cones were recognized right from chandanwari upto Shishram glacier. The primary data used for the mapping of these Arêtes, Horns and Debris cones was Google Earth™ data.

Conclusion

The paper presents the comprehensive map of unprecedented detail of glacial geomorphology in an area once covered by different glaciers. Mapped features include lateral moraines, terminal moraines, proglacial lakes, palaeo-cirques, erratic boulders, outwash plains, whale backs, glacial grooves, rochee mountanee, drumlins, glacial striations, hanging valleys debris/talus cones, subglacial material. This map will underpin further work on the glacial history and will provide a useful test for numerical ice-sheet modeling in the region. These landforms mapped and presented in this study area can be usefully employed towards a paleoglaciological reconstruction. Lateral moraines indicate the presence of glacial advances of the varying size and ages. Glacial landforms occur mostly in the various massifs of the east liddar or in close proximity to them. The method employed here shown only yield a minimum extent of maximum glaciation and for paleoglaciological reconstructions, needs to be improved with field investigations. Further different dating techniques like (OSL, thermo-luminescence and cosmogenic dating) and geophysical studies shall be carried out in the areas narrowed down by glacial geomorphological mapping which can be used for knowing the past history of glacier advances and retreats in east Liddar. The glaciers are active and complex bodies of ice and therefore, frequent measurements on the shifting of snout or percentage of retreat are needed.

Acknowledgement

The author is thankful to his coauthor for their valuable support. The authors express their gratitude to the reviewers of the manuscript; their suggestions have improved the manuscript substantially.

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