

# LATE QUATERNARY SIGNATURES OF GLACIAL EVENTS IN UPPER REACHES OF MANDAKINI VALLEY, KEDARNATH AREA, UTTARANCHAL

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## ABSTRACT

The upper reaches of Mandakini valley are glacierised and are occupied by two glaciers: Chaurabari and Companion. Mandakini valley shows evidences of glaciation up to Rambara. The area upstream of Mundkata Ganesh was studied and five glaciation events were identified, on the basis of configuration of landforms, continuity and field relations of the glacio-geomorphic features. These include:- Rambara, Lenchuri, Garuriya, Chaurabari and Kedarnath. The paper deals with late Quaternary signatures of glacial events in the area including identification of a pulse of glacial advance corresponding to the Little Ice Age (LIA).

**Key words :** Late Quaternary Glacial Events, Mandakini Valley, Kedarnath, Uttarakhand.

## INTRODUCTION

Quaternary period has witnessed large fluctuations of climate effecting glaciation due to the cooling. These climatic fluctuations are preserved as geomorphic signatures in the proglacial/ supraglacial regimes of glaciers. These signatures are both erosional and depositional in nature. Depositional landforms are formed by retreating glacier in its proglacial regime and comprise moraines, glacio-fluvial terraces, outwash plains, debris cones, eskers, etc. Erosional features are formed by advancing glaciers, mostly along the valley slopes, overriding earlier depositional landforms and cutting the valley profile. The identification of depositional landforms often become difficult due to the masking effects of the various geomorphic processes acting in the area vacated by the glacier, viz. fluvial, eolian, paraglacial, mass movement, etc. Erosional landforms, though limited to valley slopes are invariably preserved but their interpretation often becomes difficult due to uplift and neotectonic activities.

**Table 1: Chronology of glacial events in Himalaya.**

Late Pleistocene	130-10 Ka
Early Middle Pleistocene	0.6 Ma
Late Lower Pliocene	0.73 Ma
Late Pliocene	3.5 Ma

The Himalayan mountain ranges witnessed at least four phases of glacial and interglacial periods (Kumar, 2001) (Table 1). After the last major glacial event corresponding to late Pleistocene, the present interglacial period is continuing. During this interglacial phase a small but significant event of glaciation christened as "Little Ice Age" (LIA) has been noticed in several parts of Himalaya, including Gangotri (Vohra, 1971) and parts of Chenab valley. The evidences for the advancement of glaciers during LIA have been noticed in Kedarnath area too.

Kedarnath area falls in the upper reaches of Mandakini valley, Chamoli district, Uttarakhand. Mandakini is a fifth order basin of Alaknanda fourth order basin (as per inverse Strahler system). Mandakini valley is an almost



Fig.1. The peaks surrounding the catchment of its Mandakini valley, Kedarnath area.

N-S trending elongated valley. The five peaks, viz. Bharatkunta, Kedarnath, Mahalaya Parvat, Peak 5505 and Hanuman top form head of the valley with amphitheater like configuration (fig. 1).

#### PRESENT GLACIATION IN MANDAKINI VALLEY

The upper reaches of Mandakini valley are occupied by two glaciers – Chaurabari and Companion glaciers which have separate regime, orientation and flow. Both the glaciers terminate at the same place but at different elevations and are bounded separately by their lateral moraines (Table 2).

The glacier surface of Chaurabari glacier below ice fall region is about 10-20 m lower than that of the Companion glacier. The glacier snout

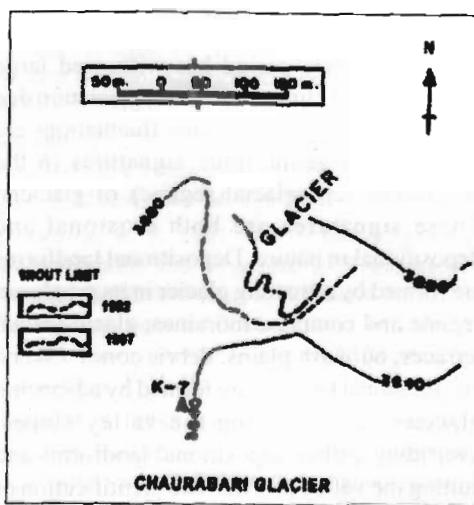


Fig. 2. Snout map of Chaurabari glacier

Table 2: Glacier parameters of Chaurabari and Companion glaciers.

Name and Identification No.	Orientation	Length (km)	Width (km)	Area (km <sup>2</sup> )	Lowest Elevation (m.a.s.l.)
Chaurabari (5013302 003)	S-SE	7.0	1.0	12.28	3840
Companion (5013202 004)	SW-S	4.35	0.40	2.11	3690

was mapped in the years 1992 and 1993 on 1:5,000 scale. The mapping revealed a recession in the snout, evacuating  $2975 \text{ m}^2$  or  $2.975 \times 10^{-3} \text{ km}^2$  of the glacier area (Srivastava *et al.*, 1997). The snout front recorded a recession of 55 m while its right and left lateral extensions receded by 65 m and 15m respectively.

There has been an overall recession between 1992 and 1997 in the snout with a net evacuation of  $6775 \text{ m}^2$  or  $6.775 \times 10^{-3} \text{ km}^2$  of the area (fig. 2), with an annual average evacuation of  $1335 \text{ m}^2$  or  $1.335 \times 10^{-3} \text{ km}^2$  of area (Swaroop and Shukla, 1998). The proglacial regime of these glaciers constituting the upper reaches of Mandakini valley has signatures of glacial events of late Quaternary period (fig. 3). The area above Rambara shows typical glacial terrain

having 'U' shaped valley profile with loose morainic material and majority of *nalus* occupied by debris cones. The area is also occupied by humps of recessional moraines interspersed with outwash plains. The area above Garuriya has very well developed outwash plain bounded by lateral moraines. Several sets of lateral moraines corresponding to different levels of glacier recession are discernible.

#### BASIN ANALYSIS

Basin analysis studies were undertaken with (i) entire basin upto Mundkata Ganesh, (ii) upto Ghindurpani having well documented glacial evidences and (iii) basin of (ii) without glaciated area.

The important observations include:

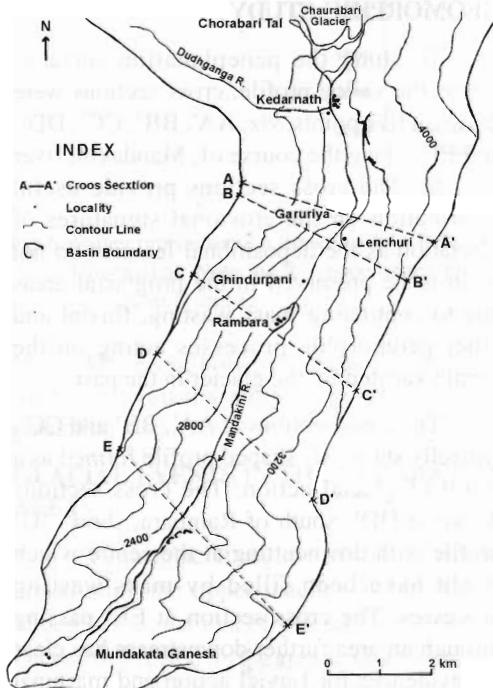


Fig.3. Map of the upper reaches of the Mandakini valley, Kedarnath area.

- The lower stream frequency and drainage density in the basin (ii) can be attributed to the nature of the valley fill and presence of glaciogeomorphic features. In case of basin (i) almost half of the basin is under fluvial influence.
- The hypsometric integral (fig. 4) of these basins were found to be 0.42 and 0.49 for first two sectors of the basin which are less than 0.5 suggesting mature stage under the fluvial regime. The lower hypsometric integral in high altitude terrain corresponding to mature stage can be attributed to the masking effect of glacier wherein the glacier ice masks the topographical irregularities and gives a false impression of maturity.
- In order to negate the effect of glacier, hypsometric curve (fig. 5) was redrawn for the area excluding the glaciated part of the basin. In this case the hypsometric integral has been found to be 0.73 indicating youthfulness of the basin.

The basin analysis this indicates that the upper reaches of the Mandakini valley have been under glacial cover that has been exposed

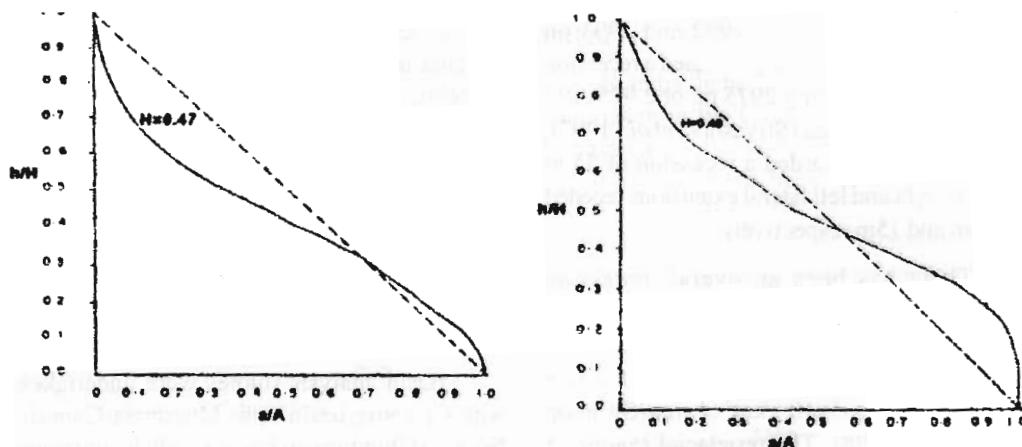


Fig.4. Hypsometric curve for (i) and (ii) sectors of the Mandakini basin.

due to recession of the glacier in the past. The nature of the valley, i.e. youthfulness can be attributed to the change in the flow regime, from glacial to fluvio-glacial and fluvial. The glaciogenic sediments in the valley fill have resulted in the poorer stream frequency and lower drainage density. Moreover, the parameters of basin analysis suggest that the entire area up to Mundkata Ganesh was perhaps under the influence of glacier regime in the past.

The superimposition of the fluvial system on a palaeo-glaciated region has modified some of the basin parameters.

#### GEOMORPHIC STUDY

To study the peneplanation surfaces across the valley profile, cross sections were drawn at five points, viz. AA', BB', CC', DD', and EE' along the course of, Mandakini river (fig. 6). The cross sections provide useful information on the erosional signatures of glaciation as the depositional features do not seem to be preserved in the proglacial areas due to continuing mass wasting, fluvial and other geomorphic processes acting on the terrain vacated by the glacier in the past.

The cross sections at AA', BB' and CC', typically show 'U' shaped profile formed as a result of glacial action. The cross sections drawn at DD', south of Rambara, show 'U' profile with downcutting at the centre which might have been filled by mass wasting processes. The cross section at EE' passing through an area further downstream has clear cut evidences for fluvial action and marginal shift of the channel towards west. This shift can be attributed to the Late Quaternary neotectonic activities. The left bank of

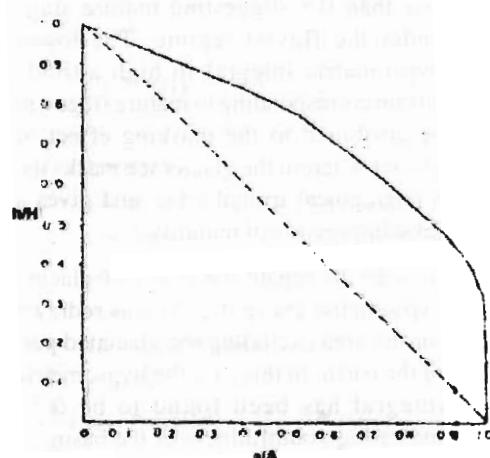


Fig. 5. Hypsometric curve for sector (iii), upto Ghindurpani excluding glacier areas.

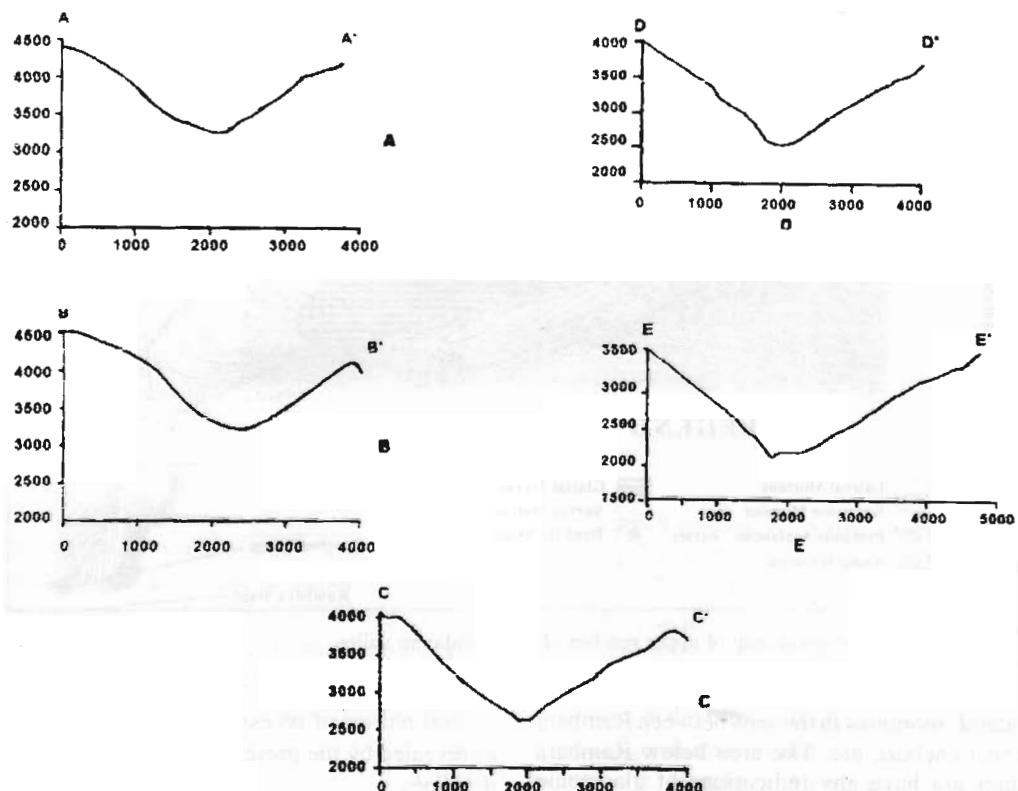


Fig.6. Valley profile section drawn at AA', BB', CC', DD' and EE' in the Mandakini valley, Kedarnath area, Uttarakhand. Note the 'U' shape of the profile in A, B and C, followed by the emergence of fluvial activity in D and E.

Mandakini river, however, show flattening at higher elevations suggesting imprints of glaciation.

#### GLACIAL EVENTS IN THE KEDARNATH AREA

The proglacial regime of these glaciers constituting the upper reaches of Mandakini valley has signatures of glacial events of late Quaternary period. In the area at least five major events of glaciogenic activity have been identified. These events are identified on the basis of configuration of landforms, continuity and field relations of the glacio-geomorphic

features. The geomorphic features include different levels of moraines, terraces (both erosional and depositional), valley profile, etc. Basin analysis, cross sections preparations and geomorphological mapping was undertaken to identify these glacial events. These events are named as Rambara, Lenchuri, Garuriya, Chaurabari and Kedarnath in chronological order (fig. 7).

**Rambara Event :** The event, is marked by the 'U' shaped valley of Mandakini river upstream of Rambara curved out by Chaurabari trunk glacier; presence of terminal moraine at Rambara; partial preservation of

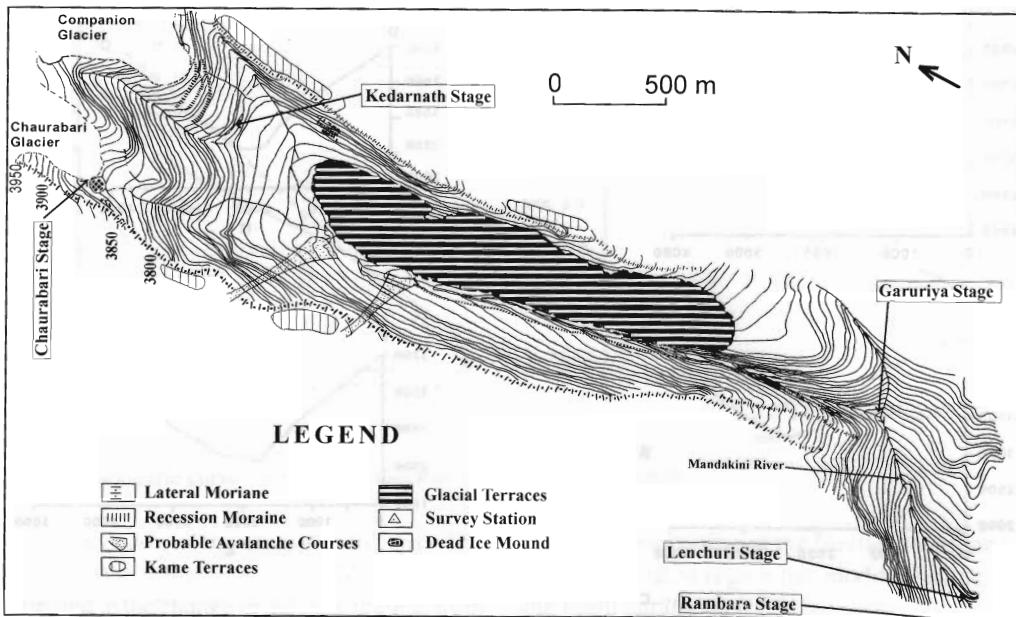


Fig. 7. Geomorphological map of upper reaches of the Mandakini valley.

lateral; moraines in the area between Rambara and Lenchuri, etc. The area below Rambara does not have any indications of glaciogenic deposits. Thus, Rambara (2700 m asl) marks the limit of clear-cut evidence of glaciation.

**Lenchuri Event :** The event (3050 m asl), is marked by the 'U' shaped valley profile, continuity of lateral moraines of Chaurabari trunk glacier, presence of erosional terraces near Garur Chatti, terminal moraine humps, and valley slope material, etc.

**Garuriya Event :** The event (3200 m als), is marked by the 'U' shaped valley profile, continuity of lateral moraines of Chaurabari trunk glacier, presence of glacio-fluvial terraces in the area downstream of Kedarnath township, kame terraces, and the valley slope material, etc. The event is most widespread and responsible for the maximum development of geomorphic features in the area. It was during this period when the glacier left the valley wall and got confined within the lateral moraines of highest level. Even during this event there were

several phases of recession and advancement as revealed by the presence of traces of lateral moraines.

**Chaurabari Event :** The event (4000 m asl) is marked by the nature of recessional moraines, independent lateral moraines of Chaurabari and Companion glaciers, and the level difference between the two glaciers, etc. During this event the Chaurabari trunk glacier receded to its maximum limit and the erstwhile tributaries were modified into two glaciers, viz. Chaurabari and Companion and later developing into independent regimes. The presence of rounded pebbles in the snout region, the nature of ground moraine in the immediate vicinity of the snout, etc. suggest that the glacier must has receded beyond the present position of the snout.

**Kedarnath Event :** The Kedarnath, an event of advancement, is marked by the moraine located behind the temple complex. The cross cutting and overriding relation of the right lateral

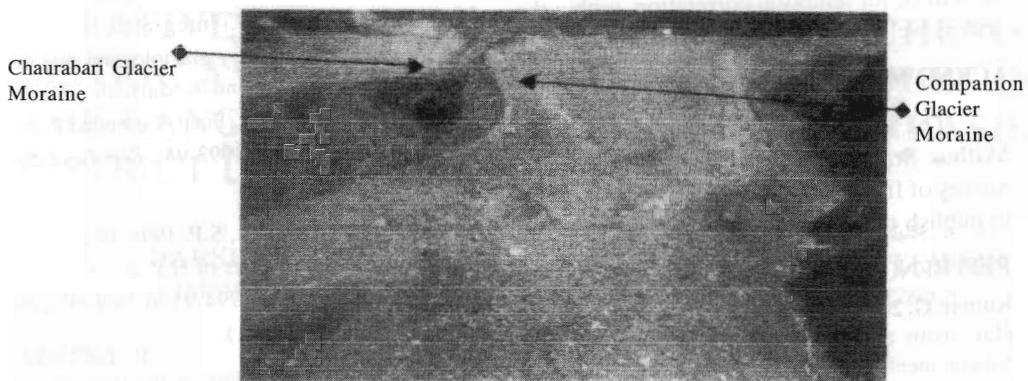


Fig.8. Lateral moraine of Companion glacier overriding the lateral moraine of Chaurabari glacier.

moraine of companion glacier vis-à-vis that of the left lateral moraine of the Chaurabari glacier indicates advancement of companion glacier perhaps during the little ice age (fig. 8). The terminal moraine hump of Companion glacier is unstabilised and is without vegetation cover. No ice cave is visible. The terminal moraine hump of Chaurabari glacier is about 275 m in height and is well stabilised with a thick vegetation cover suggesting its antiquity in comparison to terminal moraine hump of Companion glacier. The secular movement data also suggest faster recession of Chaurabari glacier. The continuing trend of recession of glacier after Kedarnath event may be the part of the current global recessional phenomenon. However, the rate of retreat of the Chaurabari glacier is more than that of the Companion glacier which can be attributed to the different glacial regimes of the two glaciers.

### CONCLUSIONS

The Mandakini valley permits an excellent opportunity for understanding the interplay of the glacial - interglacial events during Late Quaternary period. Based on the studies carried out in the upper reaches of the Mandakini valley, including geomorphological mapping, basin analysis, identification and

correlation of various geomorphic features, etc., an attempt has been made to work out the glacial history of the area. Though the entire basin from the glacier snout to Mundkata Ganesh shows evidences of past glaciation, the area upstream of Rambara has more conclusive evidences in the form of both depositional and erosional geomorphic features. In all five glacial events, viz. Rambara, Lenchuri, Garuriya, Chaurabari and Kedarnath have been identified. The Kedarnath event as identified through the configuration of lateral moraines of Chaurabari and Companion glaciers, and the nature and disposition of terminal moraines suggest a cooler climatic regime, perhaps during the Little Ice Age (LIA). Similar advancements/ static dispositions of snout front have been observed in the glaciers located in other valleys in the Himalaya. Once the glacier regime of the two glaciers, viz. Chaurabari and Companion became independent during the Chaurabari event, the advancement during LIA resulted in different behaviour of the two glaciers. Thus, while Chaurabari glacier showed little advancement, Companion glacier indicated appreciable advancement. Though the present study, brings out a comprehensive account of the glacial regime of the area and different events as deciphered from geomorphic

processes and their inter-relationship, events need to be for temporal correlation, within the area as well as for inter-basinal correlation.

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