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EVIDENCE OF QUATERNARY LANDFORM FEATURES IN THE UPPER ALAKNANDA RIVER VALLEY AND THEIR GEOMORPHOLOGICAL INTERPRETATION

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ABSTRACT

A wide variety of Quaternary landform features occur around the upper Alaknanda River valley particularly from the Badrinath shrine area upwards. Glacial, Periglacial, Paraglacial and glacio-fluvial features are the most dominant landform features. They are indicative of the pattern of retreat of the Alaknanda glacier under deglaciation in the past and its impact over the valley area. Geomorphological characteristics and processes responsible for the development of these typical features have been systematically analyzed and a Quaternary geomorphological map, prepared upon detailed field study, has been presented here. From the geomorphic evidencee it is assumed that the last stage of Alaknanda glacier retreat was rapid for which the paraglacial slope deposits were formed and the valley walls were modified under this process. The huge flux of water with heavy sediment load generated as a result of mass deglaciation contributed to the deposition of thick sediment which, in course of time formed a wide expanse of river terraces farther down the slope.

***Key Words:* Quaternary, periglacial, paraglacial, glacio-fluvial, deglaciation.**

INTRODUCTION

Geomorphic processes and landforms are the major concerns of study for the Quaternary geomorphologists working in the recently deglaciated areas in the high altitude Himalayan regions. Evidence of the extension, limits, and retreat of glaciers have been reported by many workers (de Terra and Hutchinson, 1936, Fort, 1980, Lewis, 2005, Chattopadhyay, 2008, 2011 a & b, 2012 a & b, 2016a, 2017a & b). These authors have explored through observations and measurements that the glaciers have retreated considerably in the Post-glacial period through the Holocene and the process is still in progress. Deformation and modification of mountain slopes under periglacial and paraglacial processes often produce characteristic slope deposits through the deglaciated valleys in the Alpine environments. Recently deglaciated high altitude valleys in the Himalaya bear distinct evidence of paragacial slope deposits (Chattopadhyay, 2005, 2016). As a result of the withdrawal of glaciers enormous amounts of glacial debris material are carried down with the melt water of the river and deposited in the valley lower down the slopes which are known as the glacio-fluvial deposits. With the augmentation of the fluvial process these deposits continue to take typical shapes. This glacio-fluvial process and the evidence of produced landforms in various parts of the Inner Himalaya have been reported by many workers (Benn and Owen, 2002; Aizen, and Aizen, 2002; Narama, 2002). Geomorphic characteristics and processes responsible for the development of these landform features developed through the Upper Alaknanda valley from Badrinath shrine area have been systematically analyzed in this paper.

GLACIO-FLUVIAL LANDFORMS

Glacio-fluvial valley forms (Erosional features): Cross-profile of the Alaknanda Valley from about 10km before Badrinath upstream forms a classic example of glacio-fluvial Valley with its upper part having U-shaped and the lower part V-shaped (Plate – 1). Initially glacial and the subsequent fluvial process of erosion is responsible for the formation of this valley profile. This type of valley can be identified as a **valley-in-valley profile**. From this evidence it can be inferred that in the last glacial phase the Alaknanda glacier extended from its source down to about 10km below the present location of the Badrinath shrine and following the phase of deglaciation fluvial action continued to reshape the valley form.

Glacio-fluvial deposits (Depositional features): Glacio-fluvial deposits in the Upper Alaknanda valley occur mainly in the form of **river terraces** and **alluvial fans**. From the area around Badrinath shrine upward, for a distance of about 6km the stretch of the valley, bears ostensible evidence of glacio-fluvial deposits. The main geomorphic landforms in this part of the valley are river terraces and the alluvial fans. The main terrace extends along both the right and left banks of the river (Plate – 2). The river-side margin of the terrace on either side rests at about 40m above the average water level of the river. On the right bank, adjacent to the shrine, the width of the terrace is not more than 20m and it gradually widens to the north; the maximum is found near the Mana village at a distance of about 3km to the north of Badrinath where the terrace is about 500m wide. The terrace on the left bank is less in width having a maximum of 200m. At the northern end of Mana village River Saraswati, flowing down from the north, joins with River Alaknanda and the upstream of the main river valley from this point extends to the west towards Satapanth. From this point of confluence, the river terrace on the right bank of Alaknanda gradually becomes narrow while the terrace on the left becomes wider. With meticulous observation it was found that the component material of the terraces is a mixture of unsorted debris which can be attributed to glacial origin reworked in the later stage by the fluvial process. The valley entrenchment is likely to have taken place by gradual downcutting of the river aided with the subsequent tectonic upliftment of the mountain.

Plate – 1

Plate – 1: Cross-profile of glacio-fluvial valley of Alaknanda River near Badrinath

Plate – 2

Plate – 2: The widest part of the Upper Alaknanda River Terrace near Mana village about 3km upstream from Badrinath

Series of Alluvial Fans occur at the rear end of the terraces (Plate – 3) where the mountain wall descends and form a break of slope at the rear end of the river terraces. The average height of the alluvial fans is 30-40m and they are preserved in relict from in the present day with the mat of alpine grass. Towards the upslope part of the terraces, the alluvial fans gradually give way to the Talus Slopes which are now found relict form.

Plate – 3

Plate – 3: Vegetation-covered relict alluvial fans as they have descended to merge with the Alaknanda River terrace at its rear part

GLACIAL, PERIGLACIAL AND PARAGLACIAL LANDFORMS

The Upper Alaknanda Valley, beyond 3km after Mana village, by and large bears evidence of glacial, periglacial and paraglacial processes. The cross-profile of the valley in this part is primarily formed under glacial erosion as it shows U-shape, with certain modifications in the later stage under the process of both paraglacial and periglacial. Paraglacial slope development is a normal process that takes place in the Alpine environments during and subsequent to deglaciation (Owen, 1991; Ballantyne and Benn, 1994; Ballantyne, 1995, 2000, 2002; Watanabe *et.al.*, 1998; Curry, 1999; Chattopadhyay, 2015). Evidence show that paraglacial stress-release has acted on glacially-steepened rock walls in this part of the Himalaya. During and after deglaciation the Quaternary geomorphological processes produced a wide variety of typical landform features of rock fall and talus slope types. These are associated with features of catastrophic slope failure, deep-seated rock mass deformation, fan formation and progressive slope adjustment with intermittent rockfall activity. Development of avalanche tracks and melt-water channels (Plate – 4) also helped modification of mountain slopes simultaneously. Typical features, developed under the above conditions and their evolution on the mountain slopes in this area have been identified and interpreted from the geomorphological point of view.

Plate – 4

Plate – 4: Modification of hill slope by catastrophic rock slope failure in the Upper Alaknanda valley

Catastrophic rock-slope failure and associated landforms: Catastrophic rock-slope failure is a common phenomenon in all mountains. In the cold mountain environments, immediately after glacier retreat, the exposed mountain slopes tend to exert outward pressure giving rise to shattering of rocks and thus catastrophic slope failure occurs. It is assumed from the evidence of fresh morainic deposits through the Upper Alaknanda Valley beyond Mana village (about 4km upstream from Badrinath), that from the early Holocene, as the main Alaknanda Glacier continued to retreat, catastrophic rock-slope failures occurred extensively causing initial modification of slopes (Plate – 5). However, the huge volume of debris, covering the slopes on either side in the form of shattered blocks mixed with fines, raises a question of the extent to which these are paraglacial product and how much the shattering effect due to tectonic (seismic) activity of the Himalaya. It seems probable that the debris comprising large blocks, accumulated at the base of the slopes, are by and large the product paraglacial activity subsequent to the withdrawal of the glacier from the valley, and those covering the upper part of the slopes bear the evidence of the combined activity of paraglacial (due to stress release from the rock body), periglacial (due to frost wedging and frost shattering) and tectonic (due to crushing under compression and folding of rock strata) activities. Debris occurring in the upper slopes were found fresh in form and likely to be active in the present day contrasting to those on the foot slopes, which are by and large preserved in relict form as has been assumed from the spot marks of sizeable lichens on the boulders.

Plate – 5

Plate – 5: The Upper Alaknanda valley showing the gullied upper slope zone and the lower zone of coalescing debris cones.

Paraglacial talus slopes and fan formations are the second possible response that has been observed over the glacially processed, as well as steepened slopes in this upper part of the valley. Rapid rock-fall activity from the cliff-wall responded to the development of such paraglacial **talus accumulation**. Geomorphologists working in the cold environments noticed that the huge volumes of talus deposited on the footslope below the cliff-walls are not in conformity to the rate of the present rock-fall activity. This helped them assume that the rate of rock-fall in the past, subsequent to the withdrawal of the glacier from the valley, was much greater (Luckman, 1981; Gardnar, 1982; Marion *et. al.*, 1995).

Debris cones and colluvial fans are the unique paraglacial accumulation of the Late Pleistocene and Early Holocene age; there is, however, limited information on the development of cones and fans on recently deglaciated forelands (*cf.* Ballantyne, 2002). Relict paraglacial debris cones and alluvial fans are of widespread occurrence throughout deglaciated mountain environments. In the Himalaya, some paraglacial debris cones are assumed to be of Late Holocene origin. Glacier retreat in the Upper Bhagirathi Valley (Garhwal Himalaya in Uttarakhand) over the past 200 years has been followed by the development of debris-flow dominated fans composed of reworked morainic debris (Owen and Sharma, 1998). In Langtang Himal of Nepal Himalaya, numerous cones formed after the retreat of glacier-ice and the toes of some of these cones were subsequently truncated by later glacier advances

(Watanabe, 1998; Watanabe, *et. al.*, 1998). Series of voluminous paraglacial fans occur through the study area of the Upper Alaknanda Valley. These have often been deeply trenched by snow-avalanche tracks. Most fans in this area have now ceased to grow, and exhibit fan-head entrenchment and fluvial erosion.

GEOMORPHOLOGICAL MAPPING

Geomorphological mapping is an essential part of environmental studies in geography. This helps scientists understand the occurrence and pattern of distribution of respective landform features in the selected area. A Quaternary geomorphological map, as shown in Figure – 1 has been prepared upon meticulous observation of landform features detected during the field study. For this purpose, the relevant part of the Survey of India Map (NH44-5) was used as the base map and necessary conversion of contour values from feet to the metre was made. The map, as prepared is presented below.

Figure - 1

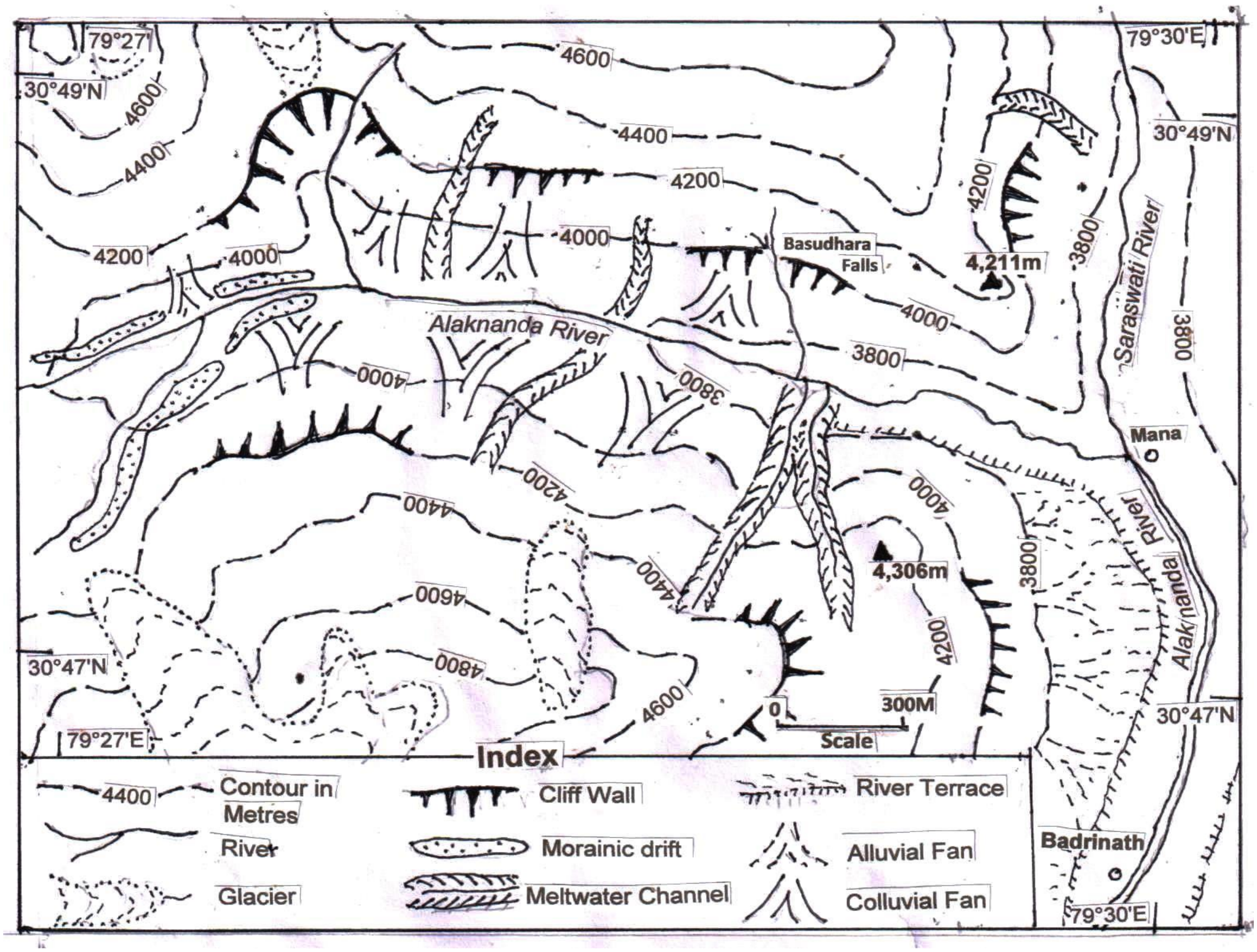

Figure – 1: Quaternary Geomorphological map of the surroundings of Upper Alaknanda valley

AN OVERALL ASSESSMENT

The Upper Alaknanda valley exhibits a wide range of Quaternary geomorphological features which include glacial, periglacial, paraglacial and glacio-fluvial landforms. From the source area of Alaknanda River down to about the Badrinath the valley form changes from U-shape (glacial) to a combined U- and V-shape (glacio-fluvial). While glacio-fluvial deposits in the form of river terraces and alluvial fans are dominant in the valley around the Badrinath shrine glacial, paraglacial and periglacial features are widespread in the valley upslope from Mana village area. Paraglacial slope evolution has been found dominant geomorphological process over the recently deglaciated mountain region in this very upper part of the Upper Alaknanda Valley. Stress release of the rock body during and immediately after the withdrawal of the glacier from the main valley created a triggering effect of this process within the rocky mountain walls overlooking the valley floor. Through the Upper Alaknanda Valley upward from Mana village on the way to Satapanth, a wide variety of paraglacially developed landform features have been identified, namely *talus accumulation*, *fan formation*, *antiscarps* and *convex bulging slopes*. It is assumed that with the gradual cessation of the paraglacial process since Late Pleistocene and Early Holocene, the features produced earlier, became relict and subject to periglacial and fluvial processes. Hence a further modification process of slope evolution continued since then. The rock-fall features deposited at the bottom of the slopes, comprising large blocks and little amount of fines represent the features produced mainly by paraglacial process during deglaciation and the angular debris, mixed with finer material occurring on the upper slopes represent paraglacially and tectonically (seismically) produced slope deposits.

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