Journal Homepage: - www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/16908
DOI URL: http://dx.doi.org/10.21474/IJAR01/16908

RESEARCH ARTICLE

GEOMORPHOLOGY, TERRACES OF VARIOUS DOMINE OF ALAKNANDA ITS TRIBUTARIES AND NEOTECTONISAM, GARHWAL HIMALAYA PARTS OF CHAMOLI TEHRI UTTAKASHI & PAURI UTTAR PRADESH (UTTRARKHAND) INDIA

Dr. A. A. Khan[1] and Dr. A.C Chaterjee[2]

1. Ex. Director Geological Survey of India, Ex. Director Rajeeve Gandhi Prodyogiki Mahavidhyalaya Bhoplal M.P. India.
2. Ex Head of Departmant School of Studies in Geology Vikram University Ujjain M.P. India.

……………………………………………………………………………………………………....

Manuscript Info

……………………….

Manuscript History
Received: 15 March 2023
Final Accepted: 18 April 2023
Published: May 2023

Key words:-
Alaknanda, Ganga, Geomorphology, Terraces, Neotectonics, Moraines. Epigenetic Gorges, Glaciated Valley, landslide

Abstract

………………………………………………………………….

The Geological and Geomorphological study in Upper Ganga basin has been attempted in parts of de Uttarkashi,Chamoli, Pauri and Tehri districts, an area of 10000 Sq.kms in parts of QA sheet 53J and 53 N on 1:50000 scale of Garhwal Himalaya U.P has been covered; presently known as Uttrakhand State of Union of India. Out of total area of study, an area about 3500 sq.Kms (1:50000 scale) has been selected for detailed Geological, Geomorphological and Sedimentological study. The area of Upper Ganga basin consisting of Alaknanda, Bhagirathi, Bhilangna, Nandakini, Mandakini, Pindar, Dhauli- Ganga Bal- Ganga, Madhmeshwar Ganga and Berhi Ganga. The Alaknanda is chracterised by six terraces followed by Bhagirathi with five terraces, Bhilangna Nandakini four terraces, Mandakini /Pindar/Dhauli-Ganga /Balganga three terraces, Madhmshwar Ganga two terraces and Berhi Ganga one terrace, amidst these Alaknanda is trunk stream and others are tributaries. Geomorphologically, the area is divided in to seven geomorphic units viz High relief formerly glaciated area, Structural hills, Denudational hills, Area of mass wasting, High level dissected fans River Terraces and Present day flood plain of Alaknanda and its tributaries. These units area developed in response to lithology to erosional land depositional activities and tectonic in which they are embedded. Each unit is characterized by distinct drainage, diagnostic geomorphic landform elements and features, photo charcters and morphogenetic expression. The other geomorphic features and elements identified in the area are point bar, channel bar, alluvial fans ,talus cone , rock cut terraces fan cut terraces , abandoned and fossil channel courses,epigenetic gorges, strant lines landslides, rock fall scree and scree slope, retreating scarp, abandoned cirque, cirque morines, arÃªtes, threshold, horn peak and glacial lake. The area genetically comprised of terraces of three domains, viz. glacial, fluvio-glacia and fluvial which represent distinct environment of sedimentation of Pleistocene, late Pleistocene and Holocene time during Quaternary period. The glacial terraces are identified at an average elevation of 1150 m above m.s.l. the fluvio-glacial terraces at an average elevation of 975 m above m.s.l. and fluvial terraces at an

Corresponding Author:- Dr. A. A. Khan
Address**:-** Ex. Director Geological Survey of India, Ex. Director Rajeeve Gandhi Prodyogiki Mahavidhyalaya Bhoplal M.P. India.

average elevation between 650 to 900 m above m.s.l. The Badrinath temple is situated in glaciated trough valley of Alaknanda, which comprise of, four levels of the glacial terraces (lateral moraine), cirque moraine on mountain flanks and the terminal moraine at the base of valley. whereas Kedarnath in the upstream of Mandakini, where number of well developed cirques were identified on high mountain, they are mostly arm chair shaped hollows with a steep to vertical head walls, concave floor and a threshold, these cirques are noticed at an average height of about 4500 m. The Kedarnath temple is situated in glaciated trough valley on quaternary platform formed by coalescing of cirque, lateral moraine and terminal moraine. The-Himalayan thrust like Central thrust Srinagar thrust, Alaknanda fault, Tons thrust show flattening dip suggesting that they lie at comparatively at shallow depth at short distance, down dip from their out crops, recent movements along the trace of these thrust/ faults are not of high and longer magnitude but have considerably affected Quaternary terraces of glacial, fluvio-glacial and fluvial domain of Alaknanda and its tributaries. Beside drainage, river bed profile, landscape architect and over all morphogenetic expression of the area, this bears the adverse impact of tectonic activity. The imprints of neotectonisam associated in the area indicate that these thrust /faults are active and have, signatures of sinking of landscape, mass wasting activities and posed neosiemic hazards and tectano-ecological problems, bears signatures of sinking of the area, mass wasting activities and neosiemic hazards. The geomophological study of the area, overall morphogenetic illustration, imprints of neotectonisam, disposition of terrces of different domains, mass wasting activities, drainage net, channel morphology, landform elements of glacial, fluvioglacial and fluvial domain of Alaknanda and its tributaries; indicate that tectonically the area is active and slow movements are taking plae along thrust, faults and lineament. In the area North of Wazri in Jamuna valley, North of Uttarkashi around Sainj in Bhagirathi valley, around Tugnath and Chamoli and South of Joshimuth in Alaknanda valley revealed that there is sharp persistent curvilinear break in topography, which has geothermal manifestation at Wazri Gagnani anda Tugnath in the form of emitation of hot springs. This curvilinear line has further reconfigurated the neo stream net works system and affected morphogenetic expression it appears to be due to horizontal movement of sub - tectonic plate towards south, which, is sole collective and cumulative causative factor in dislocation of tectonic ecology of the area and has resulted micro earthquake shocksand and segmental sinkiking of area. The overall study revealed that the the area is sensitive active and is vulnerable to any techtono-seismic event; it is matter of serious concerned and needs further attention.

……………………………………………………………………………………………………....

Introduction:-

The Geological and Geomorphological study in Upper Ganga basin has been attempted in parts of district Uttarkashi,Chamoli, Pauri and Tehri districts an area of 10000 Sq.kms in parts of QA sheet 53Jand 53 N on 1:50000 scale of Garhwal Himalaya U.P; presently known as Uttrakhand State of Union of India. Out of total area of study, an area about 3500 sq.Kms has been selected for detailed Geological, Geomorphological and Sedimentological study.

The Dehradun and Rishiksh are nearest rail heads of Northern Railway of area of study. These heads are connected by good moterable roads leading to famous pilgrimage centre Badrinath, Kedarnath, Gangotri and Janmnontri. The state highway No 54 which is connecting Rishikesh and Badrinath bifurcates at Rudraprayag along Mandakini River and terminates at Kedarnath via Sonprayag. The Tehri is about 85 kkilometers from Rishikesh on state high way No 53 connecting Rishikesh –Tehri Uttarkashi Gangotri .This road runs along Bhagirathi River between Tehri and Gangotri. A bifurcation from Tehri Gangotri bifurcates at Dharasu and connects Bhagirathi valley to Yamuna valley crossing the water divide at Ravi pass.In addition to these, there are fair weather roads which connects Kathgodam to Karanpryag via Ranikhet, Dwarhat and Adi-Badri from east and Mussoori via Dhanaulti to Tehri from west to Alaknanda and Bhagirathi valleys respectively. (Plate No.1)

Previous Work

The area of Upper Ganga basin consisting of Alaknanda, Bhagirathi, Bhilangna, Nandakini, Mandakini, Pindar, Dhauli Ganga Bal Ganga, Madhmeshwar Gangaand and Berhi Ganga, amidst these Alaknanda is trunk stream and other is tributaries. These streams emerge from different glaciers in Himalaya and decennd in sinuous to meandering channel pattern. In their courses they traverse through entrenched valleys, and deep gorges leaving glacial Fluvio-glacial and Fluvial terraces in decreasing antiquity, due to uplift and climatic changes in the area representing different phases of sedimentation in Quaternary period.

Padhi and Sharan (1972),Dubey (1974a) , Shukla Khan & Dubey (1973)Khan (1974) Dubey (1974b), Khan & Balachandran, Khan (1975), Sinha & Khan, Khan (1976),Khan eta.(1981), Khan and Nawani (1981), Khan (1981) Khan & Dubey 1985) Khan (1987) have carried out geological and Geomorphological studies in parts of Alaknanda, Bhagirathi, Bhilangna, Nandakini, Mandakini, Pindar, Dhauli Ganga Bal Ganga, Madhmeshwar Gangaand Berhi Ganga.

Present Work

The present paper is an attempt to trace integrated picture of geomorphic evolution, stratigraphy of terraces of various domain, morphogenetic, morphotectonic, and Neotetectonic analysis of Upper Ganga Basin in Garhwal Himalya during Quaternary period.

The area under study has witnessed the intensive erosional and depositional activity subsequent to recession to glaciers which has entirely modified the pre-existing, topography and given rise to seven morphogenetic regions, (Khan, 1981 and Khan et al, 1981). These regions have been developed in response to lithology of the area to erosional and depositional activity and regional tectonics in which they are embedded, Khan (1981) & Khan (1987) the glacial, inter glacial and post glacial climatic conditions; have also played the vital role in morphogenetic shaping of present day complex. These regions are delineated in the area based on their genesis, and associated diagnostic landform elements and features, (Khan 1985). Their sequential order of development is as follows: (Plate No. 2)

1. High relief formerly glaciated area;
2. Structural Hills;
3. Denudational Hills;
4. Area of Mass wasting;
5. High level dissected Fans;
6. River Terraces;
7. Alluvial Plain.

Hige Relief Formerly Glaciated Area:

The formerly glaciated area mainly comprises sharp crest asymmetric and symmetric ridges of gneiss, granite, schist, quartzite and metavolcanic rising to an average height 3050 m above the m.s.l. It is characterized by typical glacial and peri-glacial topography, embracing numerous glacial and peri-glacial features such as abandoned cirques, eroded threshold, subdued regional arêtes, horn peaks, cliffs and glacial lake, (Khan 1987). This area is mostly restricted in north, northwestern part of the area under study in the headword ends of Alaknanda, Bhagirathi and Bhilangha, Mandakini, Nandakini, Dhauli Ganga Madhmeshwar Ganga andBerhi Ganga, these snow fed river valley in this area have typical U-shaped flat bottom with the small V-Notch at the base indicating the superimposition of fluvial cycle of erosion on these pre-existing old glaciated valleys in the recent past.

These valleys are characterized by numerous Quaternary land forms of glacial, fluvio-glacial origin such glacial, fluvio-glacial terraces and cirque moraines. The cirque moraines descend in the valley from the side and forms the conspicuous series of isolated and coalescing cones in the valley floor, which generally taper off upward and their apex partly touches the threshold of a abandoned cirque and often terminate against them the prominent cirque morineis developed on the right flank of Alaknanda west of Joshimuth north of Hellon and Mana. The abandoned cirque are commonly associated with active and recent landslide in the area, as seen in the headword ends of Ganesh Ganga and around Tapoban in Dhauli Ganga. The most of cirques are located in east-west trending ridge. They are mostly associated with active glacier. But there are many cirques in the watershed region of Bhagirathi, Bhilangna, Madhmeshwar Ganga and Pindar which are devoid of any snow and ice. The assorted rock debris and fine sediments within the cirques are seen occasionally covered by thin veneer of fresh snow. Though the majority of cirques are semi-circular in shape, but semi-elliptical or even rectangular cirques are not uncommon. In the northwestern part of the area few composite cirques (small cirques within a large cirque) are also noticed, cirques which are filled by fresh snow are termed as nivation cirque.

In the upstream of Mandakini in north of Kedarnath temple number of well developed cirques were identified on the aerial photographs, they are mostly arm chair shaped hollows with a steep to vertical head walls, concave floor and a threshold these cirques are noticed at an average height of about 4500 m.The Kedarnath temple is situated in trough glaciated valley on quaternary platform formed by cumulative accumulation and coalescence of side oraines, cirquue moraines and terminal moraines.duting plestocene times.

The glacial lakes seen in the area are mainly three types, one occurs at depressed bottom part of empty cirque which is known as tarn. The other type occurs along the glacier valley between lateral moraine and side wall of the glacial trough.Besides small lakes occur along linear depression on the margin of glacier itself, even on the ice in the surfacial moraines. These are called pre-glacial lake in the watershed of Mandakini. Besides several glacial lake and Cirque Lake, entrapped water pools in side moraines were identified in high ranges in the watershed region of Mandakini, with the aid of aerial photograph. The prominent lake observed are Panya Tal at an elevation of 4700 m. Vasuki Tal 4400 m. and Bisuri Tal at 3900 m. A number of small lakes are noticed in northwest of Dautulia Tibba, lake also occur in the deeply scoured depression of these cirques and contain water even during the summer. The majority of them can be grouped under Cirque Lake.

In the north-western part of the area, two cirque lakes are observed at different levels on the east facing slop. The two successive levels of these lakes indicate lower one is the older and and upper one is younger thus representing upper one an aerial stage of glaciations such cirques are called tandem cirque.

The other prominent lake of the area, Vasuki Tal also occurs in the deep scoured part of cirque. In the upper reaches of Vasuk Ganga, northwest of Vasuki Tal, little depression in the valley at different levels are seen. These were formed by differential scouring by the valley glacier, which once extended south. These depressions were connected by the stream and appear as springs along the valley wall.

A beautiful glacial lake observed is the Blsuri Tal in the south east, it occurs in the cirque depression and surrounded by glacial drift material.

Spectacular features of glaciated mountain are aretes, which are steep serrated ridges and horn peaks, which rise to high levels. The northern part of area of study has unmistakable assemblage of these features. Arêtes were formed by encroaching of cirque. A number of horn peaks which were formed at the junction of arêtes are found in the area. prominent amongst these are the Mandani Peak 6193 m. north of Gopeshwar.

The hanging valleys are seen in the upper reaches of Alaknanda around Joshimuth, Hanuman Chatti, near Sukhi, Gangani in Bhagirathi in Bhilagna upstream of Ghansali, in Mandakni near Kedarnath temple, in Pindar upstream of Nandikesri, in Nandakini upstream of Ghat. These hanging valleys are associated with water fall. The V-into U-shaped valley is common features seen in the upper reaches of Alaknanda and its tributaries which were formed by superimposing of glacial cycle over the fluvial one.

It is interesting to note that glaciers trending E-W direction are larger in size than the others. The glacier facing north or south direction are smaller in size, mostly hanging in nature, are associated with more permanent avalanche tracks which are generally very smooth concave in nature with deep grooving on the surface.

In the Satopanth area, one south facing small glacier is seen over riding the main glacier; similarly another south facing glacier of Bhiandhar Ganga is seen coming down over the main glacial trough pushing scouring debris in the main valley forming glacial cone along valley flanks.

Innumerable crevasses in definite pattern are seen in Alaknanda around Joshimuth, Hanuman Chatti, in Bhagirathi near Sukhi, Gangani, in Mandakni near Kedarnath temple, in Pindar upstream of Nandikesri, in Nandakini upstream of Ghat along entire length of the glacier. In the amphitheatre part of cirque, crevasses form circular pattern which ease out glacier movement by the convexity which thrust out ground moraines across the threshold in the valley and at places form talus cones of moraines in thes valleys.

Structural Hills:
It is obvious that the landforms result primarily due to erosion rather than deposition show conspicuous influences of lithology and structure in varying degree depending upon the differential competency of rocks, degree of dissection, drainage development and disposition of the rocks exposed to erosion.

The present area of study constitute the parts of inner lesser Himalaya and outer edge of the Central Himalaya, lithologically it comprise of three distinct group of rocks viz. north to south (i) the Central Crystalline group (ii) Garhwal group and (iii) Dudatoli group, each group is separated either thrust or fault. These different groups comprise of gneiss granite, schist, quartzite, phyllite, limestone and meta volcanic, exhibit the strong imprints of neotectonic activity in the area. These rock units form both strike and randomly oriented symmetric and symmetric ridges, the later being most common in the area perhaps due to folded nature of the terrain. At few places particularly near the nosal portion of anticline and syncline the ridges are curvilinear and follow the strike. In general the crest lines exhibit sub-rounded to rounded characters and is mostly characterized by retreating and joint control scarps. The drainage system is mainly influenced by net work of joints, faults and fracture pattern resulting in a sub-parallel to parallel and rectangular drainage pattern.

The most prominent structural hills delineated in the area are Nagthunga Maithana syncline, Chattopipal anticline and Rudraprayag anticline.

The Nagthunga Maithana syncline has NW-SE axial trend and plunge in the southeast direction. In the north, the closure of syncline is cut off by a curvilinear lineament around Kalsir. It comprises both strike and randomly orientated ridges.

The Chatipipal anticline is overturned plunging anticline with regional axial trend in NW-SE direction. The North West extension of the fold axis is cut off in Alaknanda valley around Gauchar by E-W trending Alaknanda fault.

The structure of western part of the area appears to be much more complicated. The most important structural elements in doubly Rudraprayag anticline, with axis trending in ENE-WSW, abut against the Alaknanda Narkota and Rudraprayag, it forms the anticinal valley and Alaknanda partly curves its course along the axial plane. The Kaliyasaur fault on west swings and offset the Rudraprayag anticline axis.The huge active landslide of rotation nature near Kaliyasaur is related to this fault.

Denudational Hills:
The denudational hills predominantly comprises quartzite, slate, phyllite, limestone and basics and are characterized by symmetric to asymmetric moderately sharp to sub- round crest lines rising to the average height 0f 1870 meters above m.s.l. These hills were subjected to varying degree of dissection and are still under the active influence of different erosional processes. The chief erosional pattern recognize in these hills are accelerated headword erosion, deep gully erosion, rill erosion and at places sheet erosion. The stream running these topography have generally steep gradient and carry some sediment load from the headword ends and deposit it either on their terminus or open in to t higher orders streams. It is the endless process a dual way of one end trimming and smoothen the relief, and other forming the abundant talus cone sand alluvial fans in the hill front region.

The major part of these hills is drained by Aalknanda, and other tributaries. The other primary, secondary and tertiary streams also drain these hills which are generally obsequent, subsequent, insquent and consequent in nature and give overall denderitic look to these hills

Area of Mass Wasting:
It is characterized by the presence of numerous mass wasting processes, viz. landslide, rock fall, debri fall, slump and scree etc. It is interesting to note that some of the major landslides of rotational nature are either located close to the prominent lineaments such as Kaliyasaur, and Nandaprayag slides.In Alaknanda valley the other landslides are

associated with the remnants of abandoned cirques in the peri-glacial areas, such landslides are seen around Badrinath Joshimuth, Hanuman Chatty and Hellon in Alaknanda Tapoban in Dhauli Ganga, in the headword ends of Ganesh Ganga, Berhi Ganga and north of Okhimuth in Mandakini valley. It is evident that movements along the major lineaments, however small in magnitude are still taking place in Himalaya. Similarly in the Peri-glacial area the rocks have been rendered week because of prolonged coverage by ice cap and shattered due to the periodic thawing and freezing. Further the post-glacial activity and seasonal variations in these areas have substantially decreases resistivity and enhanced the the snsetivity of these rocks to sliding, both under the action of gravity and climatic hazards. The selected case histories of prominent landslide in Alaknanda, Bhagirathi, valleys are discussed below.

Kaliyasaur Landslide:
In Alaknanda valley the prominent landslide of Kaliyasaur is located about 21 km. upstream of Srinagar in topo sheet No. 53J/16 in Pauri district has been studied.The slide had occurred first on the 19th September 1969 at km. 147 below the village of Chantikhal on the Reshikesh- Joshimath road. During the first slide a considerable size of material is reported to have moved down the slope to the original road which lay about 75 to 92 m. (250' - 300') higher than the river level, and to have practically blocked about three fourth of the width of the Alaknanda river. This temporary blocked of the river had, however, been washed out by the end September 23 1969. The first slide, though initiated on the 19th September 1969 and reported to have been active till the 23rd September there after it is reported that it becomes more or less quiescent along most of its length, though the upstream and downstream edge of the slide was still slightly active even when the road was tentatively reopened to traffic on the 14th October, 1969.A mild earthquake shock was reported to have been felt by the villagers of Chantikhal and Khankra and in adjoining areas on the 23rd September 1969. The reported earthquake of the 19th September 1969 could not be substantiated by any instrumental data. It is also on records that minor landslides had occurred in this area in 1952, 1963 and 1965.

The climate of the area is cold with annual rain-fall of about 60" (1500mms) spread over the 3 months of monsoon and over nearly 1½ months of winter. No snow-fall is reported from this area in a normal winter season. It is digenetic that considerable precipitation, extending continuously over 5-6 days, is reported to have occurred up to the 16th September 1969 in the slide area. There was flood in the Alaknanda River on the 19th, September 1969 when the river level had risen by about 3-4.5 m. (10-15 ft).

The river Alaknanda is Antecedent River and has straight and meandering pattern cutting across rugged terrain of Himalaya, in the area of landslide it takes a sharp turn resulting acute angled bend near the toe of the slide area, resulting active erosion of the toe of the slide causing constant sliding of land mass. . The river level is understood to rise up by as much as 20' during normal floods, which submerges toe of the slide aggravating mass movement.

There are a number of natural springs emerging from the hill slope just below the village of Chantikhal. However, most of the nalas and stream are dry between the level of these springs and a point 45 m. (140') above the Alaknanda River. The spring water generally disappear in the debris of slide and re-appear down the toe of the slide in the form of small branching channels ultimately joining Alaknanda river, The anomalous behavior of stream water and distribution of the springs in vicinity indicate the major disruption in the system or surface drainage by mass-wasting activities in the recent past. The dislocation in the normal path of drainage and development of internal hydrostatic pressure due to loss of stream water has further been aggravating the land slide problem in the area.

The area of landslide encompasses the rocks of the so called “Chamoli window series" and lies about 2 to 3 km. north of the Srinagar thrust. The rocks exposed in the slide area are white and purple gritty quartzite, with minor bands of purple and leaf green shales varying in thickness from a few cms to maximum of 1.5 m. The rocks are very well bedded and show typical ripple marks. They are openly folded, but have a general dip 40° to 50° in 835°C to 530°W direction. The most prominent joints have dips of 40° to 55° in N60°W direction and 70° to 80° in N150°W direction. These joints are open as by much as 2-10 cm. at places and are very continuous and consistent in nature. Besides these prominent sets, a number of other minor sets of joints, dipping in westerly and in south-easterly directions are also present. In the slide area the rugged terrain, two prominent bedding shear zones (or fault zones) have been traced. In fact, the most prominent one of these zones could be traced for a distance of nearly over km. along its strike, and consists of highly crushed and powdery quartzite. In the shear zones the rocks has practically lost all its hardness and cohesion, and the fragments of rock could be reduced to rock flour by rubbing them between the fingers. The two shear zones are probably shifted up along a transverse fault which forms the prominent saddle near the Chantikhal Forest Rest House.

Probable cause of the slide

The landslide cannot be ascribed to particular cause and a combination of causative factors has to be considered. The most important causative factor appears to be extensive toe erosion by the river at the turning point in its course, where, in addition to the scouring by velocity of low, it was hammering and disintegrating the rock by impact. In fact there must have been a gradual process of failure of the toe as is evident from a study of air photos and topo-sheet. In the 1920's according to the topo- sheet, scarp, nearly 30 m. (100 ft.) high or even more, has been shown at the river level, whereas, it is reported that prior to the recent slide there was a rock ledge only about 15 m. (50 ft.) in height. This gradual removal of the toe support and lessening of the path of percolation of water o the major bedding shear zone, occurring near the toe was a major contributory factor in causing the slide. This shear zone, under saturation, must have tended to settle and to disturbed the whole slope which was probably in a state of limiting equilibrium.

The second contributory cause appears to be the extensive precipitation spread over of weak zone prior to the slide. This may have resulted in heavy saturation of the slope forming material and the high flood in the river must have eroded and saturated the toe to an extent sufficient to trigger off the slide in an area which was already in state of critical equilibrium and gravitational pull.

The third factor seems to be the inherent weakness of the jointed rock mass and its poor conation in the zones; moreover, due to the well known phenomenon of stress relief near a valley wall, the joints have all opened up in tension, by as much as 2 to 10 cm. thereby, further weakening the already weak rock. It appears that a portion of the zone affected by stress relief has moved out in the present slide. Unless further movement of this portion is controlled, the upper levels of the stress-relieved mass may be affected in the course.Beside these factors neotectonic activity along the existing faults and lineament have significantly contributed to sliding as evident by rotational nature landslide

Dangla Landslide Bhagirathi Blockade Around Dabrani

In August, 1978 the Kanuldia Gad is a small tributary of Bhagirathi which rise from snow clad peak about 3200 North West of Dangla which furthe joined by another small streams the Thiria Gad and Gidaraki Bad at 3050 m drain north and western portion of catchment. The Kanodia Gad ultimately mingles with Bhagirathi north of Gagnani. The gradient of Kanauldia Gad about 2 km. upstream of confluence of Bhagirathi is of order 235 m./km. In August 1978 this stream has brought out huge quantities of rock debris and blocked the Bhagirathi forming a huge natural dam causing the serious danger to life and property in the Uttarkashi tregion.

The area of study comprises of crystalline group of rock consisting of gneiss, kyanite mica schist, garnet mica schist, and intruded augen gneiss granite marble, migmatite zone of mica schist, tourmaline, banded gneiss amphibolites marble and calc-silicates. This group of rock is separated by green schist facies rocks of Garhwal group by northerly dipping Central Himalayan which has been traced south of Bhatwari near Sainj in Bhagirathi valley.

The Quaternary sediments comprises of two distinct units viz. the river borned sediments of fluvial terraces of Bhagirathi, and heterogeneous assemblage of rock clastic of glacial moraines, glacial outwash and the active flood plain deposit of Bhagirathi.The glacial moraines have occupied higher parts of valley,whereas the later group of sediments mostly confined along the valley flanks in the form of isolated pockets and lenses representing the former level of valley floor of Bhagirathi. (Plate No.4)

Causes of Formation of Artificial Dam Around Dabrani :

In Bhagirathi valley upstream of Uttarkshi natural dam was formed near Gagnani at the terminal of Kanuldia Gad. The natural damming has been resulted due to any one of the under mentioned factors, or due to cumulative effects of these parameters,

(i) The Bhagirathi in the area round Bhatwari and Dabrani in parts of Uttarkashi district descend through a glaciated valley, which has a small V-notch at the base; as such it is U-into V-shaped valley and formed by the superimposition of fluvial cycle over the glacier in the recent post. The steeply rising walls of the valley in the area are occupied by the discontinuous caps and strips of glacier moraines of variable thickness. These moraines in general consist of heterogeneous suite of rock fragments ranging in small pebble to large boulder in the matrix of

coarse to fine sand silt and clay. These sediments are mostly un-consolidated and assorted in nature and generally devoid of bedding. The torrential down pour in August, 1978 in the area has super-saturated the piles of these un-consolidated sediments, which subsequently experienced the mass movement under the action of gravity and supplied huge quantity of debris load in the valley.
(ii) The area comprised of crystalline group of rocks consisting of gneiss, schist, and granite, marble. These rocks are easily susceptible to erosion and embrace innumerable planes of weakness, joints, faults which has caused the several features of mass wasting activities like landslide, rock fall, Debris fall, along the right flank of Bhagirathi near Dabrani. The excessive precipitation in August, 1978 appears to have reactivated these landslides and had supplied the excessive Debris load in the valley which perhaps caused the chocking of Bhagirathi around Dabrani.
(iii) The Kanauldia Gad has its water shed in the area of mass wasting activities, which contains large quantity of loose and unconsolidated rock debris in the form of cirque moraines, ground moraines, talus cone. The cloud burst and excessive rains in August, 1978 appears to have mobilized these piles of unconsolidated sediments, rock debri both from glacial front and mass-wasting faces and rapidly transported and accumulated the same at the terminal of Kanuauldia Gad in Bhagirathi valley, forming a natural dam around Dabrani.Besides Dhangla landslide also appreciably contributed the debri load around Dabrani up stream of Uttarkashi in Bhagirathi valley in August 1978.

High Level Dissected Fan and Sloping Surfaces:
These dissected fans and surfaces have occupied the higher parts of valley flanks in Alaknanda, Mandakini, Nandakni and other tributaries at an average elevation of 860 m. above the m.s.l. The average slope of these fans and surfaces ranges from 10 to 15 degree and are mostly controlled by the topography and disposition of the bed rock.

These were formed by series of alluvial fans deposited distinctly in piedmont environments by numerous subsequent streams draining in the valley. These streams generally had steep gradient, high load carrying capacity, and sudden discharge characteristics. The continuous process of transport of the sediments load from the headword ends and formation of numerous alluvial cones and their subsequent coalescences had led to the formation of these fans and surface during the initial stages of valley development, (Khan et. al. 1981).

The streams subsequent to the formation of these surfaces were formed to adjust their base level in relation to the trunk stream due to micro-pulses of uplift/microclimatic changes and cyclic rejuvenation of the major streams, which incised through their own deposits, leaving behind these high level fans and surfaces in the stage of high denudation along the valley flanks.

In Alaknanda valley quartzite, schistose rocks, slate are exposed between Koteshwar and Devprayag, Rudrapryag and Nagresu section are highly valunerable to erosion and river had tendency to form wider flood plain as compared to the other rock units, due to easy erodibility and effective utilization of stream energy of stream both in lateral and vertical cutting. These streams at places have also adjusted themselves long the weaker planes during the upraise as evident from the straight segments of channel and steep and linear alignment of the scar lines along the valley slopes, where the stream did not find any weaker planes to adjust inspite of upraise and undergoing phase of increasing discharge and passing through the steep gradient, the stream accommodated discharge by lateral swing and gliding over its own deposit and had effectively consumed its enhanced energy, added to it by upraise, discharge and gradient, by lateral cutting on the nose of the tight meander.

The geomorphic features and land forms associated with this unit are point bar, channel bar, channel braids, riffle and pools, scarps fossil channel coarses and lateral cutting. The point bar, sand bar are depositional features and are mostly associated with the flood plain of stream. The point bars are formed on the convex bank of the slip off slopes generally in the sinuous to meandering stretches of the channel; whereas.

These fans and sloping surfaces are characterized by deep gully erosion, extended gullies, impersistent and partly internal drainage, high drainage density and degree of dissection due to very coarse and loose texture of sediments in contrast to the other morphogenetic regions. These fans and surfaces are characteristically composed of sub-angular to sub rounded boulder, cobble, pebble predominately of quartzite, gneiss, granite, slate, basic, phyllite in the matrix of coarse to fine silt and clay with subordinate amount of sand. As a whole, the entire assemblage of sediments is very poorly sorted and devoid of higher degree of sphericity-roundness and sorting indicating the close proximity of their provenances.

River Terraces:

The river terraces or alluvial topographic 'benches form the prominent Quaternary landscape flanking the Alaknanda Nandakini, Mandakini, Pindar and Dhauli Ganga breaking the monotony of vast rugged hilly tracts. These terraces are the abandoned flood/plains of river and as such indicate the former levels of valley floor. These were formed by a cumulative action of erosional and depositional processes of streams related with the up warping in the headword ends and consequent climatic changes in the post Pleistocene time, (Khan 1974).

Quaternary Terrances of Alaknanda and its Tributaries

1. Glacial Terraces
2. Fluvio-glacial Terrance
3. Fluvial Terrances
3. Longitudinal Profile of Alaknanda and its Tributaries
4. Geomorphic Evolution of Fluvial Terraces in Alaknanda and its Tributaries.

The sequence of terraces and of valley development in upper Ganga Basin (Khan 1981).

Table 1:- Stratigraphy Of Quaternary Deposit In Upper Ganga Basin, Garhwal Himalaya U.P.

Age	Quaternary Formation	Environment of sedimentation	Geomorphic land forms	Composition
	Younger Alluvium	Channel and Flood Plain	Flood Plain Point Bar, Channel Bar Sand Bar	Well rounded boulder, cabble, pebble of quartzite, gneiss, schist, granite, slate, limestone, phyllite and basics in the matrix of coarse to fine micaceous sand.
Holo cone Older Allu vium	Fluvial deposit	Channel and flood plain	River terraces of Alaknanda and its tributaries	Sub-rounded to well rounded boulder, cobble, pebble of quartzite granite, gneiss, schist, phyllite, slate, limestone and basic in the matrix of coarse to fine sand silt with subordinate amount of clay
Late pleis-tocene	Fluvioglacial glacial deposit	Fluvio glacial	Fluvio glacial terraces of Alaknanda & its tributaries	Sub- Angular boulders, cobbles, pebbles of quartzite gneiss, granite biotite schist, muscovite, chlorite schist, slate and basic, in the matrix of coarse to fine sand, silt and clay.
Early pleis-tocene	Glacial deposit	Glacial	Glacial terraces, terminal moraines medial moraines, cirque moraines of Alaknanda & its tributaries.	Sub-Angular to angular boulder, cobble, pebble of gneiss, granite, quartzite, granite, quartzite, biotite, muscovite, chlorite schist, in the matrix of very coarse to very fine sand, silt and clay

The successive development of Quaternary terraces of Alaknanda is as follows:

Table 2:- Stratigraphy of Quaternary terraces in Upper Ganga basin, garhwal himalaya U.P. India.

Age	Stages of valley development	Terraces	Environment of sedimentation
Recent to Holo-cene		Flood Plain and adjoining low land area of present day course of channel and associated geomorphic features, point bar, sand bar, channel braids etc.	Channel and Flood plain environment
	VI	Berhi Ganga terraces	BRT_1
	V	Madhmeshwar Ganga terraces	MDT_1 to MDT_2
	IV	Bal Ganga terraces	MDT_1 to BGT_2
		Mandakini terraces	MT_1 to MT_3
		Pindar terraces	PT_1 to PT_3
		Dhauli Ganga terraces	DGT_1 to DGT_3
	III	Bhilanga terraces	BHT_1 to BHT_4
	III	Nandakini terraces	NT_1 to NT_4
	II	Bhagirathi terraces	BGT_1 to BGT_5
	I	Alaknanda terraces	AT_1 to AT_3

Late – PleistoceneFlurio-glacial terraces Flurio-glacial of Berhi Ganga, Madhmeshwar Ganga, Balganga, Mandakini,Pindar, Dhauli Ganga, Bhilangna, Nandakini, Bhagirathi and Alaknanda

Pleistocene - Glacial terrances of Berhi Ganga, Glacial Madhmeshwar Ganga, Bal Ganga, Mandakini, Pindar, Dhauli Ganga, Bhilangna, Nandakini, Bhagirathi and Alaknanda.

Glacial Terraces:

These are the high level terraces and their occurrences are restricted above an average elevation of 1150 m above the m.s.l. upstream of Alaknanda, Karanpryag and upstream of Uttarkashi in Bhagirathi, upstream of Kund-Chatti in Mandakini and upstream of Thirpak in Nandakini valley.These terraces constitute the oldest sequence of Quaternary sediments in the area and are seen in stage of high denudation as isolated pockets and lenses along the higher parts of valley flank.

In Alaknanda valley the occurrences of these terraces are noticed around Chamoli, Pipalkoti, Marwari, Pandukeshar, Hanuman Chatti, Joshimuth and Badrinath. In the vicinity of Badrinath, four levels of the glacial terraces (lateral Moraine) have been identified, besides the terminal moraine and cirque moraine. These terraces on left flank of Vishnu Ganga constitute stepped sequence representing the former levels of valley floor. Each segment of this terrace is separated by ill-preserved and highly dissected scarp, which have mostly subdued sharpness and convex slopes due to prolonged erosion and debris slides subsequent to their deposition in the valley.

The cirque moraine comprises both coalescing and isolated talus cones descending in the valley from the sides. These cones characteristically taper off upward and terminate against the eroded thresholdes of abandoned cirque. At places, in the valley, such as around Badrinath and Hanuman Chatti and Gobindghat, the apex of these cones partly touches the outlets of cirque depression which is suggestive of activeness of these glaciers in recent time.

The type development of this cirque moraine as talus is seen around Joshimuth Badrinath section in Vishnu Ganga, Joshimuth Tapoban in Dhauli Ganga. These were mostly formed during the descend of numerous cirque glacier in the valley in the pleistocene time.

The glacial terraces consist of heterogeneous assemblage of sub angular to angular, unsorted, unstraitified rock fragments ranging from big boulders to small pebbles in size predominantly of gneiss, granite, quartzite and highly weathered biotite muscovite and chlorite schist in the matrix of very coarse to fine sand, silt and clay. These rock clastics are largely angular, very poorly sorted; display isotropic imbrications pattern and are devoid of bedding.

The fine sediments comprise of light smoky coarse to fine sand with appreciable amount of mica flakes; light to dark maroon silt and clay, light brown coarse sand with sub-ordinate amount of silt and dark red and yellow sand with silt. The sand matrix contain fairly good amount of quartz and feldspar grains and loosely composed mica flakes. These sediments around Chamoli, Joshimuth and Hanuman Chatti in Alaknanda valley display lamination and cross lamination indicative of trough like sedimentation which might have been formed by chocking of the valley during the glacier advance in Pleistocene time. (Plate No 3, 4, 5 & 6)

Fluvio-glacial Terraces:
The fluvio-glacial terraces are noticed at an average elevation of 975 m above the m.s.l. and their occurrences are restricted to a small stretch between Nandaprayag and Chamoli in Alaknanda. These terraces are sandwiched between the glacial and fluvial terraces as they abut against the glacial terraces in the upstream and fluvial terraces in the downstream and as such these represent the transitional phase of sedimentation.

These are characterized by sub angular to sub rounded boulder, cobble, pebble of quartzite, gneiss granite, slate and decomposed highly weathered biotite, muscovite and chlorite schist in the matrix and coarse to fine sand, silt and clay. The fine sediment consist of light brown coarse to fine sand and silt, very coarse of fine micaceous sand, light to dark maroon coarse to fine silt, and clay light smoky sand with subordinate amount of silty matrix, yellow to orange coarse to fine sand and silt. These sediments contain appreciable amount of quartz, feldspar and basic grains with partly decomposed mica flakes. These finer clastic constitute small bands in alternation with parting of mica flakes and coarse sandy granules, which are generally seen embedded with underlying and overlying small pebble horizon comprising predominantly of grey, pink, yellow, cream, smoky and green quartzite, grey, pink and white felšpathic gneiss, granite and dark brown, green biotite and chlorite schist.

Although the sediments of these terraces are similar in texture and composition to glacial terraces, these exhibit entirely different order of sedimentary pattern and sediment character. In contrast to the glacial terraces, these sediments display moderate degree of sphericity roundness and sorting and show preferred orientation pattern. The ill-preserved sedimentary features and long interval cyclic development of bedding is also conspicuous. These associated diagnostic sediment characters, sedimentary features and disposition of these deposit indicate an intermittent and rapid reworking of the sediments from the glacial front subsequent to the melting of glacier during the late Pleistocene times. (Plate No 3, 4, 5 & 6)

Fluvial Terraces:
The fluvial terraces or alluvial topographic benches of Alaknanda and its tributaries form the prominent Quaternary landscape in the valley breaking the monotony of vast rugged hilly tract. These terraces are formed by a combined intermittent process of aggravation and degradation in the valley associated with different phase of sedimentation of the fluvial domain. As such theses are the abandoned flood plains of the river representing the former levels of valley floors and formed due to tectonic eustatic and climatic changes during the Holocene time, (Khan 1975, Khan 1981).

These terraces are comprised of sub rounded to well rounded boulder, cobble, pebble of predominantly quartzite, gneiss, granite and schist basic, slate, phyllite, limestone, in the matrix of sand and silt with subordinate amount of clay.

In Alaknanda valley, these terraces are characterized by the association of fossiliferous boulder, cobble, and pebble of quartzite with the luxuriant assemblage of products, spirifer and other species of Brachiopods and Mullosc group typically of permo-carboniferous age. Although th other rock constituents diplay variation in in these terraces, but the association of fossiliferous cobble pebble is conspicuous in terraces AT_3, AT_5, around Devprayag, Srinagar, Nagrosu, Gauchar, Karanprayag and Nandprayag which suggest the presence of some fossiliferous horizon of quartzite in the headwords' ends of Alaknanda. It appears that these fossiliferous horizons were actively subjected to erosion subsequent to recedes of glacier in post Pleistocene time.It is a marker horizon of Quaternary terraces and used as ttol in correlation of terraces in valley

The sediments of these terraces are mostly similar in composition to the terraces of glacial and fluvio-glacial origin, but are characterized by higher order of sphericity, roundness, sorting, imbrications pattern and sedimentary features, viz. graded bedding, cross bedding, both planner and tough type, lamination, minor ripples, cut and fill features and cyclic sedimentation typically of fluvial domain.

The higher order of sphericity, roundness, sorting of these sediments indicate their derivation from the distant and mixed provenances during the different phases of sedimentation in the Quaternary times.

The fine sediment of these terraces consist of sand of different grade and shade such as smoky micaceous, coarse to fine sand; light to dark yellow coarse to fine sand and silt; light to dark maroon silt and clay with subordinate amount of sand; light brown sand with abundant granules of quartz, feldspar and mica flakes. These sediments, in general, are embedded with the coarse rock clastic comprising the various terrace horizons. In Alaknanda, valley at very few places, e.g. around Bamoth, Nagrosu, Ratura, Lameri Gulab Rai, independent beds of coarse to fine sand ranging from 2.5 m to 10 m are noticed. In this area, the sand of various grade and shade comprise of different sub units of variable thickness in alternation and display sedimentary features of minor scale, viz. lamination graded lamination, minor ripples and entrapped small lenses of fine sand mostly of cut and fill nature. (Plate No 3, 4, 5 & 6)

The Fluvial terraces of Alaknanda Valley

The Alaknanda, the trunk stream of Ganga System forms at Vishnuprayag by two tributaries, viz. Vishnu Ganga and Duauli Ganga rising from snowy peaks north of Badrinath and Niti at average elevation of 3,897 m and 5,330 m respectively in Central Himalayas.. The river descends in straight/sinuous to meandering channel pattern through the deep gorges across the Himalayan ranges, with sinuosity index ranging from 1.95 to 2.6 for meandering segment. It is joined by numerous other tributaries in its traverse in Himalaya till it finally debouches in the intermountain Doon valley at Rishikesh. The important tributaries joining Alaknanda between Vishnuprayag and Rishikesh are, Berhi Ganga at Chinka, Nandakini at Nandaprayag, Pindar at Karanprayag, Mandakini at Rudraprayag and Bhagirathi at Deoprayag, downstream of Deoprayag it is known as Ganga.

The Alaknanda all along its length across the Himalayas has characteristically NE-SW course except the swing between Karprayag and Rudraprayag and Srinagar Janesu, where it drains in WNW-ESE and NW-SE direction respectively. The other tributaries in the north eastern part of the basin viz. Berhi Ganga, Nandakini and Pindar and Patal Ganga have, however, the conspicuous NW-SE course and join Alaknanda at sharp angle. The course of Alaknanda appears to have been constantly maintained its course, inspite of rise of Himalaya as is evident from entrenched meanders, deep gorges, steep cliffs and peaks which is suggestive of its antecedent nature.

The courses of tributaries appear to have been guided by NW-SE trending lineaments, which are mostly sympathetic in nature and their trends coincide with the major NW-SE structural trends of the Himalaya. The Alaknanda all along its length displays swelling and pinching nature in its width and its flanks are occupied by terraces of glacial, fluvio-glacial and fluvial origin. In the glaciated and Peri-glacial terrain it passes through straight segments with tight meanders and the average width of the valley does not exceed 225 m. In the fluvio-glacial and fluvial part of the valley average width varies from 190 to 210 m and the widest part is of the order ranging from 230 to 245 are seen around Langesu, Gauchar and Srinagar.

The Alaknanda has formed six prominent regional terraces in the valley. These have been designated as AT0, to AT6. The AT0, being the low level surface above the present day course of the river being a part of active flood plain. The AT1, being the youngest and AT6, being the oldest terrace in the area. Each of these terraces is separated by the scarp both of linear and curvilinear in nature facing towards river. These terraces are both erosional and depositional in nature and display divergence and convergence in their relative disposition.

The erosional terraces are generally seen as isolated pockets and lenses resting over the country rocks along the higher part of the valley flanks, representing the former levels of valley floors. In general these terraces are very ill preserved and have very few matched equivalent in the valley. The occurrences of these terraces and associated features in the higher parts of valley indicate the rigorous and abrupt incision of valley floors due to relatively rapid and sudden uplift of watershed region of Alaknanda during the early Holocene times.

The depositional terraces are widely developed and have occupied the larger area in the valley around Srinagar Kaliyasaur, Kirtinagar Pharases, Dungri, Gulab Rai, Nagresu, Gauchar and Langasu, Sunala and characteristically found to be restricted within the meander of Alaknanda. These are extensively used both for inhabitation and cultivation in the valley. These are characterized by the deposition sedimentary features such as graded bedding cross bedding lamination, graded lamination, minor ripples, cut and fill features and poly cyclic sedimentation typically of wide flood plain environments and both migrating as well as incisive system of the channel of fluvial domain predominantly of depositional in nature.

The complete sequence of terraces in the valley is seen at very few places viz. around Srinagar, Koteshwar, Rudraprayag, Nagrasu and Gauchar which give almost the complete account of tectonic and climatic changes in the area. Whereas at other places one two or three terraces are preserved and many other have been eroded away. This therefore, indicates incisive as well as rapid migrating nature of the stream. These terraces are both paired and unpaired and display convergence and divergence in their relative disposition. The divergence and pairing in general is seen in the older terraces viz. AT6, AT5, and AT4, whereas the younger terraces viz. AT1, AT2 and AT3, display convergent in their disposition and mostly remained unpaired. The divergence and pairing in the older terraces indicate the abrupt and sudden incision of the valley floor due to relatively sudden upraise of head ward ends of the Alaknanda and consequent climatic changes, in the early Holocene times. The convergence and un-pairing in younger terraces, on the contrary, indicate decrease in rate of uplift and long interval climatic change towards the later phases of sedimentation in the valley. The pairing, un-pairing and relative disposition of terraces as whole in Alaknanda suggests the constant and steady decrease in rate of uplift in Himalaya from early to late Holocene time. Khan (2018)

In Alaknanda valley, these terrace (AT_3, $AT_{5)}$ are characterized by the association of fossiliferous boulder, cobble, pebble of quartzite with the luxuriant assemblage of productus, spirifer and other species of Brachiopods and Mullose group typically of permo-carboniferous age. Although these rock constituents are mostly confined in these terraces and noticed around Devprayag, Srinagar, Nagrosu, Gauchar, Karanprayag and Nandprayag ,suggest the presence of some fossiliferous horizon of quartzite in the catchment area of Alaknanda which actually been subjected to extensive erosion during third and fifth phase of erosion . subsequent to recede of glacier in post Pleistocene time

The average total thickness of fluvial terraces in Alaknanda is 118 m. The highest terrace i.e. AT6 1s noticed at an average elevation of 795 m from m.s.l. and 150 m from the present day course of the river. The average thickness of individual terrace is 16.25 m., 22.25 m., and 27.22 m., 25 m., 21.25 m., 15 m., respectively. In the upstream areas, the thickness of these terraces is constantly reduced and ultimately the profile of these terraces pinches out against the higher terraces of fluvio-glacial origin.

The scarps separating the different terraces in the valley are generally of linear and curvilinear in nature. The scarps of older terraces in general are intensively dissected by the minor rills and gullies and extended gullies. The degree of maturity is relatively high in these terraces in contrast to younger ones and scarps of these terraces are mostly more stabilized, though at places the convex slopes along the scarps are developed due to debris slides.

The terraces developed in Alaknanda are in general rectangular, semi-circular to circular and cuspate in shape. Each of this type is related to the separate genetic processes. Among these, the semi-circular is most common in the valley, which are related to the short interval meander of channel and formed due to enhanced energy conditions of the channel, associated with the increasing discharge and low gradient. Such terraces are observed around Nandaprayag, Gauchar, Papresu, Dhari-Khaliyesour, These are in general non-cyclic terraces. The elongated rectangular non-cyclic and cyclic terraces in the valley are observed around Shrinagar, Nagresu, Gauchar, Bamoth and Langesu. The former ones were formed by a combined processes of lateral coalescences and unidirectional sudden shift of straight segment of channel and subsequent incision whereas the later one, due to abrupt reactivation in energy condition due to sudden climatic changes and subsequent adjustment of base level of channel by incision of valley floor. The semi-circular to circular and cuspate terraces is related to the meander processes lateral shift of channel and ingrown incision. The point bar development in such processes is often noticed in the slip of slope of channel meander loop and the terraces occur as slices within the periphery of meander, separated by small scarps relatively of small magnitude. The ill preserved circular terraces are noticed around the confluences of Alaknanda, with Bhagirathi around Devprayag; Alaknanda with Mandakini around Rudraprayag; and Nandakini around Nandaprayag, which were formed by the initial erosion and subsequent deposition during the inception of these major tributaries.

The cuspate terraces revealing a dip of 2° to 3° are formed by incision of several loops at different elevation on the same side of valley. These suggest multiple rejuvenation through the micro episodic change in discharge and micro pulsation of unwrapping in head ward ends of Alaksandra (Khan, 1974). (Plate No 3, 4, 5 & 6)

The detail description of salient features of Alaknanda Terrance in type localities have been tabulated in Table No.3

The Fluvial terraces of Bhagirathi Valley

The Bhagirathi is the major tributary of Alaknanda. It rises from Gangotri glacier north of Uttarkashi around Gaumukh in the Central Himalaya at an elevation of about 3665 m and joins Alaknanda at Deoprayag the river descends in sinuous to meandering with an average sinuosity index of order of 1.30. The river all along the length of 160 km has formed the terraces of three domains Viz. glacial fluvio-glacial and fluvial. The fluvial domain comprised of five major terraces which are time equivalent to the five younger terraces of Alaknanda, the trunk stream of Ganga system. These terraces are designated BT1, to BT5. The BT1, is youngest terrace and BT5, being the oldest in the valley. These terraces are mostly fill and cut type and are both erosional and depositional in nature. The older terraces BT3 to BT5, are elongated, rectangular in shape and have paired equivalents on both the flanks of valleys, whereas the younger terraces BT1, and BT2 are semi circular and crescent in shape non-cyclic in nature and are restricted within the meander of Bhagirathi.

The type development of these terraces is seen at very few places in the valley Viz. Uttarkashi, Dunda, Chinyalisaur Chamb, Tehri, whereas other places such as Sarot Seansu and Nagor one or two levels of terraces were seen, which appears to be due to exposure of the area to extensive post depositional activities, reworking of terrace sediments by subsequent streams developed on the slopes of valley and extensive lateral cutting by Bhagirathi. The total average thickness of these terraces in the val1ey is 36 m. The average relative thickness of these terraces in Uttarkashi and Tehri section is 6.5, and 5 m respectively. (Plate No 3, 4, 5 & 6)

The detailed salient features of Bhagirathi terraces have been tabulated in Table No.4

The Fluvial terraces of Bhilangna Valley

The Bhilangna is a tributary of Bhagirathi. It originates from ice clad peaks of Central Himalaya at an elevation of about 3200 m and joins Bhagirathi at Tehri. It display sinuous to meandering channel pattern all along its course of 75 km and embraces the terraces of three regimes, viz. glacial, fluvio-glacial and fluvial, deposited in three distinct environments during the Quaternary times.

The Fluvial terraces are designated as BHT1, to BHT4 the BT1, is being the youngest terrace and BHT4, is the oldest in the valley. These terraces are mostly deposition in nature and exhibit divergence and convergence in their relative disposition, the former is more conspicuous in older terraces BRT4 and BHT4, whereas the later in the younger terraces. The type development of these terraces in the valley is seen around Tehri, Dewal. Asena and Ghansali Dubey, (1972) Khan (1981). Khan (1974) (1975). The total average thickness of these terraces is about 55 m whereas the relative thickness is 16, 15, 18, 16 m respectively.

The Fluvial terraces of Nandakini Valley

The Nandakini, a tributary of Alaknanda, It rises in northeast of Sutal in the Central Himalaya at an elevation of about 3660 m from the snowy peak, descends down in sinuous to meandering pattern, with sinuosity, index ranging from 1.20 to 1.25. It also passes through the straight segment of the valley and tight meanders and joins Alaknanda at Nandaprayag. It comprises three distinct groups of terraces deposited entirely in different enrolments, viz. glacial, fluvio-glacial and fluvial. In the fluvial domain four prominent regional terraces in Nandakini have been identified which are time equivalent of the four younger terraces of Alaknanda the trunk stream and the Bhagirathi, Bhilangna, and other major tributaries of the Ganga system.

These Fluvial terraces are designated as NT1, NT2, NT3, and NT4, NT1 is the youngest and NT4 being the oldest in the valley, NT0 is the low surface of the present day flood plain of the stream. These terraces are both erosional and depositional in nature. The terraces NT4, and NT3, and have generally the divergent relation, whereas NT2 and NT1, convergent mutual relation as well as with NT0, the NT4 and NT3, are mostly cyclic in nature and NT1 non-cyclic and characteristically restricted within the meander of channel. The full sequence of terraces is very rarely preserved in the valley such as around Nandprayag, Rajwaki, whereas at other places one or two level of terraces are seen. It is possibly due to frequential lateral shift of the channel, extensive lateral cutting and subsequently repeated reworking of the terrace sediments in the environments of increasing discharge and steep gradient towards the later phase in the history of river sedimentation.

The top terrace NT4, is observed at an average elevation of 1100 m above m.s.l and 80 m from the present day course of the channel. The total thickness of fluvial terraces in the valley is 80 m whereas the average relative thickness of individual terraces 10, 23.50, 23.50 and 23.50 respectively.

The Fluvial terraces of Mandakini Valley

The Mandakini rises from the Gangotri group of glaciers in the north of Sonprayag around Kedarnath at an elevation of 3562 m and mingle with Alaknanda at Rudraprayag. All along its length it has formed the stepped sequence of terraces of three distinct domains viz. glacial, fluvio-glacial and fluvial. In fluvial domain three prominent regional terraces have been identified which are designated as MT1, to MT3 and are time equivalent to the three terraces of Alaknanda and other tributaries. (Khan1981). These are polyclic depositional terraces and their wide development is seen around Barhi Bhatwari, Sauri, Agustmuni, Rampur and Tilwara. These terraces portrays divergent and convergent relation amidst each other and are generally semicircular, elongated, semi-circular to circular in shape and are both cyclic and non-cyclic in nature. These terraces the conspicuous embody sedimentary features such as graded bedding, cross bedding both planer and trough type, lamination, graded lamination, cut and fill features, around Agastmuni, Tilwara, Behri, Saurgarh, Sauri and Bhatwari.

The total average thickness of fluvial terraces in the valley between Kund Chatti and Rudraprayag is about 40 m. The highest terrace is observed at an average elevation of 810 m above m.s.l

The Fluvial terraces of Pindar Valley

The Pindar rises from the glacier top on the east of Dhakkni Devi Glacier in Central Himalaya at an elevation of 3621 m. It traverses across the Himalayan ranges and descends down through steep gorges forming straight sinuous to meandering channel pattern and joins its trunk stream Alaknanda at Karanprayag.

The Pindar all along its major part of traverse maintains straight course, between Kheta and Dewal, it almost drains in WNW - ESE direction. At Dewal it takes an acute turn changing its course to NNE - SSW, which further down stream of Nandikesri again swings in WNW- ESE direction and maintains it upto Karanprayag, where it mingles with Alaknanda. In between Dewal and Nandikesri the course of Pindar appears to have been controlled by NNE - SSW trending fault, which up stream of Dewal also control the course of Kali Ganga a small tributary of the Pindar. All along its length it shows swelling and pinching in width, which varies from 500 to 680 m between Kheta and Dewal, 600 to 700 m between Dewal and Theralli, 500 to 650 between Theralli to Narayanbag and between Narayanbag to Nalgaon the stream passes through the straight segment of deep gorge, having steep sides of valley flanks and smallest average width is 260 m. Downstream of Nalgaon the width of valley broadens out to the range from 670 to 850 m..

In Pindar valley between Theralli and Simli and Karanprayag three prominent regional terraces have been identified. These are designated as PT0, to PT3. The PT0, being the low level terrace, PT1, being the youngest and PT3 being the oldest terrace in the valley (Khan, 1975). These terraces are correlated with the three younger terraces of Alaknanda and other tributaries.

These terraces are formed by combined and intermittent processes of aggradations and degradation associated with different phases of sedimentation of fluvial regime. The process is repeated thrice in the valley during the Holocene times.

The highest terrace is observed at an elevation of 830 m above m.s.l. and 60 m from the present course of channel. The total thickness of these terraces in the valley is 55.5 m whereas the average relative thickness of individual terrace is 15 , 20 and 20 m (PT_1, to PT_3) respectively.

The Fluvial terraces of Dhauli Ganga Valley

The Dhauli Ganga is a tributary of Alaknanda, it originates from glaciated top in the Central Himalaya in upstream of Dapoban and joins Vishnu Ganga, near Joshimukh and down the Vishnuprayag it is known as the Alaknanda. The river has, conspicuous straight sinuous to meandering course and descends down through the tight gorges with the steeply rising valley flanks. The river has formed three prominent fluvial terraces besides several channel and land form elements. These terraces are genetically both erosional and depositional in nature and have been designated as DGT1, to DGT3. The DGT_1, is being the youngest and DGT3 is oldest terrace. The total average thickness of these terraces is 24 m and relative average thickness of these terraces is 10, 8 and 6 m respectively

The salient features of these terraces in type area around Tapoban are tabulated in Table No.17

The Fluvial terraces of Bal Ganga Valley

The Bal-Ganga is a small tributary of Bhilagna. It rises from the ice clad peak in the Central Himalaya southwest of Kedarnath. This stream has formed three prominent fluvial terraces, beside the glacial and fluvio-glacial terraces in the upper reaches which occur in the form of isolated and dissected caps. These fluvial terraces are mainly depositional in nature and are designated as BGT1, to BGT3, the BGT1, it is being the lowest and youngest terrace, whereas BGT3, the oldest terrace. The relative average thickness of these terraces is 5, 10 and 7 m respectively.

The Fluvial terraces of Madhmeshwar Ganga Valley

The Madhmeshwar Ganga is a tributary of the Mandakini. The stream originates from glacier southwest of Kedarnath and joins Mandakini near Okhimukh. The stream has formed two prominent river terraces, each separated by scarp. These are depositional in nature and are fill and cut type. The shapes of these terraces are semi-circular, which is mostly restricted in the channel meander and non-cyclic in nature. These terraces are designated as MDT1, to MDT2, (Khan 1981) from younger to older terraces respectively. The relative thickness of these terraces is 12 and 8 m respectively.

The Fluvial terraces of BEhri Ganga Valley

Berhi Ganga is a fault controlled small tributary of Alaknanda. It drains mostly the Garhwal Group of rocks and joins Alaknanda at Chinka. The river is so young that it has been able to develop only one terrace beside its present day flood plain and is designated as BRT_1, which indicates single phase of rejuvenation of the river. The terrace is localized within the meander of stream. This terrace is time equivalent to AT1 terrace of Alaknanda.

Imprints Of Neotectonisam And Neo- Seiesmic Events In Alaknanda And Its Tributaries

In Himalayas the occurrence of movements in recent times are naturally be expected, where mountain building actvitties have occurred recent past and mountains are “rather younf. However, in contrast to the characteristics organic movement of Tertiary and pre Tertiary periods, the movement taking place during Neogene and Quaternary period are slightly different nature what is as Cymatogeny (L.King 1950-68). These movements which have taken place along pre-existing lineaments /thrust/ faults, are small magnitutede but have perceptibly affected the young geomorphic land forms and landscape expression.

It has been found that thrusting movements have caused the pre- Tertiary and late Tertiary formatuion to ride over the plesistocene deposits.Geomorphologyl and actual measurements, consequently demonstrate that many of Himalyan thrust are tectonically quite active. According to estmate (Krishnaswamy et.al 1970) the rate of creep movement along Nahan and Riasi and other thrust may be order of 1-2cm/year. Fithch (1970) computed the rate of seismic slip of Himalayan thrust at 5.8 cms / year.The measurement Sinvhalet.al (1973) shows that along the Krol thrust near kalsi the present movement is 0.92 cms/year. There are reveling example throught out Himalyan front of the older rock riding over recent and and subrecent alluvial or talus deposits.

The sub Himalyan thrust like Srinagr thrust show flattening dip suggesting that they would lie at comparatively at shallow depth at short distance, down dip from their out crops. The recent movements along the trace of these faults /thrust are not of longer magnitude but have considerably affected Quaternary terraces, other land form and morphogenetic expression have formed the nick points in the stream bed draining the area as evident by the profile of river bed and terraces.Sinha and Khan (1975), have observed the displacement in terrace near Dewal in Bhilangna valley along, the Sringar thrust near Seansu. The wide terraces on left bank of Bhagirathi appear to be uplifted and sloping up stream appreciably. The movement of Srinagr thrust and Tons thrust which passes in close vicinity of the area have also affected the litho units terrace section.

The Sringar thrust further up stream in Bhagirathi traverses around Nalupani and forms the tectonic boundary between Barahats and Simla slates. There is a marked difference in the topography on both side of of the thrust .As per observation the Sringagr thrust is geologicaly is of recent age and presence of nick points at some of stream crossing the thrust explained is due to movements, consequebnt upon the relase of strain accumulated along it. Dhanota (1970) made attempt to correlate the epicentre of some of the earthquake that t occurred in the region to seismic activity at different depth along the Sringar thrust plane. .However, available data and records indicate that no abrupt movement has bben taken place in this part of Himalaya during the earthquake in recent times. Gnerally in case of thrust a slow creep movement seems to take place, in which accumulating strain energy is gradually dissipated. It is probable, that such types of the movements may also be associated with the Srinagr thrust.

Alaknansda is trunk steam of Ganga system formed at Vishnuprayag by intermingling of two major streams viz Vishnuganga and Dhauli Ganga rising from snowy peaks north of Badrinath. The river decends instraight and sinuous to meandering channel pattern through the deep gourges across the Himalayan ranges with sinoucity index ranging 1.95 to 2.6 for meandering segments. It is joined by numerous other stream tributaries during its traverse across the Himalya till it debouches in the plain.

The Alaknanda all along its legth across the Hiamalya has charcteritcally south western course, except the local swing beteen Karanpryag, Rudraprayag and Srinagar, where it drains in south east direction. The course of Alaknanda seems to have been cotrolled by weak planes fault/ lineament, the course has constantly maintatined by Alaknanda inspite of rise of Himalya. It is evident by by the conscicuious association of epigenetic gourges, entrenched meanders incised straight segments of channel ourses, stepped rock cut terraces, cyclic terraces, cut scars and strend lines along valley flanks. The major tributaries of Alaknanda have consipicuos south east course and joine Alaknanda at an acute angle.The course of these stream have been guided NW-SE trending lineaments which are mmostly sympathetic in nature and their ternd coincides with the major NW-SE structural trends of Himalayas.

The terraces of Alaknanda are both cyclic and non-cyclic in nature and display convergence and divergence in their relative disposition in the valley. The divergence and pairing is distinctly seen in older terraces Viz AT6, AT5, AT4, whereas the younger trerrac AT1, AT2, AT3 display convergence in their disposition the former are cyclic whereas the later mostly remained non-cyclic in nature.The divergence and cyclic nature of the older terraces indicat the abrupt and sharp incision of valley floor due to relatively sudden uplift of watershed region of Alaknanda in early Holocen times Khan (1981). The convergence and non –cyclic nature of younger suggest the decrease rate of uplift and long period of climetic changes in te region.As whole the occurrence of terraces and their mutual and dispositinon in Alaknanda indicates the steady and constant decrease in rate of uplift in Himalya from early to late Holocene time Khan (2018).

The terraces developed in Alaknnanda valley are in general rectangular; semis circular to circular and cuspate in shape, each of these types are realted to seprate genetic and tectonic processs.

Among these the semi circular,which are related with short interval meander of the channel were formed due to enhanced energy condition of the channel associated with increasing discharge and low gradient,such terraces are observed around Nandaprayag, Gauchar, Nagrasu, and Dhari Kaliyasaur. These are generally non cyclic terraces and indicate lateral shift in channel due todiffrential upwarping of different blocks of Himalaya. The elongated and rectangularnon-cyclic and cyclic terraces in the valley are observed around Srinagar, Nagrasu, Gauchar, Bamoth and Langasu. The former one were formed by combine processes of lateral coalesences and unidirectional shif of the straight segment of channel and subsiqent incision, where the later due abrupt actvation in energy condition due to sudden uplift and subsequent adjustment of of the base level of channel by incision of the valley floor.

The semis circular to circular and cuspate are related to to the meander process, lateral shift of the channel and ingrogron incision. The point bar development in such process is often noticed in slip of slope of channel meander, seprated by small scarp relatively of small magnitutde indicte the micro pules of uplift in Himalya to wards later phases of terrace formation.

The cuspate revealing a dip of 2 to3 degree is formed by incision of several loopes of different elevation on one side of the valley. It suggest multiple rejuvenation of the channel through micro-episodes of uplift in the head ward ends of Alaknanda during Quaternary time.These terraces ar observed around Rudraprayag,Karnpryag, Srinagar and Gauchar in Alaknanda valley (Khan(1981).

In upstream of Karanpryag in Alaknanda Valley around Utma and Thali tilt in river terraces of 3 to 5 degree towards North –East is recorded (Khan (1981).The sub lith units of these terraces comprising rock clastics of various shape and size in the matrix of sand show appreciable displacement and dislocation in their disposition in terraces section .The tilt in terraces block and associated characterstics of rock fabrics strongly suggest the recent movemen in the area along some lineaments.

Khan (1981) recognized linear trench across the terraces in Alaknanda valley around Nagrasu, Gholtir, and west of Gauchar along the Alaknanda fault. This East-West trending fault deeply dissected the multiple sequences of terraces and developed trunketed drainage of minor gullies of partly impersistent and internal nature. This fault seem to be active in this area as evident by shifting of the terrace block, active retreating terrace scarp, minor dislocation in straitified sand horizon,steepvertical incisionin, active alluvial caping in the terraces along the valley flanks, and divrse imbrications pattern of rock febrics along the straight segment of channel. The release the accumulated strain energy along the fault palne and subsequent reactivation of the fault has appreciably organized mass wsting processes in the linear order in the vicinity.

At several places between Deoprayag and Vishnuprayag the Alaknanda has abandoned its original course and flow through newly curved out gorges. Theses channel course are designated epigenetic gorges, Hem and Ganssar (1939) due to their lateral origin and original courses have been termed them as fossil valley Waltier (1962). However, Alaknanda have curved through the new epigenetic gorge, a fossil valley is also present on the one side of the bank and two are sepratd by a rock wedge of varable dimention. According to Khan (1981) theses epigenetic gorges in Alaknanda were formed by sudden rise of watershed area and consequent rejuvenation of Alaknanda to acive the new base level,in changed kinenetic condition, discharge and bed slope .It appers that that the superimposition of fluvial cycle on the earliear glaciated valley in the upper part and mass wasting processess associated with the weaker zones /planes have also played the vital role in forming the epigenetic gorges It is morphotectonic manifestation and is related withtectonic activity in the area of watershed of Alaknanda.The three level of epigenetic gorges in Alaknanda valley are identified at an elevation of 5m, 8m and 12m from present day course of Alaaknanda indicate cyclic rejuvenation of stream in recent past.

In Himalayas around Hanuman Chatti and Hillong tilt in the hanging moraine, association of nick points in river bed of Vishu Ganga near Vinay Chatti , association of rock slide with steep rock cliff north of Joshimuth , occurance of acive land slide around Depoban in Dhauli ganga and Patal Ganga and dissected cones of cirque moraines both in Vishnu Ganga and Dhauli Ganga are the positive vidences of neotectonisam in Himalya Khan (1981)

The gradient of river channel Karangpryag and Deoprayag is about 1:265, while Srinagar and Deoprayag is 1:165, forming an over all upward convex profile. The gradient of terraces between these two sections is 1 in 310 and 1in 245 respectively.According to Sinha & Khan ((1975) the upward convexsity might possibly be due to recent movement along the Sringar Nalupani fault/thrust crossing the Alaknanda.

In Bhilangna valley longitudinal profile of river bed and terraes indicae that the average gradient of the terraces and channel is 1:120 towards down stream , however , the terraces hacve little lesser gradient than the river channel,which might indicates that presently river is slowly under cutting its bed. Again there is slight reduction in the gradient of terraces between Dowal and Asena , the gradient is slightly more towards upstream and down stream. There is possibility that this is the result of Neotectonic movement along the Srinagar Naluoani fault/thrust which runs oblique to the river through Dewal. The Bilangna terraces at Dewal have been dissected and displaced along the fault Sinha & Khan ((1975).

In Pindar valley longitudinal profile of river bed and terraes revealed that fluvial terraces of Pindar around Simli show upward movement and tilt towards north east. The tilt in some adjacent terrace is of order of 5 degree toward south east. The upwarping and tilt has caused percptable displacement in the pebble bed of terraces and caused reverse plunge of pebble axis , which indicates the area is active and recent movement are taking place along the lineament/ faults in the area.Khan (1975).

The general shape of profile of Pindar River is concave and gentle with isolated convexity and steepness at places. The concavity and gentle shape of profile indicates the graded nature and balanced cutting of the river bed, while the convexity indicates comparatively good competence of rock constituting the river bed which is still under active cutting. The convexity in the channel profile in lower Pindar is perhaps due to deposition of coarser material in the river bed by tributaries joining Pindar in the lower segment of valley. The association of innumerable channel braids indicates under loading of channel due to loss of bed slope and low energy condition. The convexity in a river profile appear due to recent movements along the lineaments traversing the area which has also caused shifting of terrace block and tilt in older terraces in valley Khan (1975).

In Nandakini valley longitudinal profile is quite simple as compared to Alaknanda. The slope of profile is slightly concave, smooth and has gradual slope. The profiles of fluvial terraces in general follow the profile of present day channel. It appears that Nandakani has adjusted its course along some weaker planes during up rise of head ward ends during the Holocene times (Khan 1981).The gradient of river bed of Nandakani between Nanala and

Nandprayag is 1:0.55 Nanala and Ghat 1:2.77 respectively. In the area around Chamtali there is a sudden fall in the bed slope, indicating some up warping activity in Nandaki in recent past. The profile of fluvio-glacial terraces is suspended in nature; it pinches out upstream against the glacial terraces and downstream against the terraces of fluvial domain and perhaps represents the transitional phase of sedimentation in the valley. The profile of glacial terraces is restricted upstream of Nanala,where glacial terraces/glacial moraine are mostly dissected and discontinuous in nature and thereby indicating extensive erosion by renewed depositional activities subsequent to the recede of glacier in post-Pleistocene times.

In Mandakini valley longitudinal profile of terraces in general is concave with mild convexity in the area around Rampur and Tilwara. The profile of river bed is steep to gentle, between Kund Ghatti and Augustmuni it has gradient 1:10, Agustmuni and Rampur, 1:5, whereas between Rampur and Rudraprayag, the gradient is considerably reduced and profile has become nearly flat. The profile of both river terraces and river bed is slightly convex upward between Agustmuni and Tilwara. It possibly indicates some differential up warping in the area (Khan in press), caused by some recent movement along lineaments and faults.

The fluvial terraces of Mandakini generally have uniform thickness and gradual gradient in Rudraprayag and Bhatwari section whereas upstream of Bhatwari it is considerably reduced. The average gradient of these terraces between Rudraprayag and Bhatwari is 1:4.4, 1:4.4 and 1:5.56, respectively. The profile of fluvio-glacial terraces is restricted in the middle part of the valley. It is truncated upstream against the profile of glacial and downstream against the fluvial terraces, which suggests an intermediate stage of sedimentation between the domains of these two terraces in the valley during the quaternary times. The average gradient of these terraces in the valley is 1:52. The profile of glacial terraces restricted upstream of Agustmuni, it has gradients of 1:9.33, between Kund Chatti and Bhatwari, in Sonparyag section it is of order of 1:92.In Kedarnath and Kund Chatti it become steep and represent rock cut terraces capped by glacial moraines.

Epigenetic Gorges and Fossil Valley in Alaknanda:

The Alaknanda River descends across the Himalaya in straight, sinuous pattern and its course is strongly controlled by structural elements, it has abandoned its original course at several places between Vishnuprayag and Devprayag and flows through newly curved out gorges. These new channel courses have been designated as epigenetic gorges (Heim and Gansser 1939) due to their lateral origin and the original abandoned courses have been termed fossil valley. Whereas Alaknanda has curved through the new epigenetic gorge, a fossil valley is also present on one of its bank and two are separated by a wedge or hump of rocks of variable dimensions. These epigenetic gorges are formed due to superimposition of fluvial cycle of erosion on earlier glaciated valley, cyclic rejuvenation of Alaknanda associated with the different phases of up warping/climatic changes, sudden change in the Kinetics of the stream system due to tectonic and neotectonic activity alonf thrust/faults and lineament traversing the area in aternary times. In Alaknanda between Karanprayag and Srinagar at about ten places the epigenetic gorges have noticed.

Geomorphic Features and Landform Elements:

The various geomorphic landform elements and features identified in the area are described below:
(Plate No 2)

Alluvial Plain:

The Alaknanda and its tributaries in the present area form the sinuous to meandering channel pattern as their relative ratio of channel length and valley do not exceed 1.5. As these rivers mostly descend through deep gorges and tight meander they comprise of very narrow strip of flood plain. At few places, however, the river is shallow forming flat bottom and relatively wide valleys e.g. around Srinagar, Gauchar, Umta, Langasu in Alaknanda, around Berhi, Bhaniyaro, Agastmuni, Tilwara in Mandakini, with the result that the flood plains have broaden out to an average width of 300 to 450 m.

These rivers exhibit swelling and pinching in their width at an alternate stretch all along the length across the Himalayan ranges, which appear to have been chiefly controlled by geologic as well as structural conditions and also by stream kinetics energy distribution in the fluvial domain of stream during sedimentation.

In general where the rivers are flowing across the physically less competent and softer rocks such as phyllite the channel bars and channel braids are associated with active flood plain present day course of the channel and are mostly formed due to loss of bed gradient and under loading of the stream. The type development of these landforms in Alaknanda is observed around Srinagar, Nagrasu, Gauchar, Lanngasu and Nandprayag; where the channel bed is comparatively more flatten and valley is considerably wide.

These landforms generally comprise sub-rounded to well rounded boulders, cobbles, pebbles of quartzite, gneiss, granite, schist, phyllite, slate, limestone and the matrix of coarse to fine micaceous sand. These sediments appear to have been subjected to the repeated reworking as is evident by their highest order of sphericity and roundness in contrast to the other deposits in the valley

Erosional Terrace/Rock Cut Terrace:
These are rock cut benches of Quartzite, Phyllite slate which are generally overlain by a thin veneer of river borned sediments consisting of sub-rounded to well rounded rock gravel, with sand. These are essentially erosional terraces and were formed by river during the erosional phase with a view to attain the base level of the river system. In general these terraces are elongated in shape and have an average height of about 6.5 m above the river bed. The prominent rock cut terraces are identified around Pipalkoti, Chamoli, Nandaprayag, Langasu, Karanprayag, Gauchar, Ratura, Rund raprayag, Kaliyasaur and Medanpur.

Point Bar:
The point bar is channel land form element and generally formed on the convex side of the meander loop of the river, with the dimension ranging from 850 x 250 mts to 1000 x 150 mts in Alaknanda 350 x 200 to 150 x 50 m in Mandakini, 150 x100 to 80 x30 m in Pindar 150 x 100 to 100 x 50 m.

The prominent development of point bar is seen around Chamoli, Karanprayag, Gauchar, Langasu, Kallyasour, Srinagar, Kirtinagar, in Alaknanda, Theralli, Kulsara, Narayanbagard, Simli in the Pindar valley. This landform consist of sub rounded to well rounded boulder, cobble, pebble of quartzite, gneiss, granite slate, phyllite basics in the matrix of very coarse to fine sand.

Channel bar:
The channel bars are mainly identified within the active channel of Alaknanda and its tributaries. These landform elements are mostly lensoid, elliptical in shape with average dimension ranging from 100 x 65 m. The channel bar predominantly consists of very coarse to fine sand and rock gravel. The prominent channel bars are identified around Nandaprayag, Langasu, Gauchar, Nagrasu and Srinagar.

Stabilized channel bar :
The stabilized channel bars are identified around Langasu, Srinagar and Tilwar associated with the active channel coarse of Alaknanda and Mandakini in the area under study. These are mostly elliptical and lensoid in shape consisting of mainly coarse to fine sand and rock pebbles.

Alluvial Fan:
Alluvial Fan is a body of stream deposits whose surface approximates a segment of a cone that radiates down slope from the point where the stream leaves a mountainous area. Alluvial fans have greatly diverse sizes, slopes, types of deposits and source area characteristics. They are most wide spread in the drier parts of the world but have been studied in humid regions such as Japan, the 'Himalayan mountain (Drew 1873) and Canada (Winder 1965) and in the Arctic regions (Hoppe and Ekman 1964, Legget and others 1966).

The Alluvial fans in the present area of study identified are of various shape and dimension. A prominent alluvial fan occupying an area about 1.85 sq km is seen around Langasu. It is conical in shape and consists of hetrogenous and assorted assemblage of rock fragments of quartzite, slate basic in the matrix of very coarse to fine silt and clay. It is drained by radial net work of stream which have appreciably incised.

The conical fan forms the deep gullies and steep scarp across the head to the toe. The deposition of sediments is still active in the lower part by the net work streams draining across this alluvial fan.

Talus Cone:
The rock fragments found on slopes or at the foot of steep slopes and cliffs under conditions of sub polar or arid subtropical climates are variously referred to as Talus, scree or rock debris. The term talus is of French origin

("Slope") but employed in a special sense in geomorphology. There are various types of talus cones, (Sidney White, 1968) viz. rock fall talus, alluvial talus, Avalanche talus, and creep and talus cone.

The talus cone is generally formed mainly by accumulation of rock debris through many small rock falls close to a mountain wall. The talus cone in the area under study identified around Damar in Mandakini valley. It is small talus cone and has occupied an area about 800 sq. m. The slope profile of talus is slightly curved and the inclination is between 40° to 45°. It consists of rock debris of quartzite, slate, basic in the matrix of silt and clay. The rock fabrics of talus cone are mostly heterogeneous in nature and show slight imbrications and rough orientation of longer axis down the slope, probably due to sliding of debri under gravity. Besides talus cones of cirque moraines are also seen in Joshimuth - Badrinath section in Alaknanda valley.

Fan Cut Terrace:

In the area high level fans and older alluvial fans have been observed at several places in Alaknanda around Kaliyasour in Mandakini north west of Tilwara and in Attagad valley around Adibari, besides these elements are commonly seen with small subsequent streams joining Alaknanda at various places. The fans occur as distinctly sloping surfaces with the master slope in the direction across the flow of main streams. These fans are formed of material derived mainly from local high relief areas having been brought and deposited by steeply sloped tributaries at their mouths. Periodic heavy discharge in these tributaries bring greater sediment load of higher sizes while in the lean periods the sediments are relatively finer so that a pseudo stratification of coarser and finer sediments occurs in cross section, the bands appear to have a slope of 10° or more towards the river parallel to and slightly fanning away from the parent streams, which deposited them. These fans, when incised and left over in the form of sloping benches constitute the fan cut terraces.

Abandoned channel/epigenetic gorges:

In Alaknandaand Mandakini at several places have carved their courses through epigenetic gorges and left it's earlier courses on the bank as fossil valleys. These Two are separated by either a wedge of rock, or river borne sediments. These gorges were formed perhaps due to superimposition of fluvial cycle on earlier glaciated valley, sudden change in stream kinetics, or damming of the valley by mass wasting processes or by dumping of sediment load due to change of stream kinetics. The change in the stream kinetic appears to important factor in forming the abandoned channel and epigenetic gorges in the area. The prominent abandoned courses and epigenetic gorges are identified around Karanprayag, Bamoth, Gholtir, Dharkot, Ratura, lameri, Uttiyasu, Kaliyasour, Rudraprayag, and Koteshwar in the Alaknanda valley and around Tilwara in Mandakini valley.

Break in slope:

In rugged and highly undulating relief area slopes may take various forms. A geometrical terminology is given by Saviger (1956), according to him slopes may consist of elements which are can cave upward (angle constantly decreasing down slope) convex upward (angle constantly decreasing down slope) straight or rectilinear (unchanging angle) and complex (great variation of slope in a short distance) changes from one type of profile to another are termed break in slope.

The area of study display relief variation from 550 m to 3000 m and form the highly undulating and rugged terrain of Lessar and Central Himalayan mountainous tract of complex nature where the variation in slope profile is obvious. The conspicuous break in slope are identified in the present area of study are associated with the faults, lineaments, mass wasting processes glacial and peri-glacial areas due to differential weathering of landscape.

Scar lines:

The Scar lines are linear and curvilinear features which are conspicuously associated with the valley flanks of Alaknanda and its tributaries in the area under study. These lines are identified at various height and are correlatable with the prominent terrace level therefore indicate the level at which the river once formed the valley floor in the past. The prominent Scar lines are identified around Pipalkoti, Chamoli, Karanprayag, Ratura, Rudraprayag, Kaliyasour, Srinagar and Deoprayag in Alaknanda Tilwar, Rampur and Medanpur in Mandakini valley.

Landslides:

In every slope gravity produced shearing stresses exist which increase with slope inclination and height and with the unit weight of slope forming material. Within the surface zone, the processes of freezing and thawing, Shrinkage and swelling and thermal expansion and contraction produce further shearing stresses. In response of the slope to these imposed stresses is controlled by resistance to shear deformation currently exhibited by its component material, its closely dependent on the pressures exerted by ground water which generally occupies the soil pores, very slow largely irreversible deformations termed creap begins as soon as the "critical" strength is exceeded, which may be considerably lower than the strength at which the shear failure occurs (Haefelt 1953). As imposed stress approaches the average shear strength the rate of creep increases until eventually some form of the relatively rapid failure takes place to which the genetic term landslide is applied (Terzaghi 1950). The prominent landslides identified in Alaknanda, Bhagirathi and Pindar valleys in the area are described in detailed under the head of mass wasting. The other various forms of mass movement identified in the area are described.

Rock fall Debri fall :

The Rock falls comprise the more or less free descent of masses of soil or rock of any size from steep slopes or cliffs. As Rapp (1961) has emphasized, on the slope steep enough to be subject to falls, no significant protective mantle of rock waste can accumulate and mass movement can proceed as fast as weathering and disintegration of the parent mass permits.

The Rock fall and Debri fall are characterized by frequently protected phase of progressive separation of mass from its parent cliff which eventually leads to its abrupt collapse. The separation is effected initially by the growth of tension cracks, the final release of rock mass commonly occurs through shear failure of the root of the mass. These failures are confined to surface zone of rocks, in which the effects of pressure release and is of seasonal variation in temperature and cliff water pressure are most significant. In the present area of study in Garhwal Himalayas well marked annual peak of rock fall intensity in the spring suggest thawing following frost bursting to be relevant mechanism. The most of Rock fall and Debri fall mass wasting processes are conspicuously associated with the old abandoned cirques, active glaciated areas and peri-glacial area beyond average height of about 2800 m.

Scree and Scree slopes:

The rock fragments found on the slopes or at the foot of steep slopes and cliffs under conditions of sub-polar or arid sub-tropical climates are variously referred to as talus, scree or rock debris. In the area under study the scree deposits/ scree slopes are identified in Alaknanda around Langasu, Bamoth and Nandaprayag in Mandakini north of Rudraprayag, around Rampur, in Pindar around Simli and Karanprayag. These elements are mostly elongated in shape and restricted along the outer edges of valley flanks. The scree predominantly consists of sub-angular rock fragments of quartzite, phyllite slates, limestone and basic in the matrix of clay these rock clastics are highly assorted and are heterogeneous in texture. The average thickness of these deposits is about 6.5 m.

Retreating scrap:

The Retreating scraps are structural scarps and are mostly controlled by joints or faults. These scarps later are associated with rock fall and debri fall. The general trend of these scarps are NW-SE, and N-S among these NW-SE is relative most prevailed and coincide with major structural trend of Himalaya.

Crest line sharp Major:

These crest lines forms the major water divide in the area. These lines comprised of both asymmetric and symmetric ridges of quartzite, slates, phyllites basic, gneiss, granite and schist having steep, moderate and gentle slope. The height of these lines varies from 2200 m to 2778 m above the mean sea level and average height is 2310 m.

Crest line sharp minor:

These crest lines comprise of both asymmetric and symmetric ridges of quartzite, granite and geniss having steep to gentle slope. These lines form sub-water divide with the basin. The intervening part of such lines is drained by subsequent, consequent and consequent streams. The height of these lines varies 1850 to 2250 mts and average height is 2035 m.

Crest line rounded major:

These lines consist of asymmetric to symmetric ridges of phyllites, slates and gneiss which have been subjected to varying degree of dissection in response to both structure and lithology. These crest lines have developed two types of erosional slope which are generally consequent and obsequent in nature. The height of these crest lines ranges from 1950 to 2200 m above the mean sea level and average height 1s 2140 m. These crest lines form the sub-basin which is drained by mostly sub parallel to parallel streams.

Crest line rounded minor

The crest line rounded minor are mostly developed on the asymmetric and symmetric of phyllites, slates gneiss and limestone having moderate and gentle slope. These slopes are drained by sub-parallel to parallel streams. The average height of these lines is about 1500 m above mean sea level. The other geomorphic features and landform elements recognized are cirque moraines, land slide scars, old stabilized landslides, scarp associated with rock fall, debri fall, V-shaped valley, U-shaped valley, flat bottomed valley, water fall, spring and nick points.

Abandoned cirque:

Cirques are commonly described as armchair shaped hollows possessing three distinctive elements, a steep nearly vertical headwall, a concave floor meeting the headwall in sharp break of slope and a lip or threshold at the entrance which may be of bed rock, glacial moraine or both. The threshold may impound a cirque lake or tarn.

In the present area of study embraces mainly the abandoned cirques which were once occupied by glaciers and were abandoned due to glacier recedes and shift of snow line related with the climatic changes in the region. These abandoned cirques are of various shapes and size such semicircular semi-elliptical and elongated, with an average dimension varying from 1500 x 1000 m to 6000 x 6000 m. The most of these cirques are barren barring few which consist of thin cover of loose debris, consisting' heterogamous assemblage of various rock fragments. The prominent cirques are identified north of Gopeshwar, east of Pipalkoti, east and north east of Nandaprayag, north and west of Nauli at an average elevation of about 2500 m above the mean sea level.

Arêtes:

The Arêtes are generally asymmetrical and symmetrical and both linear and curvilinear sharp ridges, which make the glaciers, divide between various cirques. The slopes of Arêtes are moderate gentle to steep; the southern slopes are comparatively steeper than northern slope. The prominent Aretes are recognized around Gopeshwar, north east of Nandaprayag. Pipalkati and around Nauli in the vicinity of occurrence of abandoned cirques.

Threshold:

The Threshold is lip of cirque at the entrance which may be of bed rock, glacial moraine or both. The threshold may impound a cirque lake or tarn. The threshold in the area of study are narrow and both symmetrical and asymmetrical in nature and have developed mostly on bed rock. The width of these elements varies from 100 m - 350 m and average width is 243 m and mostly developed on the bed rock. These are devoid of any lake or tarn.

Horn Peak:

These are isolated peak or Horn developed on the arêtes due to progressive expansion of neighboring cirques. The prominent Horn Peakare in north of Gapeshwar and north- east of Nauli.

Glacial lake:

In the area under study two prominent lakes are identified viz. Diwar Tal north of Gopeshwar and Tark Tal, in the catchment of Berhi-Ganga. The dimension of these two lakes is about 50x75 m and 85x125 m respectively. These lakes contain fresh water which is use for domestic purposes locally. (Plate No.1)

Conclusion:-

The Geological and Geomorphological study in Upper Ganga basin has been attempted in parts of de Uttarkashi,Chamoli, Pauri and Tehri districts an area of 10000 Sq.kms in parts of QA sheet 53Jand 53 N on 1:50000 scale of Garhwal Himalaya U.P; presently known as Uttrakhand State of Union of India. Out of total area of study, an area about 3500 sq.Kms (1:50000 scale) has been selected for detailed Geological, Geomorphological and Sedimentological study.

The area of Upper Ganga basin consisting of Alaknanda, Bhagirathi, Bhilangna, Nandakini, Mandakini, Pindar, Dhauli- Ganga Bal- Ganga, Madhmeshwar Ganga and Berhi Ganga The Alaknanda is chracterised by six terraces followed by Bhagirathi with five terraces, Bhilangna Nandakini four terraces Mandakini /Pindar/Dhauli-Ganga /Balganga three terraces, Madhmshwar Ganga two terraces and Berhi Ganga one terrace, amidst these Alaknanda is trunk stream and others are tributaries.

Geomorphologically the area is divided in to seven geomorphic units viz High relief formerly glaciated area, Structural hills, Denudational hills, Area of mass wasting, High level dissected fans, river Terraces and Present day flood plain of Alaknanda and its tributaries. These units area developed in response to lithology to erosional land depositional activities and tectonic in which they are embedded. Each unit is characterized by drainage, diagnostic geomorphic landform elements and features, photo characters and morphogenetic expression. The other geomorphic features and elements identified in the area are point bar, channel bar, alluvial fans ,talus cone , rock cut terraces fan cut terraces , abandoned channel,epigenetic gorges, strand lines landslides ,rock fall scree and scree slope, retreating scarp, abandoned cirque, cirque moraines, arêtes, threshold, horn peak and glacial lake. The area genetically comprised of terraces of three domains, viz. Glacial, Fluvio-glacia and Fluvial which represent distinct environment of sedimentation of Pleistocene, late Pleistocene and Holocene time during Quaternary period.

The Glacial terraces are identified at an average elevation of 1150 m above MSL, the fluvio-glacial terraces at an average elevation of 975m above MSL and Fluvial terraces at an average elevation between 650 to 900 m above m, s.l.

The Alaknanda is Antecedent River which traverses across the strike of Himalyan ranges and negotiate both across and along thrust/fault and linaments.The channel morpohology of Alaknanda is diverse and associated various digonestic morphotectonic features and elements, amidst these the epigenetic gorges which are assocated at different level i.e at 5m, 10m, 12m, and 15m within the present valley suggest the channel system has been under tremoundos stress and under tectonic influence. It was governed and controlled by consequential and residual energy system and frequential newly generated energy system by neotctonic movements along thrust/fault/linaments traversing the area.The disposition of epigenetic gorges and their association with Alaknanda suggests at least three major tectonic events in Holocene time.The morphogentic illustration of channel morphology of Alaknanda indicate that area is active, sensitive and prone to Neosiesmic hazards.

The-Himalayan thrust like Central thrust Srinagar thrust,, Alaknanda fault, Tons thrust, show flattening dip suggesting that they lie at comparatively at shallow depth at short distance, down dip from their out crops, recent movements along the trace of these faults /thrust are not of high and longer magnitude but have considerably affected Quaternary terraces of glacial, fluvio-glacial and fluvial domain of Alaknanda and its tributaries. Beside drainage, river bed profile, landscape architect and over all morphogenetic expression of the area, bears the imprints of neotectonisam which revealed that the area is under stress, sensitive active and posed to earthquake.

The geomophological study of the area, overall morphogenetic illustration, imprints of neotectonisam, disposition of terrces of different domains, mass wasting activities, drainage net, channel morphology, landform elements of glacial, fluvioglacial and fluvial domain of Alaknanda and its tributaries; indicate that tectonically the area is active and slow movements are taking plae along thrust, faults and lineament.

In the area North of Wazri in Jamuna valley, North of Uttarkashi around Sainj in Bhagirathi valley, around Tugnath and Chamoli and South of Joshimuth in Alaknanda valley revealed that there is sharp persistent curvilinear break in topography, which have geothermal manifestation at Wazri Gagnani anda Tugnath in the form of emitation of hot springs. This curvilinear line has further reconfigurated the neo stream net works system and affected morphogenetic expression It appears to be due to horizontal movement of sub - tectonic plate towards south,which, is sole collective and cumulative causative factor in dislocation of tectonic ecology of the area and has resulted micro earthquake shocks and and segmental sinkiking of area. The overall study revealed that the the area is sensitive active and is vulnerable to any techtono- seismic event; it is matter of serious concerned and needs further attention

The Badrinath temple is situated in glaciated trough valley of Alaknanda, which comprise of, four levels of the glacial terraces (lateral moraine), cirque moraine on mountain flanks and the terminal moraine at the base of valley. whereas Kedarnath in the upstream of Mandakini, where number of well developed cirques were identified on high mountain, they are mostly arm chair shaped hollows with a steep to vertical head walls, concave floor and a threshold, these cirques are noticed at an average height of about 4500 m. The Kedarnath temple is situated in glaciated trough valley on quaternary platform formed by coalescing of cirque, lateral moraine and terminal moraine.

The study revealed that the the area techtonicall is active, sensitive and volurnable to any techtano seismic event; it is matter of serious concerned and needs further attention.

Table No. 3:- Salient features of fluvial terraces in type area of Alaknanda Valley.

(i) Locality : Srinagar (30^0 12' – 78^0 47')

Terrace and its Designation

	River bed	AT_1	AT_2	AT_3	AT_4	AT_5	AT_6
Age	________________	**Holocene** ________________					
Elevation above MSL (m)	**600**	**600**	**615**	**635**	**650**	**670**	**690**
Geomorphic break (m) -	**15**	**20**	**20**	**15**	**20**	**20**	
Elevation above RB (m)	**-**	**20**	**35**	**55**	**70**	**90**	**110**
Slope	**----- Towards west -----**		**----Towards SW ----**		**Towards west -----**		
Nature of surface	**----- Depositional ---------**			**---- Erosional ------**			
Cycle sedimentation -	**---------- Polycycle --------------------------**			**Not exposed -------------**			
Orientation of L-Axes -	**NW-SE**	**E-W**	**NNE-SSW**		**NE-SW**	**E-W**	**E-W**
Plunge of L-Axes -	**----- Towards East --------------------------**				**Towards NE -------**	**Towards West ----------**	
Relative disposition -	**Divergent**	**Divergent**	**Convergent**		**Divergent**	**---------------------------------**	
Paired / Unpaired -	**Unpaired**	**Paired**	**Unpaired**	**Paired**	**Paired**	**Isolated Patches**	
Nature of scarp -	**------------------ Curvilinear --------------------**				**------------ Linear -------------**		**Curvilinear**
Sedimentary features -	**------- Not exposed -------**		**a) Graded bedding b) Cross bedding c) Lamination and cross limitation**			**Cross bedding**	**-**
Terrace Shape -	**Cuspate**	**Rectangular**	**--**			**Isolated cap**	**Semi-Circular**
Land use pattern -	**------------------------------ Inhabitation and cultivation --**						

Composition/Litho constituents Arranged in probable order of abundance

River bed :- **Quartzite, granite, gneiss, schist, basic, phyllite, slate, shale and sand**

AT_1 :- **Quartzite, gneiss, granite, schist, basic, limestone, phyllite, slate and sand.**

AT_2 :- **Quartzite, gneiss, granite, schist, phyllite, slate, sand and silt.**

AT_3 :- **Quartzite, gneiss, granite, fossiliferous, limestone, basic, phyllite, slate, shale, sand and silt.**

AT_4 :- **Quartzite, gneiss, granite, basic, schist, phyllite, slate, shale, sand and silt.**

AT_5 :- **Quartzite, gneiss, granite, basic, schist, phyllite, slate, shale, sand, silt and clay**

AT_6 :- **Quartzite, limestone, gneiss, granite, schist, phyllite, slate, shale, sand, silt and clay.**

** **The fabric elements of river terraces range in size from boulder to small pebble. The finer clastics comprise of very coarse to very fine sand, silt and clay. These rock fabrics are generally subrounded to well rounded and mostly spherical, oblate, prolate and bladed in shape.**

(ii) Locality : Pharasu (30^0 14-30" – 78^0 52'.00")

Terrace and its Designation

	River bed	AT_1	AT_2	AT_3	AT_4	AT_5	AT_6
Age		Holocene					
Elevation above MSL (m)	605	615	635	660	675	700	725
Geomorphic break (m)	-	15	20	25	15	25	25
Elevation above RB (m)	-	15	35	70	85	110	135
Slope	Towards SW	----Towards West --------------------- Towards South West -------------------------------					
Nature of surface	Depositional	Erosional	Depositional	Depositional	------ Erosional ---------		
Cycle sedimentation	-	---------- Uncycle -----------		------Polycycle ----------	---Not fully exposed --		
Orientation of L -Axes	-	E-W	NNE-SSW	NE-SW	NW-SW	NW-SW	NW-SW
Plunge of L-Axes	-	----- Towards East -------------------------- Towards NW ------- Towards North ----------					
Relative disposition	-	-------- Convergent -------------		----------- Divergent ---			
Paired / Unpaired	-	-------------- Unpaired ------------		------ ------------------ Paired ---------- --------			
Nature of scarp	-	------------------- Curvilinear --------------------		------------- Linear --------------			
Sedimentary features	-	Graded Bedding Lamination	-	Graded lamination cross cross bedding.	Bedding lamination fill features	- cross bedding	-
Terrace Shape	-	Cuspate	------- Rectangular ----------------------		Semi-Circular ------ circular		
Land use pattern	-	------------------------------- Inhabitation and cultivation ---					

Composition/Litho constituents Arranged in probable order of abundance

River bed :- Quartzite, gneiss, schist, basic, slate, shale, limestone and sand

AT_1 :- Quartzite, gneiss, granite, schist, , phyllite, slate, shale and sand.

AT_2 :- Quartzite, limestone (fossiliferous), gneiss, granite, phyllite, slate, shale and basic.

AT_3 :- Quartzite, gneiss, sandysilt, granite, schist, limestone, phyllite, slate, shale, sand and silt.

AT_4 :- Quartzite, gneiss, Fossiliferous, limestone, phyllite, slate, basic, shale, sand, silt and clay

AT_5 :- Gneiss, granite, quartzite, schist, slate, shale, sand, silt and clay

AT_6 :- Quartzite, granite, schist, limestone, gneiss, basic, slate, , sand, silt and clay.

** The fabric elements of river terraces range in size from boulder to small pebble. The finer clastics comprise of very coarse to very fine sand, silt and clay. These rock fabrics are generally subrounded to well rounded and mostly spherical, oblateprolate and bladed in shape.

(iii) Locality : Rudraprayag and Ultiyasu Area (32^0 30' 00 – 79^0 57'30")

Terrace and its Designation

	River bed	AT_1	AT_2	AT_3	AT_4	AT_5	AT_6
Age		Holocene					
Elevation above MSL (m)	625	635	650	670	685	715	740
Geomorphic break (m)	-	10	15	20	15	30	25
Elevation above RB (m)	-	10	25	45	60	90	115

Slope ------------------ ------------------- --------------------- Towards South West ---
Nature of surface - ------------------------------------- Depositional --------------------------------------- - Erosional
Cycle sedimentation - Section not Section not Unicycle ------------- Polycycle ----------
Fully exposed fully exposed
Orientation of L-Axes -------------------------- North East ------------------------------- South West -------------------- -------------------
Plunge of L-Axes - 5^0 towards north east 10^0NE 9_0NE 10^0N
Relative disposition - ---------------------------- Divergent -- Occur as islated caps
Paired / Unpaired - --- Unpaired ----------------------------- ---------------
Nature of scarp - --------------------------------- Linear -- Curvilinear
Sedimentary features - Graded Bedding cross bedding cut & fill features lamination & Cross lamination --- ----------
Terrace Shape - --------------------- Rectangular --- --------------Circular
Land use pattern - ------------------------------- Inhabitation and cultivation -------------------------- ---------------

Composition/Litho constituents Arranged in probable order of abundance

River bed :- Quartzite, gneiss, granite, schist, basic, phyllite, shale, limestone and micaceous sand.
AT_1 :- Quartzite, slate, phyllite, basic, gneiss, granite, fossiliferous, limestone and sand.
AT_2 :- Quartzite, slate, basic, phyllite, gneiss, granite, schist, fossiferous Limestone, sand and silt.
AT_3 :- Quartzite, gneiss, granite, schist, basic, slate, limestone, Fossiliferous, silt, sand and clay.

AT_4 :- Quartzite, gneiss, granite, schist, basic, slate, phyllite, Fossiliferous, limestone, silt, sand and clay.
AT_5 :- Quartzite, gneiss, granite, schist, limestone, slate, red, silt, phyllite, sand and clay
AT_6 :- Quartzite, granite, schist, gneiss, limestone, phyllite, slate, , sand, silt and clay.

The fabric elements of river terraces range in size from boulder to small pebble. The finer clastics comprise of very coarse to very fine sand, silt and clay. These rock fabrics are generally subrounded to well rounded and mostly spherical, oblate, prolate and bladed in shape.

(iv) Locality : Nagrasu (32^0 17' 25" – 79^0 10'00")

Terrace and its Designation

	River bed	AT_1	AT_2	AT_3	AT_4	AT_5	AT_6
Age		Holocene					
Elevation above MSL (m)	650	670	695	710	745	765	790
Geomorphic break (m)	- 20	25	15	35	20	25	
Elevation above RB (m)	-	20	45	60	95	115	140

Slope Towards west ------------------ SW SW ----------------
Towards --------------------
Nature of surface - Deposi Erosi -------------- Depositional-----------------
Erosional
Cycle sedimentation - - Unicycle ------------- Polycycle --------------------------------
Orientation of L -Axes - NW-SE NW-SE NW-SE NNE-SSW E-W E-W
Plunge of L-Axes - 5^0 towards 5^0 towards 5^0 towards 5^0 to 10^0 5^0 to 10^0 10^0 towards
NE North NW towards North towards East
East
Relative disposition - -------------------- Divergent ----- ------ convergent - ----------- divergent
Isolated Caps
Paired / Unpaired - --------- Unpaired ---------- Paired --------- Unpaired ----------
Unpaired
Nature of scarp ------- -------- Linear ---------- ---------- Curvilinear ---------------------------
----
Sedimentary features - ------------------------------------ Graded Bedding -------------------------------------
----
Cross Bedding Lamination | Lamination & cut and fill features | - lamination | Graded lamination cross cross bedding and cut and fill features
Terrace Shape - cuspate Rectangular ---- Semi Circular ---------
Isolated semi
Circular to circular lences
Land use pattern - ------------------------------- Inhabitation and cultivation --------------------------
----

Composition/Litho constituents Arranged in probable order of abundance

River bed :- Quartzite, gneiss, granite, schist, basic, slate, phyllite, shale, fossiliferous, limestone and sand.

AT_1 :- Quartzite, gneiss, granite, schist, slate, phyllite, basic, shale, limestone, silt and sand.

AT_2 :- Quartzite, gneiss, granite, phyllite, limestone, fossiferous slate, shale, sand and silt.

AT_3 :- Quartzite, gneiss, granite, Fossiliferous, limestone,basic,phyllite Slate, shale, sand and silt.

AT_4 :- Quartzite, gneiss, granite, limestone, shale, basic, slate, Coarse to yellow sand, yellow purples silt and clay.

AT_5 :- Quartzite, gneiss, granite, schist, basic, shale, slate, Purple sand, red silt and clay.

AT_6 :- Granite, schist, gneiss, Fossiliferous, limestone, phyllite, slate, , And slate red fine sand, silt and clay.

** The fabric elements of river terraces range in size from boulder to small pebble. The finer clastics comprise of very coarse to very fine sand, silt and clay. These rock fabrics are generally subrounded to well rounded and mostly spherical, oblate, prolate and bladed in shape.

(v) Locality : Gauchar-Bamoth (30^0 17' 30" – 79^0 10'00") (Photo No.21)

Terrace and its Designation

		River bed	AT_1	AT_2	AT_3	AT_4	AT_5	AT_6
Age			Holocene					
Elevation above MSL (m)		650	670	690	715	745	785	800
Geomorphic break (m)	-	20	20	25	30	40	15	
Elevation above RB (m)		-	20	40	65	95	135	150
Slope	West	-	Towards west		-------	NW	West	NW

Nature of surface	- Section	----------	Depositional	------------- full exposed	Section not	Polycycle full exposed
Cycle sedimentation	-	Unicycle	Polycycle	------------		
Orientation of L -Axes	-	------------NW – SE	--------------------------		E-W	NW-SE E-W
Plunge of L-Axes	-	------ 5^0 to 10 towards North East --				
Relative disposition	-	Convergent	----------- Divergent	-----------	Convergent	----------- Divergent ------------
Paired / Unpaired	-	-- Paired --				
Nature of scarp	-	--------------------- Linear	-------------------		---------- Curvilinear	------------- ----------------
Sedimentary features	-	------------------	Cross bedding, graded bedding, lamination, cross lamination and cut and fill features ------------------			
Terrace Shape	-	---------------- cuspate -----------		Semi Circular	-------------------------------- -------------------	
Land use pattern	-	------------------------------- Inhabitation and cultivation --------------------------- ---------------				

Composition/Litho constituents Arranged in probable order of abundance

- **River bed :-** Quartzite, slate, phyllite, basic, gneiss, granite, limestone and micaceous sand.
- **AT_1 :-** Quartzite, gneiss, granite, schist, slate, basic, limestone shale, and micaceous sand.
- **AT_2 :-** Quartzite, gneiss, granite, fossiferous, limestone, phyllite, slate Shale, sand, silt and clay.
- **AT_3 :-** Quartzite, phyllite, gneiss, granite, slate, basic, schist, shale, Fossiliferous, limestone, sand, silt and clay.
- **AT_4 :-** Quartzite, gneiss, granite, schist, fossilifeous, limestone, phyllite, slate, sand silt and clay
- **AT_5 :-** Quartzite, gneiss, granite, schist, slate, fossiliferous, limestone, Phyllite, silt, clay and sand.
- **AT_6 :-** Granite, schist, gneiss, granite, Fossiliferous, limestone, phyllite, slate, clay, silt and sand.

**** The fabric elements of river terraces range in size from boulder to small pebble. The finer clastics comprise of very coarse to very fine sand, silt and clay. These rock fabrics are generally subrounded to well rounded and mostly spherical, oblate, prolate and bladed in shape.**

TABLEno.4

SALIENT FEATURES OF FLUVIAL TERRACES IN TYPE AREA OF BHAGIRATHI VALLEY

(i) Locality : Tehri 30^0 28’ 22” : 78^0 22’ 48”

Terrace and its Designation

Age	River bed	BT_1 Holocene	BT_2	BT_3	BT_4	BT_5
Elevation above MSL (m)	427	432	440	447	456	462
Geomorphic break (m)	-	5	8	7	9	5
Elevation above RB (m)	-	5	13	20	29	34
Slope	-	Towards south	Towards south	Towards south	Towards south	Towards south

Nature of surface	-	Depositional	Depositional	Depositional	Erosional	Erosional	
Cycle sedimentation	-	Polycycle	Polycycle	Polycycle	Polycycle	Polycycle	
Orientation of L -Axes		-	NW-SE	NW-SE	NW-SE	NW-SE	N-S
Plunge of L-Axes	-	5^0 to 15^0 North		5^0 to 15^0 North		5^0 to 15^0 North	5^0 to 15^0 North 5^0 to 15^0 North
Relative disposition	-	Convergent	Convergent	Convergent	Convergent	Convergent	
Paired / Unpaired	-	Unpaired	Unpaired	Unpaired	Paired	Paired	
Nature of scarp	-	Curvilinear	Curvilinear	Curvilinear	Linear	Linear	
Sedimentary features	-	Graded bedding, cross lamination cut and fill features ----------------------					
Terrace Shape	-	--------------- cuspate , elongated and lensoid ------------------------------------ -----------					
Land use pattern	-	------------------------------ Inhabitation and cultivation ------------------------ -------------					

Composition/Litho constituents Arranged in probable order of abundance with

- **River bed :-** Quartzite, gneiss, schist, slate, limestone, coarse to file sand.
- **BT_1 :-** Quartzite, gneiss, granite, schist, phyllite, basic and limestone with very coarse to fine sand and silt.
- **BT_2 :-** Quartzite, gneiss, granite, limestone, phyllite, schist and basic Very coarse to fine and silt.
- **BT_3 :-** Quartzite, gneiss, granite, basic, schist, limestone with Coarse to fine sand.
- **BT_4 :-** Quartzite, gneiss, granite, schist, basic, slate, phyllite, Coarse to tine sand, silt and clay.
- **BT_5 :-** Gneiss, granite, schist, phyllite, slate, coarse to fine sand.

**** The fabric elements of river terraces range in size from boulder to small pebble. The finer clastics comprise of very coarse to very fine sand, silt and clay. These rock fabrics are generally subrounded to well rounded..**

(ii) Locality : – Chinyalli Saur (Photo No.63)
(30^0 31' 52" : 78^0 22' 20")

Terrace and its Designation

		River bed	BT_1	BT_2	BT_3	BT_4	BT_5	
Age			Holocene					
Elevation above MSL (m)			429	436	446	454	464	472
Geomorphic break (m)			-	7	10	8	10	7
Elevation above RB (m)			-	7	17	25	35	42
Slope			-	-----------	Towards south		-----------	---------- - -----------
Nature of surface	-		Depositional	Depositional	Depositional	Depositional	Erosional	
Cycle sedimentation	-		Polycycle	Polycycle	Polycycle	Polycycle	Polycycle	
Orientation of L -Axes			-	5^0 to 10^0 ----------- N – S --- ---------------------				
Plunge of L-Axes	-		5^0 to 10^0 ----------- towards north --- -----					
Relative disposition	-		-----------	Convergent ------------------------------------ Divergent				
Paired / Unpaired	-		Unpaired	Unpaired	Unpaired	Unpaired	Paired	
Nature of scarp	-		Curvilinear	Curvilinear	Curvilinear	Curvilinear	Linear	
Sedimentary features	-		----- Graded bedding & cut & fill features -------------- Section not well exposed					
Terrace Shape	-		------------------------Crecent -- Elongate					

Land use pattern - ------------------------------- Inhabitation and cultivation -------------------------------------

Composition/Litho constituents River bed :- Quartzite, gneiss, granite, schist, phyllite, slate, limestone, micaceous
Arranged in probable order of meta-volcanic, coarse to fine sand.
abundance BT$_1$:- Quartzite, gneiss, granite, schist, phyllite, slate, limestone, micaceous,
meta-volcanic, coarse to fine sand.
BT$_2$:- Quartzite, gneiss, granite, limestone, schist, meta-volcanic, slate,
Coarse to fine sand.
BT$_3$:- Quartzite, gneiss, granite, schist, basic, phyllite, slate and occasional,
Meta-basic and coarse to fine sand silt and clay.
BT$_4$:- Quartzite, gneiss, granite, schist, phyllite, and slate with very coarse
To very fine sand, silt and clay
BT$_5$:- Quartzite , gneiss, granite, schist, phyllite, slate with very coarse to
very fine silt and clay.

**** The fabric elements of river terraces range in size from boulder to small pebble. The finer clastics comprise of very coarse to very fine sand, silt and clay. These rock fabrics are generally subrounded to well rounded and mostly spherical, oblate, prolate and bladed in shape.**
(iii) Locality : Dunda
(30^0 41’ 51” : 78^0 21’ 05”)

Terrace and its Designation

	River bed	BT$_1$	BT$_2$	BT$_3$	BT$_4$	BT$_5$
Age		Holocene				
Elevation above MSL (m)		448	451	456	463	468 473
Geomorphic break (m)		-	3	5	7	5 10
Elevation above RB (m)		-	3	8	15	20 30
Slope		-	-----------	Towards SW		----------- ---------- - -----------
Nature of surface -		Depositional	Depositional	Depositional	Depositional	Erosional
Cycle sedimentation -		------------- Unicycle			-----------------------------------	Polycycle Polycycle
Orientation of L -Axes		-	-------------	10^0 to 25^0 NW-SW	5 – 15 N-W	--------- 10^0. 20^0 NE-SW -----
Plunge of L-Axes -		5^0 to 10^0 ---------- towards north --				
Relative disposition -		------------------- Convergent -------------------------				----------- Divergent ---------
Paired / Unpaired -		Unpaired	Unpaired	Unpaired	Paired	Paired
Nature of scarp -		Curvilinear	Curvilinear	Curvilinear	Linear	Linear
Sedimentary features -		Graded bedding, cross bedding Lamination, cross lamination				Section not fully exposed
Terrace Shape -		------------- Semi circular -------------------				Elongate ---------------- Rectangular
Land use pattern -		------------------------------- Inhabitation and cultivation -------------------------------------				

Composition/Litho constituents River bed :- Quartzite, gneiss, granite, schist, phyllite, slate, limestone

Arranged in probable order of abundance		**meta-volcanic and coarse to fine micaceous sand.**
	BT_1 :-	**Quartzite, gneiss, granite, schist, phyllite, slate, limestone meta-volcanic, coarse to fine sand.**
	BT_2 :-	**Quartzite, gneiss, granite, phyllite, slate, limestone, basic and Coarse to fine sand.**
	BT_3 :-	**Quartzite, gneiss, granite, schist, phyllite, slate, limestone, Coarse to fine sand, silt and clay.**
	BT_4 :-	**Quartzite, gneiss, granite, schist, phyllite, slate coarse to fine Sand, silt and clay.**
	BT_5 :-	**Quartzite , gneiss, granite, schist, slate and very coarse to very fine sand and clay.**

** **The fabric elements of river terraces range in size from boulder to small pebble. The finer clastics comprise of very coarse to very fine sand, silt and clay. These rock fabrics are generally subrounded to well rounded and mostly spherical, oblate, prolate and bladed in shape.**

(iv) Locality : Uttarkashi
(30^0 43' 00" : 78^0 26' 00")

Terrace and its Designation

	River bed	BT_1	BT_2	BT_3	BT_4	BT_5
Age		**Holocene**				
Elevation above MSL (m)		**460**	**464**	**469**	**474**	**479 491**
Geomorphic break (m)		**-**	**4**	**5**	**5**	**5 12**
Elevation above RB (m)		**-**	**4**	**9**	**14**	**19 31**
Slope	**-**	**-**	**-----------**	**Towards West**		**----------- ----------**
Nature of surface	**-**	**Depositional**	**Depositional**	**Depositional**	**Erosional**	**Erosional**
Cycle sedimentation	**-**	**-------------- Not exposed**		**--------------------------- Polycycle --------------------------**		
Orientation of L -Axes		**-**	**------------- Towards NW ---**			
Plunge of L-Axes	**-**	**---------- 5^0 to 12^0 ----------- towards west ---------------**				**15^0 -20^0 east ---------------**
Relative disposition	**-**	**------------------- Convergent -------------------------**				**----------- Divergent ---------**
Paired / Unpaired	**-**	**Unpaired**	**Unpaired**	**Unpaired**	**Paired**	**Paired**
Nature of scarp	**-**	**Curvilinear**	**Curvilinear**	**Curvilinear**	**Linear**	**Linear**
Sedimentary features	**-**	**---------------- Graded bedding ------------------ Cross lamination Lamination and cut and fill feature**				**Graded bedding & cut & fill features**
Terrace Shape	**-**	**------------- Crecent --------------------------------**				**---------- Lensoid ------------------------**
Land use pattern	**-**	**------------------------------- Inhabitation and cultivation -------------------------------------**				

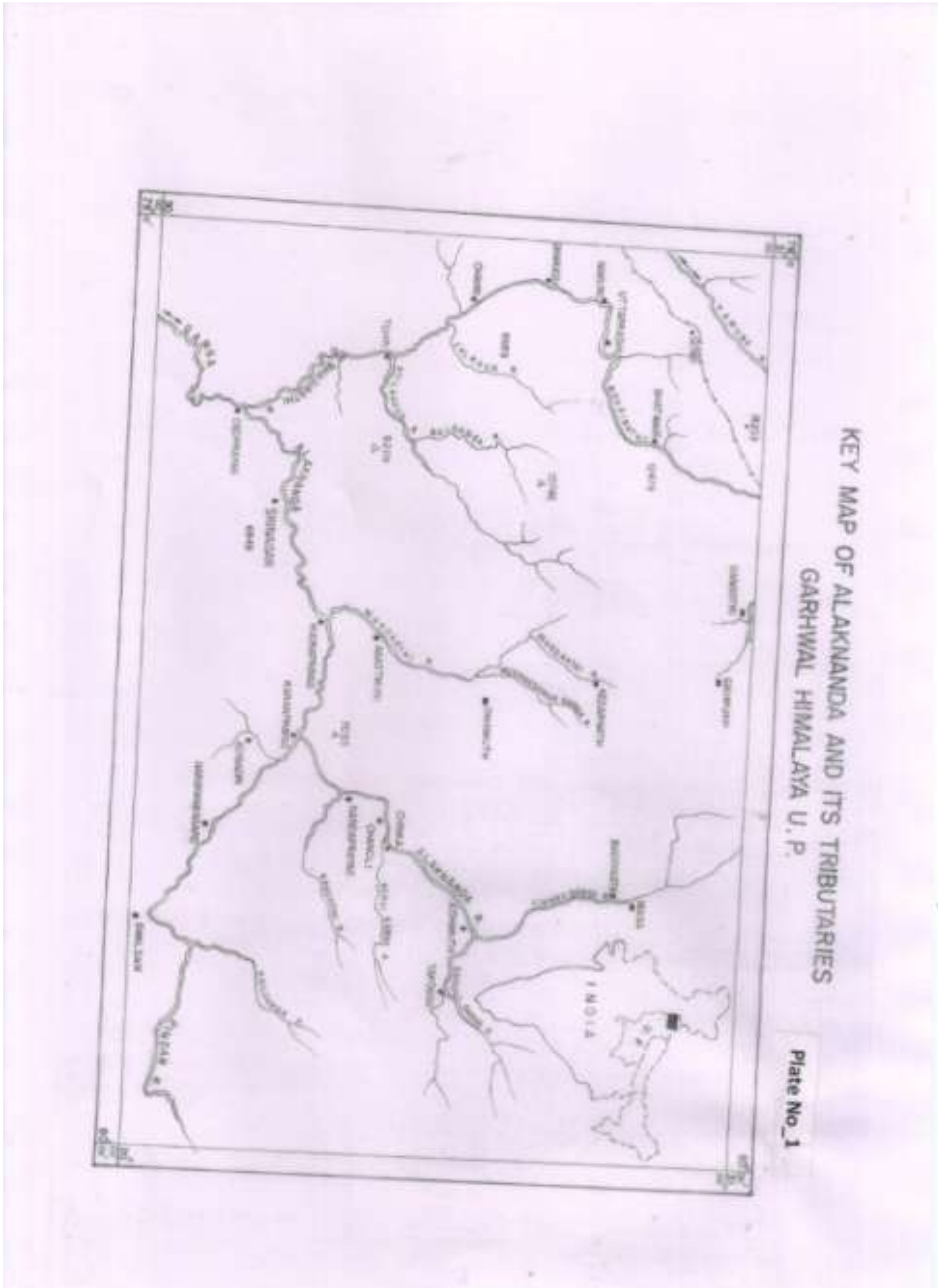
Composition/Litho constituents Arranged in probable order of abundance	**River bed :-**	**Quartzite, gneiss, granite, schist, limestone, meta-volcanic and coarse to fine sand.**
	BT_1 :-	**Quartzite, gneiss, granite, schist, phyllite, slate meta-volcanic, coarse to fine sand.**
	BT_2 :-	**Quartzite, gneiss, granite, phyllite, slate and coarse to fine sand.**
	BT_3 :-	**Gneiss, granite, schist, phyllite, slate, limestone and Coarse to fine sand.**
	BT_4 :-	**Gneiss, granite, schist, phyllite, slate, limestone coarse to fine Sand, silt and clay.**

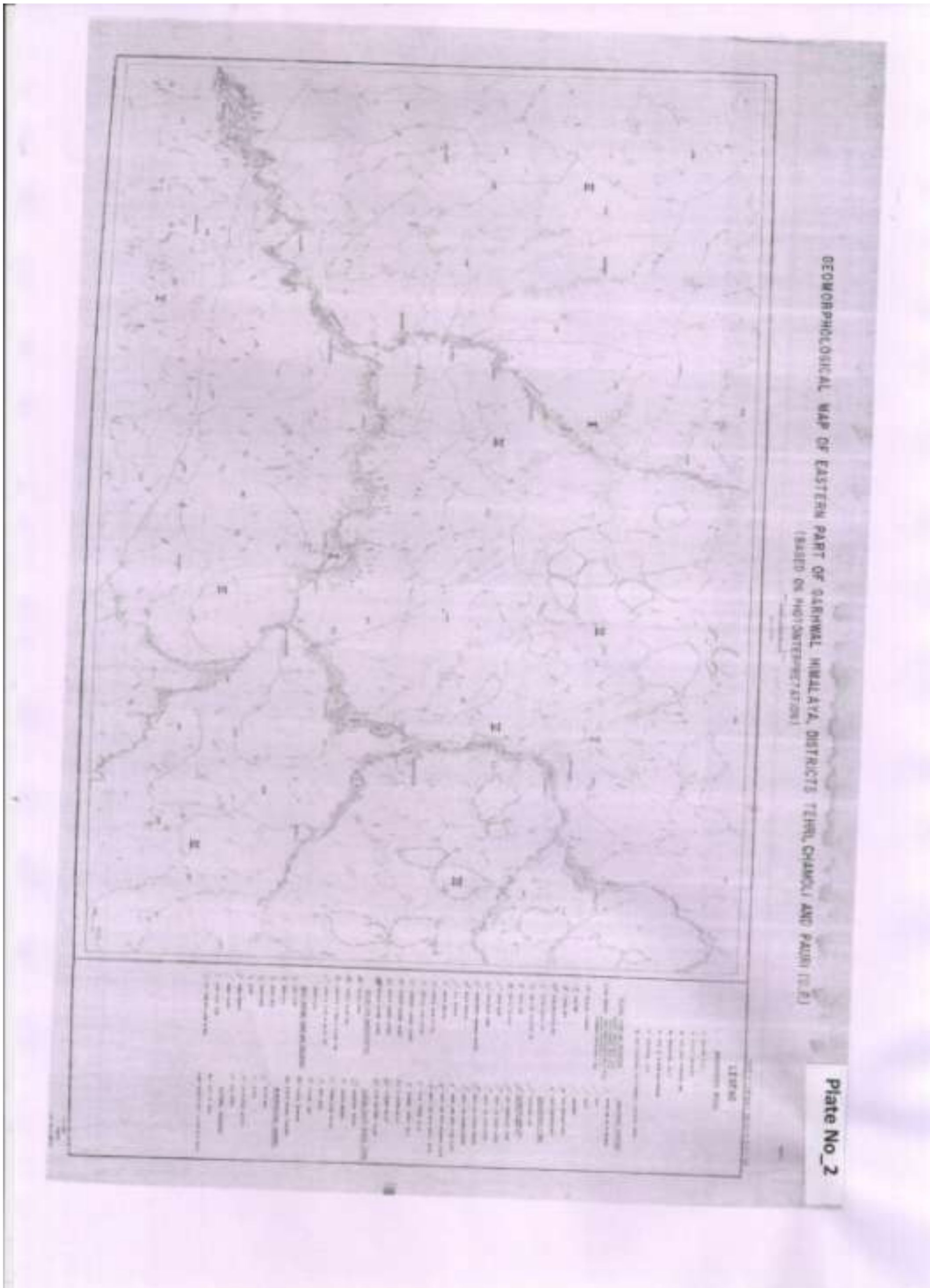
BT_5 :- **Gneiss, granite, schist, phyllite, slate and very coarse to very fine sand, silt and clay.**

** **The fabric elements of river terraces range in size from boulder to small pebble. The finer clastics comprise of very coarse to very fine sand, silt and clay. These rock fabrics are generally subrounded to well rounded and mostly spherical, oblate, prolate and bladed in shape. TABLE –**

Table No. 21:- Evolution Of Quaternary Terraces In Upper Ganga Basin, Garhwal Himalaya, U.P.

Age	Environments	Possible Cause	Phase of Aggradation / Degradation	Alaknanda	Bhagirathi	Bhilangna	Nandakini	Mandakini	Pindar	Dhauli Ganga
---------------- Holocene ----------------	---- Fluvial Environment ---	Tectonic / Climatic / Eustatic Changes	Aggradation / Degradation	AT_0	BT_0	BHT_0	NT_0	MT_0	PT_0	DHT_0
				Simultaneous processes of erosional / depositional in progress						
			Aggradation / Degradation	AT_1	BT_1	BHT_1	NT_1	MT_1	PT_1	DHT_1
				Riverine depositional processes in progress						
			Aggradation / Degradation	AT_2	BT_2	BHT_2	NT_2	MT_2	PT_2	DHT_2
				Riverine depositional processes in progress						
			Aggradation / Degradation	AT_3	BT_3	BHT_3	NT_3	MT_3	PT_3	DHT_3
				Riverine depositional processes in progress						
			Aggradation / Degradation	AT_4	BT_4	BHT_4	NT_4			
				Riverine depositional processes in progress						
			Aggradation / Degradation	AT_5	BT_5					
				Riverine depositional processes in progress						
			Aggradation / Degradation	AT_6						
				Riverine depositional processes in progress						


KEY MAP OF ALAKNANDA AND ITS TRIBUTARIES
GARHWAL HIMALAYA U.P.
Plate No_1


GEOMORPHOLOGICAL MAP OF EASTERN PART OF GARHWAL HIMALAYA, DISTRICTS TEHRI, CHAMOLI AND PAURI (U.P.)
(BASED ON PHOTOINTERPRETATION)
LEGEND
Plate No_2

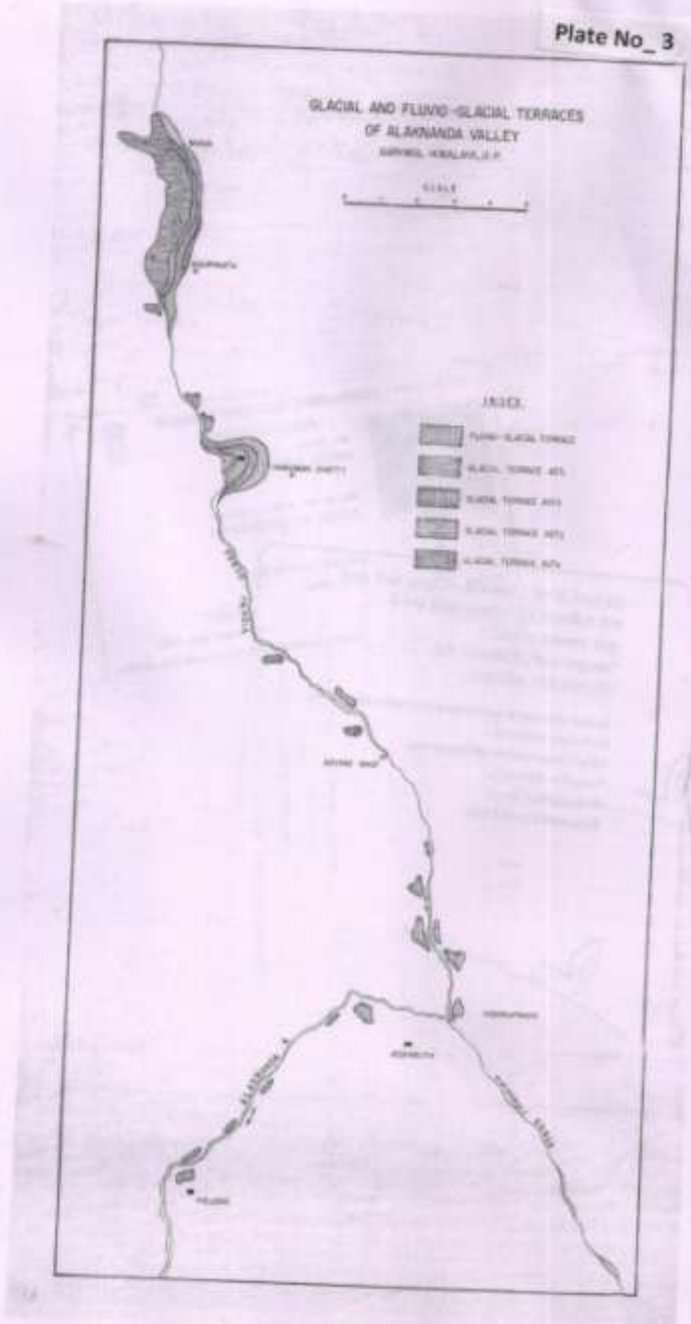
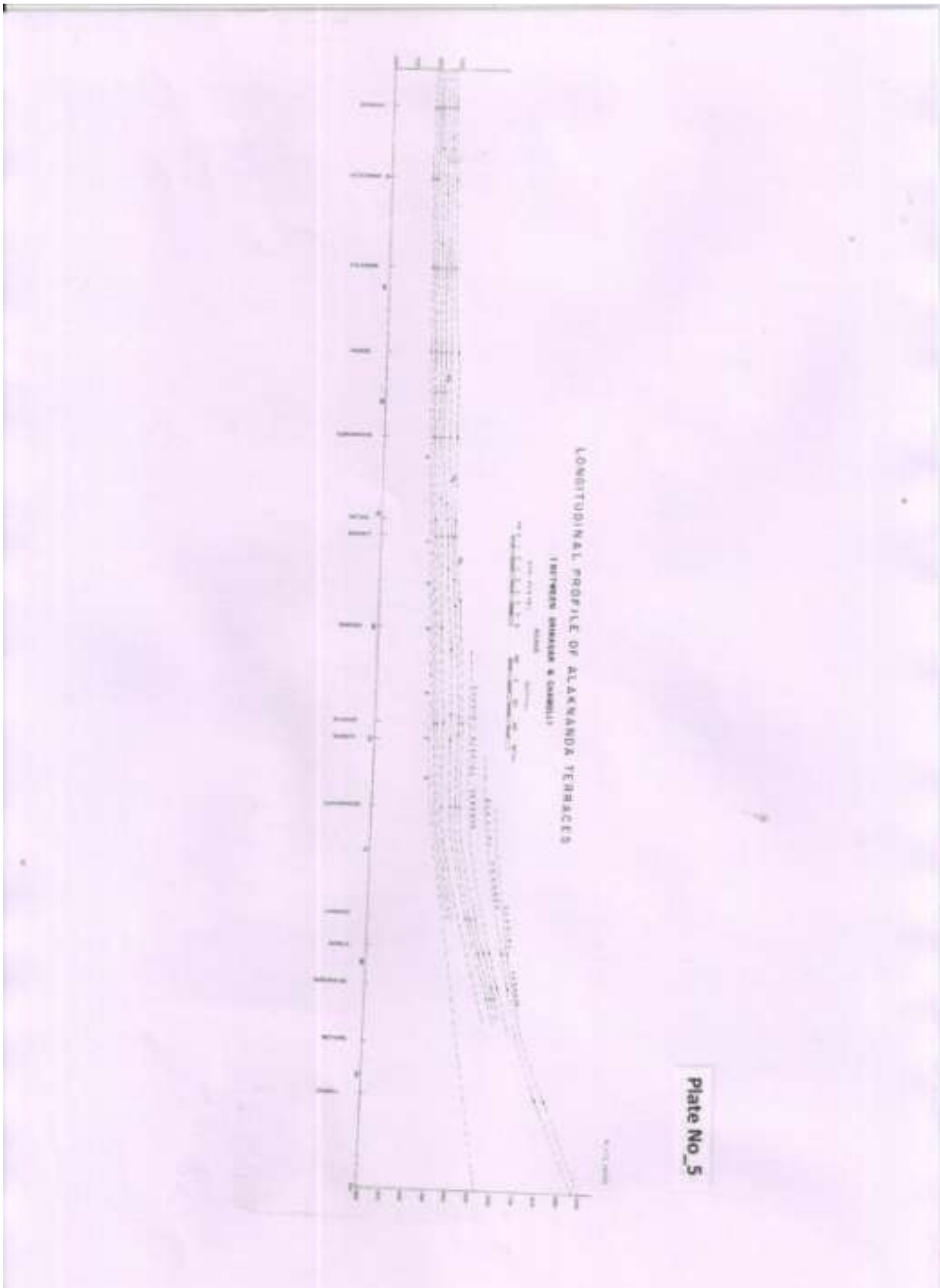
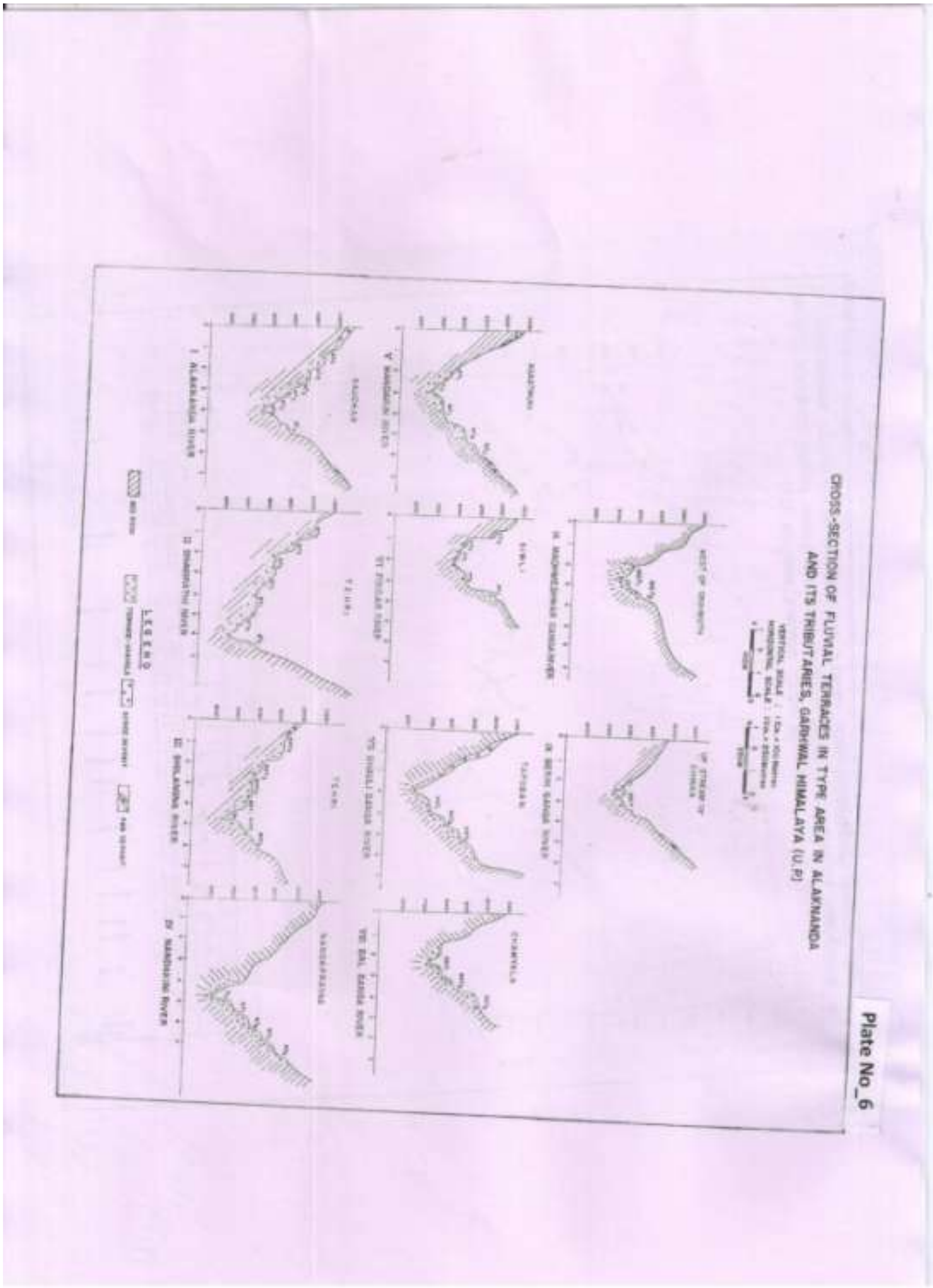


Plate No_ 3
GLACIAL AND FLUVIO-GLACIAL TERRACES
OF ALAKNANDA VALLEY
INDEX


Plate No_4
GLACIAL AND FLUVIO-GLACIAL TERRACES
OF BHAGIRATHI VALLEY


LONGITUDINAL PROFILE OF ALAKNANDA TERRACES
Plate No_5



References:-

1. Dubey, U.S. (1972) Progress Report on Geomorphological study of river terraces of Alaknanda , Bhagirathi, and Ganga valley, Garhwal Himalaya U.P.(Unpublished G.S.I Report 1972)

2.Dubey, U.S.(1974) Progress Report on Geomorphological studies of river terraces of Alaknanda and Bhagirath valley system Garhwal Himalaya U.P. .(Unpublished G.S.I Report 1972

3.Dubey, U.S (1974a) Report on Geomorphological and sedimentological studiesof the river terracs of Alaknanda , Bhagirathi,Ganga valley , Garhwal Himalaya U.P.(Unpublished G.S.I Report)
4.Padhi, R.N and Sharan, R.B (1972), A study of River Terraces of Alaknanda Valley Rec.Geol.surv India V 104pt 1 pp 39
5.Shukla , H.N Khan,A.A. and Dubey, U.S (1973) Report on Geomorphological studies of the River Terracs of , Bhagirathi and other Pleistocene landform .(Unpublished G.S.I Report).
6.Sinha,K.K.and Khan, A.A.(1976) A Report on Geomorphological studies of parts of Garhwal Himalaya , U.P. (basd on Photo Interpretation with selected field Checks) 11Geomorphology Course I.P.I.Dehra Dun).
7.Khan, A.A (1981) Geology and Geomorphology of Eastern part of Ganga Complex in parts of Tehri, Chamoli, and pauri District Uttar Pradesh . (Unpublished G.S.I Report FS 1976-77)
8..Khan, A.A.(1974) Report on Geomorphological studies of river terraces and other Pleistocene landform of Alaknanda and Pindar Valley . .(Unpublished G.S.I Report)
9.Khan , A.A.(1974)Report on Geomorphological studies of river terraces and other Pleistocene landform of Alaknanda and Pindar Valley . .(Unpublished G.S.I Report)
10.Khan, A.A and Balchandran, V (1974-75) Record Vol 109 of Geological Survey of India, Part I PP 59
11. Khan, A.A. (19 75) Report on Geomorphological studies of river terraces and other Pleistocene land forms in Alaknanda, Pindar and Attagad valley . (Unpublished G.S.I Report of FS 1973-74)
12. Khan , A.A (1981) Geology and Geomorphology of Eastern part of Ganga Complex in parts of Tehri,Chamoli, and pauri District Uttar Pradesh . (Unpublished G.S.I Report FS 1976-77)
13. Khan ,A.A and Dubey ,U.S (1981) Evaluation of Quaternary Landscape of intermontane Jamuna valley in Dheradun U.P;) and Sirmur (H. P). Rec.Geol.Surv.Indi; Vol112, pt 3 pp 125- 135.
14..Khan, A.A. and Nawani , P.C (1981.) Quaternary geological and geomorphological Evaluation of Eastern part of Ganga Complex, Garhwal Himalaya U.P India (Abstract) IV Regional Conference Geol. SE Asia Manila Philippines
15. Khan, A.A and Dubey, U.S (1985) An attempt to study the sedimentary structures and paleo current of Quaternary terraces of Alaknanda valley of Garhwal Himalaya U.P (Accepted for publication in GSI Record of 1985).
16. Khan.A.A (.1987) Geomorphic Evaluation and Quaternary Sedimentation in upper Ganga Basin Garhwal Himalaya (U.P.). Ph.D. Unpublished thesis submitted to Vikram University Ujjain M.P. India
17..Khan.A.A (.2018) Quaternary deposits of Narmada valley in relation to Geomorphology and Neotectonic of the area with special reference to Hominid occurrence D.sc. unpublished thesis submitted to Barkatullaha University Bhopal M.P. India.