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RESEARCH ARTICLE

GEOLOGY OF ALAKNANDA BHGIRATHI AND YAMUNA VALLEY, GARHWAL HIMALAYA, PARTS OF CHAMOLI TEHRI UTTAKASHI & PAURI DISTRICTS, UTTRAKHAND STATE, INDIA

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Abstract

The Alaknanda is the trunk stream of Ganga system it drains the eastern part of the area of study .The rocks of Alaknanda valley and adjoining area consist of three units viz Central Cryastalline , Garhwal Group and Dudatoli Groups which from north to south are separated by thrust or fault. The Central Crystalline Group in this area consist of /comprises of northerly dipping sequence of Kyanite schist,Garnet mica schist quartzites and para amphibolites of Tugnath formation and it is intruded by granite at Ragsi,the main Central Thrust seprates it from Garhwal Group.The Dudatoli Groupis represented Pauri Phyllite and Kirsu Quartzite which forms the northern limb of Dudatoil syncline .The north Almora Thrust makes it boundary with Garhwal group. The later is divisiable in to Rudraprayga ,Lamri , Chamoli and Gawangarh and Patrali Formation which occurs in normal stratigraphic order. It is intruded by biotite granite by biotite graninte at Nainidevi and Mohankal , with tourmaline granite around Chirpatikhal and also by basic intrusive . The Rudraprayg , Lameri and Chamoli formations are equivalent to Uttarkashi Shyalnan and Nagnithhank Formation respectively in Bhagirathi valley. The Garhwal Group of has been subjected to three phases of tectonic deformation. The south east to southerly plunging folds such as Marithanasa and Pingapani synclines .Karanprayg anticline were developed during the second phase of movements. The Alaknada fault which cuts off set of the formation and earlier structures between Sunala is the strike slip fault in western part, appears to be the youngest elements. Geologically , the Bhagirathi valley and adjoining areas comprises of four distinct units namely from north to south the Central Crystalline Group , the Deoban Group the Simla Group,and Krol belt rock separating from one another by thrust or faults. The main Central Thrust passing through Sainj in northern part brings the northerly dipping crystalline rocks in sharp contact with under lying Deoban Group (Garhwal Group) sedimentries which comprises a lower Deoban Formation of Phyllite, slate meta basics, minor quartzite and lime stone, the middle Deoban formation of lime stone and upper Deoban formation of Quartzite and basics. The southern contact of Deoban Group is faulted one with comprising

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mainly siltstone, greywacks and slates dipping south .This fault called Sringar Nalupani fault of fundamental nature. In the southern and eastern part of the area this fault marks the contact between Deoban and Chandpur formation. In the western part south heading Ton Thrust separates the underlying Chanpur formation from the underlying Simla slates which shows abundant development of slump balls rod etc. indicating syndepositional disturbances in the basin of sedimentation; while in Chanpur formation, is manly argillaceous, becoming arenaceous towards the top The Tons thrust passes through Laluli in Nagun Gad and is probably truncated by Tehri Nalupani fault at Chandpur in Bhagirathi valley. The full sequence of Krol rocks is exposed beautifully in Mussoorie syncline. The tectonic succession in Yamuna valley is Naogaon sheet comprising more metamorphosed rocks overly the Deoban group rocks separated from the latter by what is called the Naugaon thrust sheet which is folded in a North to Northwest plunging synform. The western limb of the folded thrust crosses Yamuna near the confluence with Kamola Gad and runs along the Kamola Gad. The rocks of the Naugaon sheet can be seen overlying the Deoban formation limestone along this section. The thrust hade towards east in this section. It follows a southerly trend till Tiyan when it takes an easterly swing, heading northward. It closes around Gair. The eastern limb of the synformal thrust sheet, heading westward crosses the Yamuna River at Kisna, Basic intrusive are seen along the thrust sheet near Kisna and around. The complexity of structural and tectonic set up in the area and lack of fossils make the task of correlation extremely difficult. However, on the basis of lithological similarities as well as structural disposition an attempt has been made to correlate the various litho units in the present area.

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Introduction:-

The Upper Ganga Basin consisting of Alaknanda is the trunk stream and Bhagirathi, Bhilangna, Nandakini. Mandakini Pindar, Dhauli Ganga, Bal Ganga, Madhmeshwar, Ganga and Berhi Ganga are the major tributaries. These streams originate from the ice clad peaks, deep in Himalaya and drain out cross the Central Himalayan and Lesser Himalayan ranges in parts of district Uttarkashi, Chamoli, Tehri and Pauri district of Uttar Pradesh presently known as Uttrarkhand state, these rivers and mingle with Alaknanda at various points. The Alaknanda ultimately joins Bhagirathi at Deovaprayag and down the stream known as Ganga which debouches into Gangetic plain across the Siwalik ranges south of Haridwar.

These streams traversing across the Himalayan ranges have formed the stepped sequence of Quaternary terraces in valleys breaking the monotony of hilly tract. These terraces were formed in response to the climeto-tectonic changes in the watershed region of Ganga and its tributaries in Quaternary time.

The study of evolution of these Quaternary terraces in upper Ganga system in Garhwal Himalaya, with particular emphasis on Quaternary sedimentation and allied studies have been attempted and published elsewhere

Area Of Study:

The study has been carried out along Ganga and its tributaries in parts of Uttarkashi, Chamoli, Pauri and Tehri district, between latitude 30°00'00" to 31°00'00" N and Longitude 77°45'" to 80°00'00"E covering an area about 11000 sq.km. in Survey of India top sheets No.53J/ 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16 and 53N/ 3, 4, 6, 7, 8, 10, 11 and 12 on 1:50000 scale in Garhwal Himalaya, U.P. (Plate No. 1 & 2).

Communication:

The Dehradun and Reshikesh are the nearest rail heads of Northern Railway. These heads are connected by good motor able road leading to famous pilgrimage centre Badrinath, Kedarnath, Gangotri and Jamuntori. The state high

way No.54 which is connects Reshikesh and Badrinath, bifercates at Rudraprayag along the Mandakini river and terminates at Kedarnath, Tehri is about 85 kilometers from Reshikesh on State Highway No. 53, connecting Reshikesh-Tehri, Uttarkashi Gangotri, This road runs along Bhagirathi river between Tehri and Gangotri. A bifercation from Tehri-Gangotri road at Dharasu connects Bhagirathi valley to Yamuna valley, crossing the water divide at Ravi pass. An all weather road running along Bhilangna river joines Tehri with Ghansali which bifurcates at Gadolia connects the Bhagirathi valley to Alaknanda valleys, crossing the water divide at Khandikhal. There are two fair weather roads one from Tilwara connects Mandakini valley to Bhagirathi valley and another at Okhimuth with Chamoli via Gopeshwar to Alaknanda valley.

In addition to these, there are fair weather roads which connect Kathgodam to Karanprayag via Ranikhet, Dwarhat and Adi-Badri from the east and Mussoorie via Dhanaulti to Tehri from the west, the Alaknanda and Bhagirathi and Yamuna valleys respectively.

Climate:
In the lesser Himalaya specially above 1300 meters altitude a temperate climate is with warm summer and severe winter prevails, while the lower altitude experience sub- temperate to sub-tropical climate with mild winter and hot summer. Mansoon usually sets in the end of June and rainy season last till the end of September. The rain fall is about 550 mm. from October to middle of March is the winter season with occasional and local showers. In the higher altitude over 1500 meters snow fall is experienced and during the winter months and still higher parts, specially the northern parts remained under snow covered over the longer part of the year. The whole of the stretch of U.P. Himalaya has been divided into seven climatic zones. The present area falls mainly in second third and fourth zone and partly in the fifth and sixth zone.

Physiography:
The area under discussion is drained by Alaknanda and its tributaries viz. Bhagirathi, Bhilangna, Nandakini, Mandakini, Pindar, Dhauli Ganga, Bal Ganga, Madhmeshwar Ganga, Behri Ganga and others. These tributaries join Alaknanda at various points the Bhagirathi joines Alaknanda at Deoprayag and downstream known as the Ganga.

The Alaknanda, the trunk stream of Ganga system formed by two streams viz. Vishnu-Ganga and Dhauli-Ganga at Vishnuprayag at an elevation of 3000 mts. These two streams rise from ice clad peaks in Central Himalaya north of Badrinath and Taboban respectively.

The Alaknanda down the stream of Vishnuprayag decends down in sinuous to meandering pattern through the deep gorges and tight meander and have formed various geomorphic features like terraces, epigenetic gorges, rock cut benches all along its length of its course between Joshimuth and Deeprayag.

The Alaknanda is Antecedent River which has maintained its course inspite of rise of Himalaya. It evident by its traverse across the rugged topography which shows inverted relief, influenced by lithology and structures resulting over the configuration of ridges and series of synclinal ridges and faulted anticline valleys, curving out its course along the faulted anticline and syncline; forming stepped sequence of rock terraces in the deep gorges. The Alaknanda in the upper reaches upstream of Joshimuth show north-south course up to Chamoli northeast-southwestcourse between Chamoli and Karanprayag. In Karanprayag and Rudraprayag section it has conspicuous east-west course, which appears to have been controlled by East-West trending Alaknanda Fault. Downstream of Rudraprayag it overall descends down in north east-south west direction up to Devprayag, where it joined by Bhagirathi. The Bhagirathi originates from Gangotri glacier at Gaumukh. It flows west North West form its source to Purali, where it takes a sharp southerly swing the westerly trend of the river is possibly because of its being subsequent to East- West trending fault. The swing to the south also appears to be controlled by the N-S trending joints, noticed in the Central crystalline.

Between Sainj and Uttarkashi i.e. in the area of Garhwal group of rocks it appears to be subsequent to the axis of anticline fold or minor faults. Further down stream of Uttarkashi it resumes its original westerly trend along the Uttarkashi fault.

The upper Bhagirathi valley, the river is fed by numerous streams, such as the Jadh-Ganga, Jalandra gad and the Siam gad. These streams appear to be subsequent to the joints in granite. The drainage pattern in the "Central crystalline" country is rectangular. In the rocks of Garhwal group the tributary streams are mainly transversal e.g.

Kaldi gad, but the Bara gadi gad is also subsequent to the Uttarkashi fault. The Bhagirathi valley is characteristically glaciated valley and is typically U-in shaped in Sukhi and Gomukh section.A rapid down cutting by the river has formed a deep narrow gorge about 150 m. deep in the base of this U-shaped valley, between Gangotri and the Jhala Bridge. Downstream of Jamgla, upto Jhala Bridge, the narrow gorge has been filled up by the sand and gravel due to siltation connected with the daming of the river at Sukhi by landslide. In this glacial valley, moraines are seen upstream of Jamgla to beyond Gaumukh. Further downstream at Sukhi, the true profile of the valley is concealed due to recent land slide, but afterwards the U-shaped valley could be seen at about 200 m. above the present river level.

The deeply incise valley continues down to Malla where on approaching the major tectonic plane the 'Main Central Thrust' it gradually widen out, giving rise to river terraces at Sainj, crossing over the Main Central Thrust the valley again narrows down a little up to Maneri, where it is comparatively wide, due to a fault. Further, downstream, the valley widen out resulting in deposition of a number of terraces at different levels. The whole of drainage system of Alaknanda consist of primary, secondary and tertiary streams, which are obsequent, subsequent resequent and insequent in nature. The density of stream is moderate to high and is not uniform all over the area.

Presently the area is in its sub-mature to mature stage but not true mature. The original consequent drainage has largely been replaced into subsequent stream forming deep longitudinal canyons and gorges. The area shows evidences of having undergone more than one geomorphological cycle and has been subjected to intermittent cyclic uplift in recent past.

Previous Work:

Auden (1937) studied the snout of Gangotri Glacier and related aspects of glacial morphology. Bose (1966) examined the Fluvio-glacial geomorphology and occupancy of glacial in Alaknanda valley; Tiwari (1963 and 1969) studied the various aspects of Gangotri and Pindari glacier and their morphology; Kumar 1964, 1966,1967, Dutta 1964, 1966 Mehdi 1972 Agarwal 1974 studied various aspects of geologyof the area. Kaushik et.al. (1972) studied Regional geomorphology of upper Alaknanda and Bhagirathi valley; Kaushik et.al. (1972) examined the various aspects of Geomorphology related with traverse gorges of Alaknanda and put forward different hypothesis for the formation of these gorges; Kaushik (1972) grouped the various glacier in Garhwal Himalaya and described various erosional and depositional features of glacial origin. Saran R.B. (1970-71) carried out traverse mapping of river terraces of Alaknanda and Bhagirathi and studied their various aspects. Dubey U.S. carried out sampling and sediment logical studies in addition to mapping of terraces in parts of Ganga, Alaknanda and Bhagirathi valley with the aim to understand environment of sedimentation, load characteristics, current capacity and other sedimentological parameters of the basin.

Shukla H.N. and Khan A.A. (1973) and Dubey U.S. (1974) continued the work in parts of Alaknanda, Bhagirathi, Bhilangna and their major tributaries and differentiated the terraces of three distinct domains, viz, Glacial, Fluvio-glacial and Fluvial. In Fluvial system of Bhagirathi Bhilangna, they recognized five and four terraces, respectively and correlated them with the younger terraces of Alaknanda.

Khan A.A. (1975) carried out mapping in the Pindar valley and identified three prominent regional terraces, which were correlated with the three younger terraces of Alaknanda and its tributary. Besides, some sedimentological studies were also attempted.

Balachandran, V, and Khan, A.A. (1974-75) studied the various aspects of Quaternary geology and geomorphology in the eastern part of Doon valley in Ganga basin and recognized six terraces in the Ganga river.

Sinha K.K. and Khan A.A. (1975) carried out detailed photo-geomorphological studies from I.P.I. Dheradun in the upper reaches of Garhwal Himalaya in parts of Uttarkashi, Tehri, Chamoli and Pauri districts Uttar Pradesh and recognized several geomorphic units. They also recognized three fluvial surfaces in Bal-Ganga and correlated them with the three younger terraces of Alaknanda and its tributaries.

Scope Of The Present Work:

The author has been associated with the area to study Geological and Geomorphological aspect of Upper Ganga Basin in Garhwal Himalaya, U. P. from 1972 to 1981 as a part of his official assignment, under Geological Survey of India, Research Programme. The close and continuous association of author, with the project had provided an

opportunity to examine the vast area over 11000 sq.km. especially in the remote and inaccessible part of Garhwal Himalaya, along the major valleys across the snow line in watershed of Ganga and its tributaries. It enable author to study, classify and correlate Geology, of most rugged and in accessible area entire Upper Ganga Basin, in Garhwal Himalaya. In addition, it also provided the close look to study the various aspects of Geology, glacial geomorphology, fluvial geomorphology, denudational geomorphology, structural geomorphology, Neotectonism, and Quaternary Sedimentation of Alaknanda and its tributaries.

The present area of research comprises two major tributaries of Ganga viz. Alaknanda and Bhagirathi, the former drains eastern part of Ganga Basin alongwith its tributaries in parts of Chamoli and Pauri, whereas the later (Western part) in parts of Tehri and Uttarkashi district of Garhwal Himalaya. These eastern and western parts of Ganga Basin constitute the parts of Lesser and Central Himalaya which have undergone to series of structural deformation in their geological history. Inspite of serious efforts of Geo-scientist since beginning of 18th Centuary, the larger part of area is still unexplored, due to rugged topography, extreme climatic conditions and inaccessibility. The litho-stratigraphy and structure has been described below in three different parts viz. Geology of Alaknanda valley, Geology of Bhagirathi valley, and Geology of Yamuna valley for description purposes keeping in view of the complexity of Geology, structure and correlation difficulties.

Geology Of Alaknanda Valley:

Previous work:

Herbert (1842) was the first to examine and prepare a sketch geological map of the area in connection with the mineral survey of the region. Middle miss (1887) classified the rocks of the Dudatoli region into the Schistose 'Series' and the Granite-gneiss. Auden (1939) (Plate No.4) and Gansser (1939) independently gave an account of the geology of the pilgrimage route to Badrinath via Almora, Auden (1949) grouped the rocks lying north of the Schistose 'Series' (which he had previously designated as the Barhat 'Series' in 1939), occurring in the tectonic 'Chamoli Window' the northern and southern tectonic contacts were named the Main Central 'Thrust' and North Almora 'Thrust' (Heim and Gansser, 1939) passing at hilang and Diwalikhal respectively. Auden (1953) extended the North Almora 'Thrust' upto Tilkha- nikhal and considered the Garhwal 'Series' to be equivalent to the Nagthat-Blaini-Krol-Tal succession of the Krol unit, and the andesitic flows to be contemporaneous with the Panjal Trap. Nautiyal (1953) took a traverse along the Pindar river and mapped the rocks of the Garhwal 'Series' between Karnaprayag and Narayan Bagar.

In recent past Kedar Narain (1958 and 1961), Blade, et.al. (1962), Kumar (1964, 1966, 1967, 1972a, 1972b and 1972c), Dutta (1964 and 1966) carried out investigations in connection with the copper and lead deposits of the area. Dutta and Ghose (1971) described the controls of sulphide mineralization around Dhanpur while Kumar (1971) gave an account of the various sulphide mineral occurrences in the Pokhri area. He suggested a tectonic succession which is given in Table 1.

Table I:- Tectonic Succession In The Pokhri Area (After Kumar 1971).

Central Crystalline
North dipping Main Central Thrust
Garhwal Group (Calcareous formation Quartzitic formation)
South dipping North Almora Thrust
Almora-Dudatoli Crystalline

Mehdi, et.al. (1972) referred these quartzitic and calcareous formations as the Chamoli and Gwanagarh Formations respectively and worked out the lithostratigraphy of the Garhwal Group (Table 2) in the Dobri-Lameri-Chamoli Section.

Table 2:- Lithostratigraphy Of The Chamoli And Gwanagarh Formations (After Mehdi, et.al. 1972).

Gwanagarh Formation
Chamoli Formation
Lameri and Pipalkoti Formation
Rudraprayag Formation

Mehdi, et.al. (1972) grouped the rocks occurring south of the North Almora Thrust into the Dudatoli Group (Schistose series of Middlemiss) which was later divided into the Pauri phyllite, Maithana Quartzite and the Dudat oli Formation by Kumar, et.al. (1974) representing the Chandpur and Nagthat- facies. Agarwal (1974) recorded bryozoan fossils from the Lameri Formation ranging in age from ordovician to Silurian. Prakash (1974) also recorded the presence of acritarchs from this formation. Jain (1972b) carried out heavy mineral studies of quartzites of the Garhwal Group.

Stratigraphy :
The stratigraphy of the Srinagar-Nandprayag area is given in Table 3. The ages assigned to various groups are based on the work of Mehdi, et.al. (1972) and Agarwal (1974).

Table 3:- Stratigraphy Of The Srinagar-Nandprayag Area Alaknanda Valley.

Age	Inner Lesser Himalaya	Southern Central Himalaya
Silurian to Precambrian	Garhwal Group	
Precambrian	Dudatoli Group (Kumaun Supergroup)	
Archean		Central Crystalline

The details of the Lithostratigraphy of the Central Crystalline in the Alaknanda Valley are given in Table 4. The Pandukeshwar Formation which is not exposed in the present area has not been dealt here.

Table 4:- Lithostratigraphy Of The Central Crystalline In The Alaknanda Valley.

Formation	Member	Lithology
Pandukeshwar		Banded psamite-gneiss, garnet- mica schist, para-amphibolite, ortho-augen gneiss, calc-sillicate.
Tungnath	Chandersila Schist	Hetrogenous sequence of biotite schist, garnet-mica schist, gneiss. Para-amphibolite
	Bhimgora Quartzite	Fine granined, white, sericite Quartzite.
	Ragsi Schist and Gneiss	Kyanite-paragonite-and Kyanite- paragonite-muscovite schist, gneiss intruded by tourmaline granite.

The Tungnath Formation is extensively developed around the Shrine of that name. The sequence represents kyanite-almandine-muscovite sub-facies, almandine-amphibolite metamorphic facies of the Barrovian type. The Ragsi Schist and Gneiss forms the base of the sequence. It is profusely intruded by the tourmaline granite and quartz vein around Ragsi. A quartz vein containing kyanite is noticed traversing the granite at about 2.8 km. north of Kalsir. The kyanite- paragonite schist is green,whereas the kyanite-paragonite- muscovite schist, well exposed at about 1.5 km. NNE of Kalsir in the Nagol Gad, is a crumbling silvery white rock with lenticles of quartz. The granite is medium to coarse granied, locally porphyritic. The phenocrysts are mostly of feldspar.

The Bhimgora quartzite occurs as a conspicuous horizon overlying the Ragsi Schist and Gneiss. It is conformably overlain by a band of para-amphibolite of the Chandersila Schist. This is fine grained white sericite quartzite which

physically resembles the fine-grained quartzite of the Garhwal Group but has lost all its sedimentary characters due to re- crystallisation.

The Chandersila Schist consists of heterogeneous sequence of biotite schist, garnet mica Schist, and gneiss and para amphibolites. The para-amphibolite constitutes a persistent band and is made up of pale-green to bluish-green hornblende and quartz plagioclase and biotite occur in subordinate amount.

The other minerals associated as accessories are ilmenite and leucoxene.

Dudatoli Group (Kumaun Supergroup)
It is represented in the area by the Pauri Phyllite and the Khirsu Quartzite members of the Maithana Formation in the Dudatoli group (Kumar et.al. 1974). The formation forms the northern limb of the Dudatoli Synciline. The details of lit host ratigraphy are given in Table 5.

Table 5:- Lithostratigraphy Of The Dudatoli Group, Alaknanda Valley.

Formation	Member	Lithology
Maithana Quartzite	Khirsu Quartzite	White, flaggy to schistose quartzite with partings of phyllite occassionally bearing garnet towards top.
Pauri Phyllite	Pauri Phyllite	Grey, chloritic schistose phyllite with lenses of marble and biotite Schist.
	Bhainswara Quartzite	White, flaggy quartzite and associated phyllite and basaltic flow.

The Pauri phyllite consist of two members viz. (1) Bhainswara quartzite which is composed of white flaggy quartzite phyllites and basaltic flows and (ii) Pauri phyllites, which mostly composed of chloritic phyllite and marble lenses. These two units are represented by persistent horizon in the area and are overlian by Khirsu quartzite it appears to be the eastern continuation of the phyllite mapped around Pauri (Kumar et.al. 1974), pinches out south of Kirsal. Sills of basic intrusives (epidiorite) are also seen in this phyllite west of Bhainswara.

The Khirsu Quartzite is made up of fine mosaic of interlocking quartz with shreds of sericite and chlorite marking the schistosity parallel to bedding. The rounded to subrounded zircon and greenish tourmaline, and sphene are the heavy minerals concentrated along bedding planes.

Garhwal Group :
This group has attained the maximum development in this area and shows considerable variation both laterally and vertically. It is broadly divisible into five formations (Table 6).

Table 6:- Lithost Ratigraphy Of The Garhwal Group In The Alaknanda Valley.

Formation	Member	Lithology
Patroli	Patroli Quartzite	Quartzite, fine-grained, massive, sericitic, white to greenish, occassionally banded with interbeds of chlorite phyllite and biotite schist.
Gwanagarh	Dobri Dolomite	Dolomite, light grey, massive with lenticular black chert, and is stromatolitic.
	Dobri Quart zite	Phyllite/slate, black to dark grey, laterally grading to crumbling purple phyllite
	Bhishna Quartzite	Quartzite, fine-grained, white sericitic with intraformational conglomerate

		Dhanpur Dolomite	Dolomite, light grey, massive, stromatolitic with intraformational lime-breccia at base, white and black bleached slate/phyllite, chert and interbedded limestone and phyllite.
Chamoli	Bhekuna	Basic metavolcanic (spilitic), dark-green biotite-hornblende schist, hornblende-actinolite-chlorite schist, actinolite schist, veins of epidote and tourmaline quartzite	
		Nagnath Quartzite	Interbedded quartzite and phyllite, Quartzite fine-grained, white, occasionally greenish, thick bedded, occasionally banded. Marble and calc-silicate bands in upper part.
		Karnaprayag Metavolcanic	Basic metavolcanic (spilite) and Keratophyre, massive to schistose, amygdaloidal, occasionally prophy- ritic consisting of dull green chlorite schist, actinolite-biotite- albite schist with veins of epidote, Intertrappean purple phyllite.
		Haryali Quartzite	Quartzite, thick bedded, massive coarse gritty to fine-grained with occasional pebble bed, white to purble, current and graded bedded, ripple-marked with thin partings of chocolate micaceous phyllite clay stone. Lenticular dolomite/limestone bands in basal part.
		Dhari Metavolcanic	Dark green chlorite phyllite, Metavolcanic amygdaloidal with phyllite and quartzite bands.
Lameri	Lameri C	Dolomite, light grey, massive	
		Lameri B	Phyllite/slate, dark grey to black, Pyritous
		Lameri A	Dolomite, light grey, massive, stromatolitic at base
Rudraprayag		Kurjan phyllite	Chloritic phyllite, light grey to dark grey, carbonaceous at places
		Thalassu Schistose Grit	Schistose grit and quartzite, greyish white, sericitic with lenticular epidiorite and basic metavolcanic.
		Rudraprayag Quartzite	Quartzite, white to grey, fine- to medium-grained, current bedded and slates.

Rudraprayag formation:
Mehdi, et. al (1972) proposed this formation to include the quartzite and metavolcanics underlying the Lameri Formation. It is divide into three members the Rudraprayag Quartzite, Thalas su Schistose Grit and Kurja Phyllite.

Rudraprayag Quartzite:
This member includes the interbedded sequence of quartzite and slate exposed in the southern limb of the Rudraprayag Anticline on the left bank of the Alaknanda river near Rudraprayag. The quartzite is white fine to medium grained and depicts current bedding.

Thalassu Schistose Grit:
It is best developed between Thalassu and Deolak on the Rudraprayag Mohankhal road section and includes white to greyish white schistose grit, quartzite, epidorite and basic metavolcanic patches. Due to pinching away of the Kurjan Phyllite south of the Alaknanda Fault and absence of the Dhari Metavolcanics in the Gaucher area, it directly comes in contact with the Haryali Quartzite of the Chamoli Formation.

Kurjan Phyllite :
The chlorite phyllite is best developed between Kurjan and Kuinthi. It is intruded by granite mylonite and it abuts against the Alaknanda Fault. The amphibolite is essentially made up of green hornblende, quartz and garnet, and

subordinate epidote, sphene, iron-ore, and plagioclase appear to be a product of contact metamorphism of richly chloritic and Calcareous sediments.

Lameri Formation:
Conformably overlying the Rudraprayag Quartzite is a sequence of dolomite-limestone and slate/phyllite which has been referred to as the Lameri Formation by Mehdi, et al. (1972). It is limited to the eastern closure part of the Rudraprayag Anticline and is cut-off westward near Funar by the Punar Fault. The dolomite shows development of stromatolite (Colenia sp.), along the road section about 2.5 km. upstream of Rudraprayag. The disposition of the stromatolite indicates top up position of the beds.

Agarwal (1974) recorded the bryozoan fossils from the slate/phyllite horizon ranging in age from ordovician to Silurian. Prakash (1974) also recorded acritarchs from the dolomite.

Chamoli Formation:
Mehdi, et al (1972), considering the Pipalkoti Formation to be equivalent to the Lameri Formation, proposed the name Chamoli Formation to include all quartzites overlying the latter. It is revealed that the quartzite overlying the Lameri Formation occurs in two horizons separated by the calcareous Gwanagarh Formation. The one which underlies the latter has been referred to as the Chamoli Formation, and the other appearing to be the youngest, overlies the calcareous Gwanagarh Formation, as the Patroli Formation.

The Chamoli Formation is extensively developed and occupies large areas of the Chamoli district after which the formation has been named. It is characterized by quartzite and a number of pen- contemporaneous submarine basic flows of spilitic composition and profuse intrusions of dolerites, now metamorphosed to epidioritę.

Dhari Metavolcanic :
It is probably the oldest basic flow within the Chamoli Formation, and is generally exposed in the anticlinal cores such as between Dhari and Kotli, near Rigoli etc. The formation is characterised by basic flows and associated slates with minor quartzite lenses. The basic flows are generally drab-green, vesicular and amygdaloidal. The amygdules are generally of quartz, felspars and chlorite. The rock is invariably altered to chlorite phyllite.

Haryali Quartzite:
It is the most extensively developed member of the Chamoli Formation and is best exposed around the prominent Karyali peak after which it has been named. It is characterized by white to purple or maroon coloured quartzite which is thick bedded fine to coarse-grained, and gritty with occasional lenticular pebble beds. Associated with quartzite is thin chocolate colored micaceous phyllite and clay stone in the southern part i.e. near the North Almora Thrust.

Karnprayag Metavolcanic:
This is the second major basic flow of spilitic composition occuring within the Haryali Quartzite. It is best developed just east of Karnprayag after which it has been named. In the northern limb of the Karnprayag Anticline, it is off-set by the Alaknanda Fault towards east and continues beyond Pogta in the north-west. In the southern limb of this anticline, it pinches out east of Toryal. Further westwards it assumes a pinch and swell nature and is ultimately cut-off by the Kaliya saur Fault. It reappears at Dungri Panth and continues beyond Machhni. Although predominently schistose in character, it is massive at places, for example east of Chhatoli and becomes indistinguishable from the other massive variety (epidiorite). It is also amygdaloidal and porphyritic in the vicinity of Sidoli, Mathar etc. Purple phyllite is also seen associated with it between Mathar and Katloari, south of Sidoli. Keratophyre is seen east of Adbadri, and at the crest of the Karnprayag Anticline, south of Chhatapipal. The metavolcanics have been subjected to varying amount of alteration and weathering as a result of which, at places, dull green chlorite schists are produced and elsewhere actinolite-biotite-albite schists are formed.

Nagnath Quartzite:
It is the youngest member of the Chamoli Formation. The phyllite partings in it assume greater prominence and the quartzite is generally fine-grained, white, at places greenish, sericitic thick-bedded (individual beds upto 1.5 m. thick) and speakled with minute grains of tourmaline and zircon. At about 2 km NNE of Alikande, at a place locally known as bhukunda, micaceous hematite and magnetite occur in association with chlorite-phyllite within this quartzite. The main phyllite band is exposed around Kaleshwar in the Alaknanda valley upstream of Karnprayag and

continues to Simili in the Pindar river where it is interbedded with quart- zite. This phyllite is grey to dark grey, at places, brown coated, and slaty. The other prominent band is seen at Deothan which pinches out east of Alikande in the east and assumes greater dimensions westward where it is intruded by granite. The phyllite is choritic to carbonaceous, at places graphitic, grey to dark grey, black and coated with white encrustations of iron aluminium sulphate.

In the upper part of the Nagnath Quartzite appear bands of marble, dolomite and calc-silicate at two levels. The lower dolomite occurs as a linear band, 3 km long and 200 m wide, overlying the Deot han phyllite. It is overlain by granite and sericite schist with a fault contact the Chamethi Fault.

Bhekuna Metavolcanics:
It is the third major basic flow associated with the Chamoli Formation. It is restricted to the southern limb of the Maithana Syncline and is well exposed around Bhekuna after which it has been named. It is predominantly vesicular and amygdaloidal, the amygdules being of various shapes and sizes measuring a few mm to 2 cm. in diametre and filled with felspar, biotite and epidote.

Gwanagarh Formation:
The Chamoli formation is conformably overlain by an argillo-calcareous sequence referred to as Gwanagarh Formation by Mehdi, et.al. (1972). Due to the North Almora Thrust the formation pinches out on either sides and reappears between 500 m east of Sarkuta and 1.5 km. SSW of khankra. It is due to folding that the formation is repeated in the Pindar river valley at Bhagoli and appears between Langasu and Bungra in the Alaknanda river section. In its northwestern continuation it appears to be concealed due to the Kande Fault excepting east of Salna and one km northeast of Dungri where it appears as a lensoid body. In these sections the formation has attained lesser development and is represented by marble, tremolite marble, calcsilicates, and is intruded by a granite. Lenses of magnesite are invariably associated with it.

Patroli Formation:
It is the youngest formation of the Garhwal group exposed in either limb of the Maithana Syncline. It mainly consists of quartzite which is fine-grained, white to greenish and thickly bedded. In Nagol Gad, between Raisu and Kande, it is banded due to the presence of dark bands rich in euhedral magnetite and rounded to subrounded zircon. At about 0.5 km. south-south-east of Deokhal rounded to subrounded pebbles of green quarzite measuring 2.4 cm. in diameter are present within this quarzite. Near Tirsula, at a place locally known as Bamnath, micaceous hematite occurs as impersistent bands. The current-bedding though not so pronounced as in the Haryali Quartzite, indicates its normal top up position. Depending on the percentage of sericite or chlorite the quartzite is hard and compact at one place to schistose at other.

The Patroli Quartzite encloses bed of chlorite
Phyllite extending northwestward from east of 7156 peak to north of Kalsir where it is cut off by the Main Central Thrust. South of Nandprayag, a bed of biotite chlorite schist is interbedded with the quartzite. It contains por- phy roblasts of felspars in a fine matrix of quartz, biotite and chlorite. The felspars are all sericitised. (Plate No.5).

Intrusives :
The Garhwal group is intruded by the granite and dolerite (metamorphosed to epidiorite). Extreme mylonitisation of granite has given rise to sericite-quartz schist in certain area.

Granites:
There are two types of granite rocks; (a) biotite- granite-gneiss and (b) tourmaline granite. The former extends from north of Gauchar to beyond Nainidevi in the northwest, and has intrusive relationship with the Kurjan Phyllite, where the latter crops out south of Langasu, intruding the Gwanagarh Formation.

The biotite granite-gneiss, now considerably mylonitised and recrystallised, is fine-grained along its argin but acquires a coarse-grained nature towards the centre of the gneissic body, and bears large porphyroblasts that exhibit strain textures, and consists of perthite, plagioclase and quartz in the order of abundance. Other minerals present, include muscovite and brown biotite with subordinate amount of green biotite.

The tourmaline granite is medium-grained and is mainly made up of hypidiomorphic granular aggregate of felspar (microcline and plagioclase) and quartz with subordinate greenish biotite. The plagioclase has a distinct sieve structure developed through its lateration to minute grains of epidote and shreds of sericite.

The intrusive granites occur in the north-western part of the area between Chirpatyakhal and 2 km. west of Tilwara in the belaun Gad. These are mainly tourmaline- biotite granite, but siliceous granite near Budna and Chirpatyakhal and some augen gneiss near Mamni and Gorthi have also been noticed. In an area between Palakurali and Dhankurali, besides the above varieties, a very coarse- grained, non-foliated, generally porphyritic granite, rich in biotite is also present, indicating thereby multiple phases of granitic instrusions. The granite is profusely traversed by epidiorites.

Epidiorite:
Profuse instrusions of dolerite (= diabase) in the form of sills and dykes are observed in various formations of the Garhwal group, particularly the Chamoli and older formations, and the granite. The dolerite was subsequently metamorphosed during regional metamorphism and has been termed variously as epidiorite, metadolerite or amphibolite by different workers. Unaltered dolerite is mainly confined to the western part of the area. The epidiorite is generally greenish grey, mottled with grey felspar, fine-to-medium. grained, massive weakly-foliated particularly along the margins, and shows spheroidal weathering. It is essentially made up of subophitic to ophitic, pleochroic green hornblende and felspars with abundant leucoxene and ilmenite.

Structure:
As in other areas of the inner Lesser Himalaya of Uttar Pradesh, the three stratigraphic groups-the Kumaun Super group, Garhwal Group and the Central Crystallinę, constitute three separate tectonic units (Plate No.6). The North Almora Thrust and the Main Central Thrust respectively mark the southern and the northern boundaries of the Garhwal Group.

North Almora 'Thrust'
It separates the Pauri Phyllite and the Khirsu Quartzite of the Kumaun Supergroup from the Garhwal Group. The fault trending WWW-BSE and dipping at 45-60° southwards has been variously referred to as the Shrinagar Thrust (Mehta, 1971) and Shrinagar Shear (Bhargava, 1972). Mehdi, et al, (1972) traced it to join with the North Almora Thrust (Heim and Gansser, 1939) and the Saryu Thrust (Valdiya, 1962) in the east. Agarwal and Kumar (1973) traced this fault to the Bhagirathi and Yamuna Valleys where it had been referred to as the Major Tectonic unit (Auden, 1939), Nalupani Fault (Dhoundiyal and Ali, 1967) and Dharasu Thrust (Jain, 1972a). Kumar, et al (1974) have also shown that this fault does not sear around the Dudatoli crystalline to join with the South Almora Thrust as postulated by Heim and Gansser (1939), Gansser (1964) and interpreted by Rupke (1974). The fault plane in the present area is characterized by a wide shear zone in which fragments of greenish quartzite, purple slate, quartz-mica- schist are noticeable. Some graphitic carbonaceous matter is also seen along the fault-plane SW of Randoli. Drag folds noticed in the Khirsu quartzite close to the fault, South of Mathar, Plunge 10-15° towards north- west, whereas those developed in the Chamoli Formation quarzite, north of kotesar plunge towards east at 70-80°. The structural elements of the folds at the fault contact, exposed in the Alaknanda river section west of Kotesar, suggest a movement in $80° W-N80°E direction along almost vertical plane.

Main Central 'Thrust'
This northerly dipping (60-70°) fault plane brings the almandine-amphibolite facies Ragsi Schist and gneiss of the Central crystalline to rest over the low grade (green schist facies) patroli Formation of the Garhwal Group. Due to this fault, the closure part of the Maithana Syncline is cut-off north of Kalsir.

Structure of Garhwal Group:
The structure of these rocks in this part of the Lesser Himalaya is the most Complicated due to the effects of various tectonic episodes. There are atleast three phases of tectonic activity which clearly visible in the present day regional structural patterns. The second generation WB-SW trending broad, and open plunging folds and faults are superimposed on the earlier NW-SE doubly plunging folds and faults, such as the Maithana and Pingalapani Synclines Karnprayag Anticline. It is during the first movements that granitic intrusions took place. Towards the end of this period, a large number of NW-SE trending faults, such as Kande and Chamethi Faults, were developed resulting in the mylonitisation of granite giving rise to sericite quartz schist. It is probably during this period that the dolerite (epidiorite) were also emplaced. At this stage of work it is not clear whether the large number of cross folds

and faults, having second generation structural pattern in the western part of the area lying between the Alaknanda Fault and the North Almora 'Thrust' are the result of the forces acting along these major faults or the Alaknanda Fault is the youngest structural element off-setting all the earlier structures.(Plate No.2)

Geology Of Bhagirathi Valley

Previous work:

The stratigraphy and structure of the lesser Himalaya in Bhagirathi has been a subject of study since the mid-nineteenth Century. However, the problems of the stratigraphic and tectonic correlation are so complex as to defy any definite and conclusive answer. Some of the pioneer workers in the area include Meddlicott (1864- Mem. G.S.I. Vol. III), Oldham (1883-88), Medlemiss (1887-90) etc. Middlemiss classified the rock types as Siwaliks, outer formation and inner formation separated from each other by thrusts. (Rec.GSI Vol. XV). Griespack (1891) took traverses in Bhagirathi valley and divided the rocks of Harsil area into Vaikritas and Haimantas. Later, Auden (1935, 37 and 49) observed that Vaikritas were partly the metamorphic equivalents of epigrade Haimantas and the latter were lithologically iden- tical to Simla Slates and Chandpurs. he grouped the rocks between Tehri and Uttarkashi under Chandpurs, simla slates and Garhwal Series, each separated by a thrust (Plate No.4 & 8).

Srivastava and Pant (1963) mapped a small area around Maneri in connection with Maneri-Bhai Hydel Project.

Ali (1965, 67), Dhoundiyal and Ali (1967) mapped part of Bhagirathi valley and named the tectonic contact between the "Barahat Window Zone" and the overlying Simla Slate" in this valley as Nalupani fault. They agreed with Auden about possibility of existence of Tons thrust in Bhagirathi valley but concluded that "Tons thrust did not appear to be of any great magnitude here". They also agreed that Simla slates vary considerably laterally (Bhagirathi valley) and often resemble Chandpuri.

Chatterjee and Agarwal (1970) disproved the existence of Tons thrust in Bhagirathi valley on the basis of structural studies and tentatively ground the rock occurring to the southwest of North Almora thrust under Tehri formation. Later Kumar, Agarwal and Mukherjee (1971) described refolded folds from Uttarkashi-Bhatwari area.

Jain (1971) recognised the following structural and stratigraphic units in Dharasu-Uttarkashi area:-

Krol Thrust sheet	Nagthat formation	
	Chandpur formation	
	Laluri formation	
Dharasu Thrust sheet	Dharasu Formation	
Allocht hnous zone (Singuni Uttarkashi Thrust sheet)	Dichli Dolomite	
	Gamri Quartzite	Garhwal group
Parautochtho- nous zone (Dunda-Uttar- kashi window)	Dunda-Uttarkashi Formation	

Jain (1972) favoured Upper cretacean age for the basic rocks in the Uttarkashi region which, he thought, were tectonically controlled and emplaced.

Agarwal (1971-72) mapped a part of the area between Dharasu and Uttarkashi and has given the following tentative stratigraphic succession:

Garhwal Group	Nagni Tank Formation
	Sliyalna Formation
	Uttarkashi Formation
	Fault (North Almora Thrust)
	Tehri Formation (Chandpurs)

In the Yamuna valley Ranga Rao (1972) grouped the rocks to the NE of Tons Thrust into three structural units.

Tethys zone :- Lying unconformably over Haimantas Vaikrite Haimanta Zone with intruded granite of the Central Himalaya.

(Jankimai Chatti lim estone represents roof zone of

Deoban sheet)
---------- Main Central Thrust ----------
Chamoli window :- Garhwal series comprising quartite-shale sequence with minor limestone.
---------- Badiyar Thrust (dips south) Nawagaon Syncline :- ----------
---------- Exposes Deoban and Rama Sarai sheets Tons Thrust ----------

He considered Simla / Morar-Chakrata / Dharasu phyllites to be older than Deoban and with an unconformable contact.

Dhoundiyal and Ali (1967) took a few traverses in the Yamuna valley and their finding are almost same as that of Ranga Rao.

Agarwal and Srivastava (1973) mapped small part of the area around Barkot in Yamuna valley and have named the sequence below the Deoban as Chandpurs in place of Simla Slates.

Ganesan and Verma (1975) carried out tectonic correlation in parts of Yamuna and Bhagirathi valleys and have tentatively traced the Tons thrust upto Tehri in Bhagirathi valley. Plate No 4)

Present work:
The area under study comprises mainly sedimentary rocks ranging in age from Pre-Cambrian to Eocene. The rocks have suffered intense tectonic activity like folding, faulting and thrusting and metamorphism to variable degrees making the stratigraphic correlation of the various litho units extremely difficult specially because of general absence of fossils. The correlation of the different beds and their general order of superposition is, therefore, tentative and based mainly on previous works in the area as well as field observations. Some of the important traverses taken during the field check are -

i. Section across the Lesser Himalayan rocks between Gangani, and Barni Gad along Yamuna valley. Section along Barni Gad.
ii. Section along Dha rasu-Barkot road across the Srinagar Nalupani fault.
iii. Section between Sainj and Tehri along Bhagirathi Valley.
iv. Section along Bhaldina - Lambgaon (along Jalkur N.) -
v. Uttarkashi (along Indrawati Gad).
vi. Section between Tehri and Tharaelli along Bhilangna Valley.
vii. Section between Ghansali and Silyare along Balganga river and Ghansali and Paunli along Nail Chami Gad.
viii. Section along Godolia Gad and Takoli Gad across the Alaknanda - Bhilangna water divide.
ix. Section between Tehri and Devprayag via Lindolakhal.
x. Section between Devprayag and Srinagar along Alaknanda valley.
xi. Section along Tehri-Chamba-Narendranagar road and Hiyuni river.
xii. Section along Chamba-Dhananlti-Mussoorie road.
xiii. Section between Subakhol and Aglar N.
xiv. Section across Khurmola Gad between Junga and Mathali.
xv. Section along Gangani-Wazri-Hanuman Chatti in Yamuna valley.
xvi. Section along Sainj Gangnani- Harsil in Bhagirathi valley.

The above the last two traverses are of reconnoitory nature and outside the area of study. These traverses were taken to study the regional geology, specially the nature of the main central thrust and the crystalline rocks. In the Bhagirathi valley 3 distinct tectonic units are recognised.

Stratigraphy :
The lithostratigraphy and tectonic position of various rocks from north to south these are (1) Central Crystalline group (ii) Deoban (Garhwal) group and (iii) Chandpur and overlying sequence of Krol belt rocks. There is yet another tectonic unit the Simla group, though a little controversial mainly because its contacts with the overlying Chandpur are rather indistinct and its lithology, too, with respect to the latter, is confusing. The general tectonic and lithologic sequence in the Bhagirathi valley is as follows :-

Table 7:- Tectonic And Lithostratigraphy Of Bhagirathi Valley.

North Central Crystalline group		Amphibolite, migmatite, granite, granite geniss and biotite gneiss.
---------Main Central Thrust ---------		
Deoban group (Garhwal group)	Upper Deoban Formation	Metavolcanics, quartzite with intrusive basics, occasional limestone, metavolcanics with slate and quartzite bands.
	Middle Deoban Formation	Limestone and dolomite with minor quartzite.
	Lower Deoban Formation	Limestone, Quartzite with interbedded slate and occasional limestone grey, green, purple slates and phyllitic basic rocks.
------ Srinagar-Nalupani Fault ------		
Simla Group	Dharasu-Barkot Formation	Green, grey phyllite, slate, siltstone, quartzite, greywacke.
------ Tons Thrust ------		
Krol belt rocks	Subathu	Clive shale, quartzite,limestone.
	Tal Krol	Quartzite and limestone, Limestone with slaly hori- zons, sandstone at base.
	Infra Krol	Shales, laminated with lenses of limestone.
	Blaini	Pebble beds, shales, silt- stone, limestone.
	Nagthat	Quartzite, slate, phyllite, conglomerate with associated volcanics.
	Chandpur	Phyllites, slates, quartzite with associated minor limestone.

In the Yamuna valley, the following tectonic and lithologic sequence is seen :

Table-8:- Tectonic Succession In Yamuna Valley.

Naugaon Thrust Sheet rocks
------- Naugaon Thrust -------
Upper Deoban Formation
------- Unconformity -------
Deoban Group Middle Deoban Formation
------- Unconformity -------
Lower Deoban Formation
------- Fault -------
Simla Group ------- Slate, phyllite, greywacke, limestone minor quartzite.

Central Crystalline Group:
The Central crystallines, overlying the Deoban Group (Garhwal Group) rocks are the oldest formations in the area.

Their present position, above the sedimentaries of the "Inner Himalayas" is because of thrusting - the Main Central Thrust. The crystallines comprise amphibolite, migmatite, granite gneiss, biotite gneiss, mica-schist etc. At the thrust contact near Sainj in Bhagirathi valley and near Wazri in Yamuna valley, presence of sheared gneisses is noticed. The amphibolite also shows shearing in the vicinity of the thrust contact. In the Bhilangna valley, highly sheared and milonitised gneisses are encountered just a little south of Thayeli. The granitegneiss shows 'augen' structure at few

places. At places the gneisses are foliated, the foliation trending N450 to 65°W - $450 to 65°E with northeasterly dip.

Deoban group (Garhwal group) rocks:
This is a major tectonic unit occupying the Central part of the area. About 40% of the area is covered by rocks of this unit. It consists of three formations which have been named tentatively as Lower Deoban, Middle Deoban, and Upper Deoban.

Lower Deoban Formation:
This is an essentially arenaceous sequence of inter-bedded quartzite and slate with minor limestone and phyllitic basics which often show intricated folding (Photo No.91). The basal horizon is exposed in the Bhagirathi river and Indrawati Gad a tributary, meeting the former at Uttarkashi. The slate outcrop is narrow and is seen in impersistent patches viz. in northeast of Kotyalgaon in Indrawati Gad. The quartzite slate sequence is seen on the right bank of Bhagirathi mainly in the northern limb of WNW-BSE trending Maneri and Indrawati Gad anticlines. Lenticular patches of limestone occur within this formation as seen near Ganwan. The quartzite is fine to medium grained, often sericitic and ranges in colour from white to grey. Symmetric ripple marks with right side up are often exhibited by the quartzite as seen in section along Indrawati Gad. This quartzite is rather thinly bedded sometimes the individual bed is about 20 cm. to 1 metre thick. At places e.g. in ENE of Kotyalgaon. Shearing along planes oblique to bedding has developed sericitic material. The strike of this formation varies locally because of folding. Major joints are -

i. Strike NW-SE - dipping vertical.
ii. Strike NNE-SSW - dipping at 850 to WNW.
iii. Strike WNW-ESE - dipping at 55°SSE

Middle Deoban :
The quartzite slate sequence of Lower Deoban Formation is overlain conformably by a dolomitic limestone horizon which varies greatly in thickness and is impersistently exposed in the area. The limestone is seen along Rano Gad where it trends MW-SSE with gentle to moderate dips towards east. It is again seen in exposed in Shyalam Gad, north of Badethi and near Dunda (Photo No.90). It is exposed in the limbs of a syncline near Gangori and is also seen in the faulted south-western limb of Indrawati Gad, between Boga and Kiyangaon. In general the limestone is light to dark grey in colour and massive.

Upper Deoban Formation:
The most extensively developed and the characteristic of the Deoban (Garhwal) group rocks belong to this formation. It comprises quartzite and basic pen-contemporaneous flows alongwith later basic intrusives. The metavolcanics occurring mainly as sills have been altered to chlorite schist in most places. The chlorite schist shows intricate folding patterns, drag folds being beautifully exhibited in the road section a.little before Dunda. In Lambgaon-pratapnagar section also the chlorite schist show plunging folds with gentle easterly plunge. At places the metavolcanics have retained their amygdaloidal character as seen near Utron and Southwest of Bhalunia.

The Quartzites along with the basic intrusive is the best developed member of the Deoban (Garhwal) group. It can be differentiated from the Lower Deoban formation quartzites by its general coarseness of grain size, graded bedding and lack of slate interbedding. The quartzite is often gritty, becoming conglomerate at places. Near Nalupani pebble bed is noticed the pebbles being mainly of white quartzite and are well rounded. The gritty quartzites comprise of grits of white quartz. At places current bedding (both wedge and festoon shaped) have developed. The Nalupani quartzite show beautiful current bedding. Ripple marks are also exhibited as seen on the left bank of Bhagirathi near Adolak and near Sankuni Khal. These sedimentary structures like current bedding, ripple marks, graded bedding etc. show the right side up position, indicating their normal order of super position. Bedding is at times very difficult to identify because of intense jointing. However, sometimes, colour laminations or sedimentary structures indicate bedding. At times fracture cleavage, developed parallel to bedding, renders the rocks a platy appearance. The presence of pyrite crystals has been noticed in this quartzite. The chlorite schists, so commonly associated with the metavolcanics, however, occur as lenticular patches along some planes of weakness, within the quartzite. Thus for example a thin band of chloride schist, about 30 cm. in thickness is seen along a vertical joint in the quartzite in the road section near the suspension bridge over Bhagirathi at Athali.
Major joints in the quartzite are -

1: NW – SE - Vertical

ii:	NW – SE	-	- 45° to SW
iii:	WNW-ESE	-	Vertical
iv:	NNE-SSW	-	Steep dips either side
v:	ENE-WSW	-	70° to 30° to NNW

There are a few metavolcanics which occupy the core of syncline. These are at places amygdaloidal, for example in Dhanari Gad exposure.

Epidiorites are the youngest of the intrusive basics covering large patches as seen in Uttarkashi Lambgaon-Bhaldiana section. It is massive, medium to coarse grained, Occasionally weakly foliated rock. At places development of felspar porphyroblasts give the rock an appearance of diorite gneiss or porphyritic diorite. The epidiorite occurs as a sill forming the ridge top between Rano Gad and Shyalam Gad and also in the hill NW of Uttarkashi.

Simla Group:
The rocks of Simla group are seen on both flanks of the Barni Gad anticline but the maximum development of these rock, in the present area, is between Kishna-Barkot-Gangani section along the Yamuna valley and along silkyara-Dharasu- Tehri section in Bhagirathi valley. The rocks comprise essentially of greenish or grey-purple phyllites, silt stone, greywacke and slate with slump structures. This rock is exposed between the Naugaon Sheet and Srinagar Nalupani fault. Presence of quartz-biotite gneiss within this group is seen alongwith this inter laminae of phyllites and thick basic rocks at base, from silkyara. Near Dhara su the gray-wacke is exposed in the Dharasu Barkot road section colour banding is conspicuous in the grey wacke. Between Tehri and Dhara su the phyllites and slate of this group rarely show sedimentary structures, characteristic of this formation. The rocks become increasingly argillaceous towards south and south west.

Krol Belt Rocks:
It is a thick sedimentary Sequence in the 'outer Himalayan zone. Rocks belonging to this belt have been grouped under Chandpur, Nagt hat, Blaini, Infra Krol, Krol, Tal and Subathu formations.

Chandpur :
This formation has a wide distribution in the south western and southern parts of the area. These rocks are exposed to the southwestern side of Srinagar Nalupani fault between Srinagar in southeast and Tehri in northwest and cover the area around Chamb and west of it. It also occupies the area between Srinagar and Devprayag in Alaknanda valley.

This formation comprises phyllites, slates and minor quartzite alongwith lensoidal limestone beds. Foliation is well developed in the Chandpur rocks and the foliation planes have a shining lustre. Varve like laminations are also seen. Puckering and Chevron type folding is typical of these rocks.

The associated quartzites are rather impure and grey in colour. Such a thin quartzite band is seen exposed to the southeast of Hindola Khal and continues along the NW-SE strike trend upto the Alaknanda river in south east. The quartzite dips towards southwest.

Impersistent, lensoidal limestone bands are also seen in the Chandpur formation. A thin limestone bed is observed.

Nagthat formation comprises well bedded, massive white and light purple quartzite often current bedded with minor grits, pebble beds and occasional phyllites and shales. Graded bedding is also seen in these quartzite as observed in the area east of Dhanaulti. Thin pebble beds are seen with pebbles of mainly white, pink quartz in a silliceous matrix. The pattern of graded bedding, and current bedding show that the rocks are in their normal position of superposition. Bedding is very well developed in Nagthat quartzite. There is no marked facies variation in this formation.

The Nagthat formation is overlain by the Blaini and Infra-Krol formations. The Upper contact is rather sharp in contrast to the gradational contact with the underlying Chandpur formation. Intrusive basic rock is commonly seen in the Nagthat formation.

Blaini and Infra Krol formations:
The Blaini formation is exposed in the Mussoorie syncline and forms an important stratigraphic member in the Lesser Himalayan rocks. The Blaini formation and the over lying Infra-Krol formation have been mapped as one unit in the area. The Blaini formation is unconformably underlain by the Nagthat formation while the Infra-Krol formation overlies it conformably. The lithostratigraphic sequence of the Blaini formation is as follows :-

Member 3	Flesh coloured limestone with inter bedded shale.
Member 2	Carbonaceous shale, varved argillites.
Member 1	Boulder beds.

The boulder bed comprises subrounded to subangular, often flat pebbles of shale, quartzite, limestone, slate, phyllite and sub rounded to well rounded quartzite boulders. In Suaknoli-Aglar Nadi section two horizons of boulder bed are seen near Beli. While the southern horizon contains fragments and pebbles in siliceous matrix, the pebbles ranging in size upto 1 to 2 cm. The northern horizon however contains boulders of quartzite upto 50 cm. in diameter. The material appears as tillite and therefore, thought to be of glacial origin at least partly. This formation has been correlated with Talchir boulder bed and is considered to be of Fermo-carboniferous age.

The Infra-Krol formation, conformably lying over the Blaini formation, is exposed in Mussoories syncline, Hiyuni Nadi section between Agra khal and Jajal, etc.

Lithologically this formation comprises thinly bedded carbonaceous shales which is occasionally bleached and shows mottling.

Krol formation:
Forming a conspicuous topography in the Lesser Himalaya, this formation is predominantly calcareous in nature. It is conformably underlain by the Infra-Krol and conformably overlain by Tal formations and is exposed in the Mussoorie syncline area. This formation has been mapped as one unit in the present study. Neverthless, Auden (1934) subdivided this formation in 5 members, namely A, B, C, D and E. Krol A consist of thinly bedded shales with minor limestone; Krol B is mainly a red shale with minor limestone member, Krol C comprises massive grey dolomitic limestone with minor shale, Krol D and E are cherty, dolomitic limestone with shale intercalations. The outcrops of the Krol formation trending NNW-ESE in the western part of the Mussoorie syncline southeast closure of the Swerves to N-S direction near Mussoorie syncline and again to WWW-ESE in the southern limb of the syncline.

Tal Formation:
The Krol limestone sequence is conformably overlain by the Tal formation which occupies the core of the Mussoorie syncline. The basal parts of Tal formation, resting conformably over the Krol limestone, is a splintary carbonaceous shale, occasionally mottled with chert and phosphorite intercalations. These stales are often coated with ferruginous material. These shales are overlain by the upper Tal quartzite which has a distinct topographic expression and is whitis!. to dirty brown in colour and fine to medium grained in texture. It is a hard, thickly bedded and well jointed quartzite. Current- bedding is occasionally exhibited. In the northern limb of the Mussoorie syncline this quarzite bed has a WNW-ESE strike and dips at an angle of 450 towards south. The contact with the underlying Krol limestone is faulted one in the southwest of Magni. The quarzite if overlain by shell limestone of light to dark grey colour. Recently this limestone horizon is reported to contain Fermian fossils, making its startigraphic position doubtful.

Subathu Formation:
This formation comprises mainly olive and purple shales with quartzite and limestone intercalations. A small outcrop of this formation is seen at Dudhor in Agrakhal- Narendranagar section another outcrop of this rock is seen at Laluri in the Nagun Gad.

Lower Deoban Formation:
Consisting of quartzite, phyllite and basic flows, with estone, this formation occupies the core of the Barni Gad anticline which is an isoclinal anticline with axial plane dipping Northeast. These rocks are exposed along the Yamuna river between Barni Gad and Billa. In the basal parts it comprises greenish chloritic, well cleaved phyllites with occasional greenish grey quartzite bands as seen to the north of Earni Gad. The chloritic phyllite of volcanic origin is also seen interbedded here. This phyllite quartzite unit is overlain by a thin limestone bed exposed in a

MW-SE trend just north of Kuwa. The limestone is bluish grey to whitish, platy and often marbly with shale partings. Towards, southeast, near Bijauri this limestone bed is uncomformably overlapped by the overlying Middle Deoban formation, The limestone bed is succeeded upward by a sequence of phyllite, basic flows and quartzite. The quartzite is white to grey and crossbedded. The volcanics comprises both massive as well as phyllite with amygdaloidal surfaces.

Middle Deoban Formation:
This formation is exposed in both limbs of the isoclinal Deoban anticline with Lower Deoban formation in the core, This formation consists of bluish grey to buff white dolomitic limestone showing profuse algal structures in the northern limb. A slate bed is exposed just north of hill beneath the middle Deoban formation. The Middle Deoban formation unconfor- Lower Deoban formation in Barni Gad anticline as seen by the overlapping of the Kuwa limestone of the latter by the Middle Deoban Formation.

Simla Group Rocks:
Represented by mainly phyllites with concordant gneissis bands these rocks are exposed between Barkot and Gangani in the Yamuna valley. The rocks comprise green and greenish grey phyllite, slate with occasional basic sills. It occurs with faulted contacts on either side. The slates of Simla group are overlain by the Deoban limestone to south of Earnigad and have a faulted contact.

Upper Leoban Formation:
The quartzite-basic rock sequence occurring in the Yamuna valley to the north and east of Gangani belong to the formation. This is a thick sequence of quartzite, white to light brown in colour, closely jointed and showing current bedding with right side up along with the intrusive basics. They often thus lenticular patches of chlorite and tale schist, along planes of shearing. The general attitude of the bedding is WNW-ESE with northerly dips in the Yamuna valley, These rocks are conformably underlain by the limestone of Middle Deoban formation of Gangani which is exposed in an antiform structure.

The thick sequence of quartzite and basic rock is overlain by Crystalline group of rocks is seen near Wazri.

Naugaon Thrust Sheet Rocks:
These are synformally folded, thrust bound sequence of gneiss, marble, limestone, quartzite, phyllite, schist and volcanics. Its base is marked by Naugaon Sheet which separates the Naugaon Sheet rock from the underlying Deoban formation in the south and west and the Simla group rocks (Barkot - Dhurasu phyllites-slate) in the east. The quartzite of Naugaon sheet is well exposed on Naugaon-Purola road.
The stratigraphic sequence in Purola sheet rocks is as follows:-

F	-	Schist with quartzite
E	-	Quartzite
D	-	Schist
C	-	Quartzite
B	-	Limestone
A	-	Basics with genesis

Alluvium:
The alluvium in the area is confined to the river flood plain and the terraces. The alluvial plains of the major valleys are rather narrow. At few places like Srinagar, Tehri, Chinyali Saur, Uttarkashi, Barkot, Naugaon etc. the rivers have developed wide fluvial terraces comprising mainly bouldary to sand grades and silts. These are under intensive land use for cultivation.

Structure:
The major tectonic elements in the area may be mentioned as below:-
i: Main Central Thrust.
ii: Srinagar - Nalupani fault.
iii: Tons Thrust.
iv: Furola Thrust.

Main Central Thrust:
The Crystalline group rocks of the central Himalayas are brought in juxtaposition to the autochthonous sedimentaries of the "inner" Lesser Himalaya by the northerly hading Main Central Thrust. The trace of this thrust runs through Wazri in the Yamuna valley, following a WNW-ESE to E-W trend, emerging in the Bhagirathi valley at Sainj. It, then takes a sharp southerly trend, along the Dogadda Gad, a tributary of the Bhagirathi river, runs along -S course of the Ealganga river south of Thatikathur, again veers round to SSE trend between Chhatera and Thayeli (in Bhilangna river) from where it follows SE to SE trend before crossing into Mandakini valley.

Srinagar Nalupani fault:
Cne of the major tectonic element bounding the Deoban (Garhwal) group to the south, separating the shallow water orthoquartzite-Limestone facies of the Garhwal group from the deeper water turbidites of the Srinagar-Nalupani fault. it has been variously referred to as "the major tectonic break (Auden 1938), Nalupani fault (Dhoundiyal and Ali 1967), Dharasu Thrust (Jain 1971), Dharokot dislocation (Saklani and Pande 1970), Dharkot Thrust (Saklani 1971), Srinagar thrust (Mehta 1971) Srinagar shear (Bhargava, 1972), Badiyar fault (Ganesan and Verma, 1975), North Almora thrust (Ali 1967, Maithani 1970, Agrawal 1972). The present study reveals that it is a major fault trending NNW-ESE in the Yamuna valley bringing the N-S trending Simla group rocks (Dharasu-Barkot Phyllites) to the South in contact with the Deoban group in the northeast.

Furtherorth, it is probably overlapped by the Main Central thrust. It follows a SSE trend, running along Dharasu-Barkot road upto Genwala before crossing over to the ridge. between Khurmola Gad and Bhagirathi where it emerges at Nalupani.

At Nalupani and further South east, the fault dips steeply towards north as seen from the trace of North Section, a little NE of haundhar, the fault is again seen hading in northeast direction. Continuing further southeast, in Bhilangna river, the fault passes through Dewal and has a WNW-ESE trend and northeasterly dip. It swings to southeast and passes through Jakhand in takoli Gad section where it separates the limestone of Chandpur formation from the purple slates of Deoban group, through Dyuli, where the Chandpur phyllites in the southwest are brought in contact with this quartzite band and metabasics of the Deoban (Garhwal) group in northeast and ultimately crosses the Alaknanda river at Moleswar, a little east of Srinagar, separating a thin limestone band of Chandpur formation from the underlying metavolcanics and quartzite of Deoban (Garhwal) group. The fault is south dipping in the Alaknanda section. Further southeast it is reported to merge with the North Almora thrust separating the Dudatoli group rocks from the Deoban (Garhwal) group. Thus it can be seen that it is a major tectonic break traversing the entire stretch between the Alaknanda and Yamuna valleys, being ultimately either overlapped or merged with other tectonic breaks.

Tons Thrust:
The Tons thrust between the Simla group rocks and the overlying Chandpur formation which is very clearly demarcated in the Tons and Yamuna valleys extends east to southeastward upto Bhagirathi valley. Auden traced this thrust upto khand in Bhagirathi valley and according to him, "it appears to terminate abruptly along the Bhagirathi river against another major tectonic line which divides the Barahat series (Garhwal group) from the Chandpurs". Tracing this thrust in Bhagirathi is however quite difficult as the lithological dissimilarity the Simla group and Chandpur formation rocks is not marked. however there is some structural dissimilarity alongwith marked slaty and greywacke- quartzite associations in Simla group as compared to predominatly phyllitic rocks, highly puckered, of the Chandpurs. The Tons thrust is indicated by a lineament seen aerial photographs. The lineament runs: roughly along the upper reaches of the Bhadri Gad, crossing it near Dharara and following an easterly trend upto Bhauntor, then swerving to southeast along the southern flank of Nagun Gad. It is possibly covered by the terrace alluvia of the Bhagirathi around Khand, and crossing the Bhagirathi, it is truncated by the Srinagar Nalupani fault near Chaundhar.(Plate No20

Naugaon Sheet :
In the Yamuna valley the Naugaon Sheet comprising more metamorphosed rocks overly the Deoban group rocks separated from the latter by what is called the Naugaon thrust sheet which is folded in a North to Northwest plunging synform. The western limb of the folded thrust crosses Yamuna near the confluence with Kamola Gad and runs along the Kamola Gad. The rocks of the Naugaon sheet can be seen overlying the Deoban formation limestone along this section. The thrust hade towards east in this section. It follows a southerly trend till Tiyan when it takes an

easterly swing, hading northward. It closes around Gair. The eastern limb of the synformal thrust sheet, heading westward crosses the Yamuna river at Kisna, Basic intrusives are seen along the thrust sheet near Kisna.

Folds :
There are number of major folds in Deoban group and Krol belt rocks.

Indravati Gad anticline:
This anticline can be traced along the Indravati Gad between Aleth in SE and Uttarkashi in NW where from it takes a swing to WNW-direction upto east of Raturi Sera, Swerving to NNW-N following the Rano Gad. It is faulted along the axial plane so that the Lower Deoban formation exposed in the northern limb of the anticline is not repeated in the southern limb where the quartzite and volcanics of Upper Deoban formation is exposed. Bhagirathi river follows the axial trace of this fold between Uttarkashi and Raturi Sera.

Maneri anticline:
Extending between Gagnani in west and Sainj in east, this anticline exposes the quarzite and associated volcanics of the Lower Deoban formation. This anticline is also faulted along the axial plane called the Gangori-Jamak fault which is subvertical. Towards west the anticlinal axis swings to northwest, crossing the Kaldi Gad.

Darmali syncline:
A syncline running in NW-SE direction through Dunda is seen forming the ridges to the NW of Dunda and SE of Darmali respectively. The synclinal axis extends from south- east of Darmali, to around the peak 2300 in northwest. The Core of the syncline is formed of the Quartzite and volcanics belonging to Upper Deoban formation.

Dharasu syncline:
The grey wacke, quartzite, phyllite slate of the Simla group exposed in the ridge north of Dharasu is folded in a synform with the axis trending NNW-SSE.

Junga-Mathali Syncline:
Another syncline in the grey wacke, quartzite, slate and the underlying phyllite, exposed in Junga-Mathali section is disposed in a synformal structure with its exis passing through peak 2090.

Barni Gad anticline :
In Yamuna valley, the Deoban group sequence is folded in an anticlinal fold along Earnigad, plunging towards south- east to east south east. Inverted northerly dips in the cross bedded limestone/grit about 500 metres south of .2212 m. hill have been observed by Ganesan and Verma (1975) in the over- turned southern limb of the Barnigad anticline. The closure of this antiform is not very clear as it affected by Tiyan fault in addition to being overlapped partly by the augaon thrust sheet.

Naugaon syncline:
The Naugaon sheet rocks occur in a synclinal disposition which trends roughly N-S near Naugaon, but towards south, its axial trace swervest SE.

Takoli Gad anticline :
An antiformal structure trending NW-SE is observed in the Chandpur phyllites along the Takoli Gad.

Chandrabadani syncline:
A major synformal structure with the axial trace trending NW-SE is seen between Chandrabadani in the northwest and Bhagwan on the right bank of Alaknanda river in the southeast. The case of the syncline near Chandrabadani is formed of the Nagthat quartzite while the underlying Chandpur phyllite with associated grey wacke and minor quartzite constitute the main bulk. The Chandpurs show well developed syndepositional structures, exposed in the Devprayag- Srinagar road section.

Mussoorie syncline :
Perhaps the most conspicuous folded sequence is exposed in the Mussoorie syncline part of which forms the southwestern extremity of the present area. The syncline comprises rocks of Krol belt from Chandpur to Tal alongwith remanants of Garhwal nappe and the Eocenes. The axis of this syncline has a WNW-ESE trend at Lal

Tibba (2277). It takes a southeast swing around Tibri and continues upto Dhanchula further east of which it has a B-W trend upto Kunji and a south easterly trend upto Lamyali in the Hiyuni river section. Tal formation occupies the core of this syncline. Metamorphics of Garhwal nappe occur in two small patches in the core and have thrust contact with the underlying Tal formation. Aglar river marks the faulted axial trace of the complementary anticline to the north of Mussoorie syncline.

In addition to the above mentioned folds, there are many other folds, both antiformal and synformal, of smaller magnitude.
Three major trends of the fold axis are observed these are WNW-ESE, NW-SE and N-S respectively.

Faults:
There are a number of faults of major and minor dimensions which have caused shift in outcrops of the various formations, thinning of many formations, at times overlapping of formations. Some of the important faults are-

i. Srinagar-Nalupani fault- This is a fault of fundamental and deep seated nature. It is a high angle reverse fault which hades in either direction across its general NW-SE trend. It has already been described earlier.
ii. Indrawati Gad-Rano Gad fault.
Iii. Aglar Nadi fault-along the axial trace of the compli- mentary anticline to the Mussoorie syncline.
iv. Hiyuni river fault-A major N-S fault between Jagal in south and nail in north.

Correlation:
The complexity of structural and tectonic set up in the area and lack of fossils make the task of correlation extremely difficult. However, on the basis of lithological similarities as well as structural disposition an attempt has been made to correlate the various lithounits in the present area.

The Lower Deoban formation which occurs in an overturned antiformal structure (Barnigad antiform) plunging to the SE is mainly a phylillite, slate, quartzite with minor limestone formation. This has been correlated with the Lower Deoban formations comprising quartzite slate with minor limestone and which occurs in the core of the Indrawati Gad anticline in the Bhagirathi valley. These two are overlain by a dolomitic limestone bed-the Middle Deoban limestone formation. The limestone bed exposed at Gangani in Yamuna basin is disposed in an anticline structure which can be correlated with the limestone disposed in the Khattukhal anticline, Naugaon syncline and Barnigad anticline. Overlying this limestone in the Bhagirathi valley occurs the thick sequence of quartzite basic rock the Upper Deoban formation. The Middle Deoban limestone exposed at Gangani is also overlain conformably by the quartzite basic rock sequence of Upper Deoban formation.

The Upper Deoban formation is however not exposed on either flank of Barnigad anticline as as the Middle Deoban limestone formation of the Barni gad anticline has a faulted contact with Simla group rock on the southern limb and in the northern limb it is in contact with the Nauga on thrust sheet.

The stratigraphic position of the Simla group rocks is however not clear since its base is not seen anywhere. This formation has however been considered by earlier workers on the oldest sedimentary formation in the area forming the base for the thick overlying sedimentary rocks. Their present disposition is becuase of faults as shown in the cross sections. However, it may be mentioned here that these rocks could be younger and not older than the Deoban (Garhwal) group and may overly the quartzite basic rock sequence of Upper Deoban. The comparatively lesser degree of compaction of the sediments (mostly these rocks are siltstones, grey wacke, and slate) indicates a lesser degree of metamorphism suffered by these rocks.

Another evidence in favour of a faulted contact and Simla group rocks being older is the presence of thick basic rocks at the contact of these rocks with overlying and under- lying formations. It would require a much detailed study to arrive at definite conclusions about its relationship with the reoban group rocks. Similarly, part of the Chandpur formation rocks which are mainly arenaceous comprise greywacke slate sequence and which show profuse slump and other sedi- mentary structure and which are exposed in an antiformal structure to the east of Bhagirathi river between Deoprayag and Tehri, may possibly belong to Simla group of rocks. However, with the meagre data available from the present study and photo-characters of both these groups of rocks almost identical. It is not possible to draw a distinction between the two in Tehri-Devprayag section and the whole area has been included in Chandpur formation.

The metamorphic of the central crystalline have a thrusted contact with the underlying rocks.

The position of the Naugaon thrust sheet is rather tentative. The contact, both in the western and eastern limb of Naugaon syncline, of the rocks of Naugaon sheet with the Deoban group, alongwith occurrence of thick basic rocks at Kisna along the eastern contact, are definitely faulted. Its southern boundary, however, could to be traced in the field and even on aerial photographs, it is only tentatively demarcated.

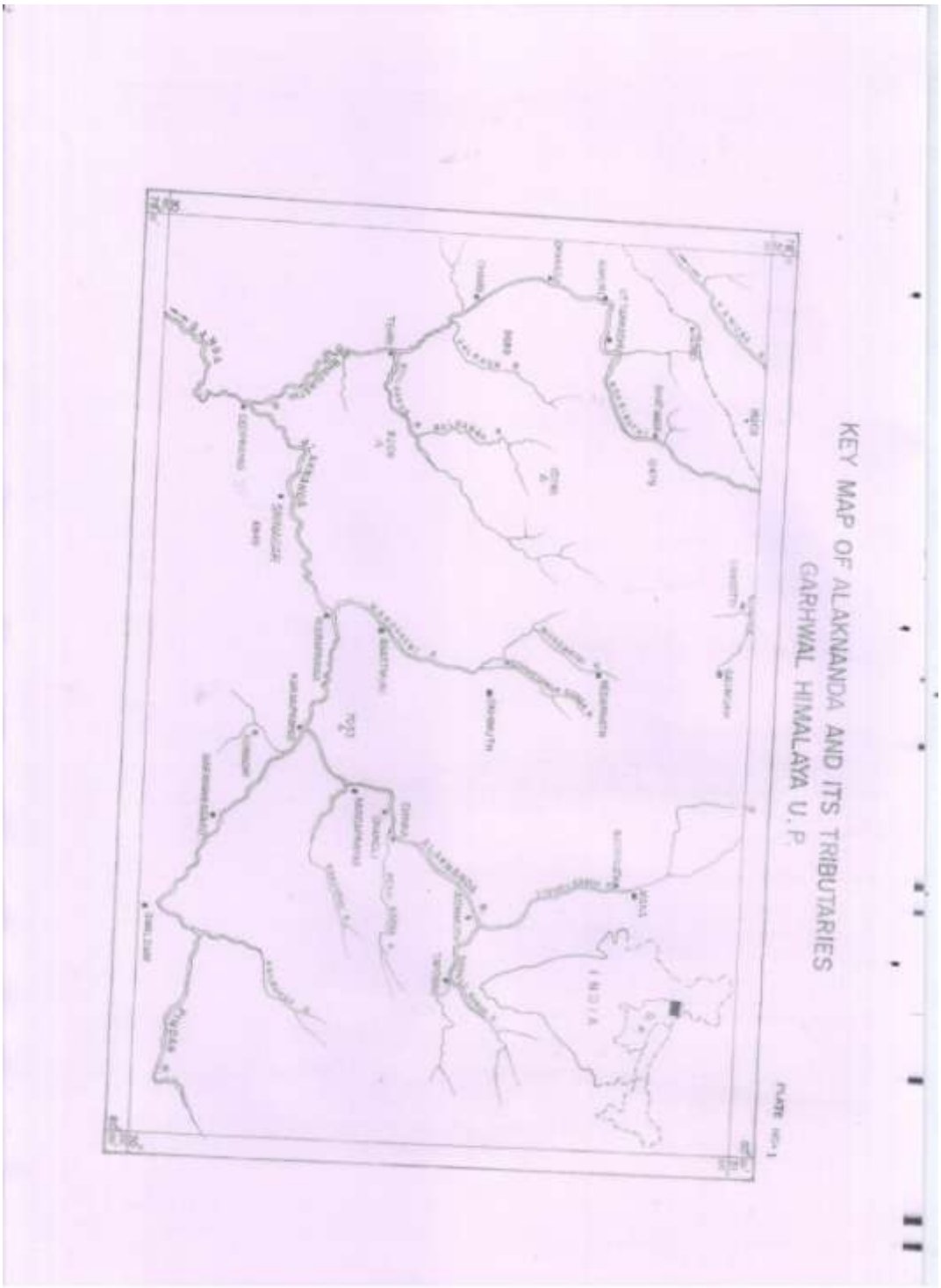
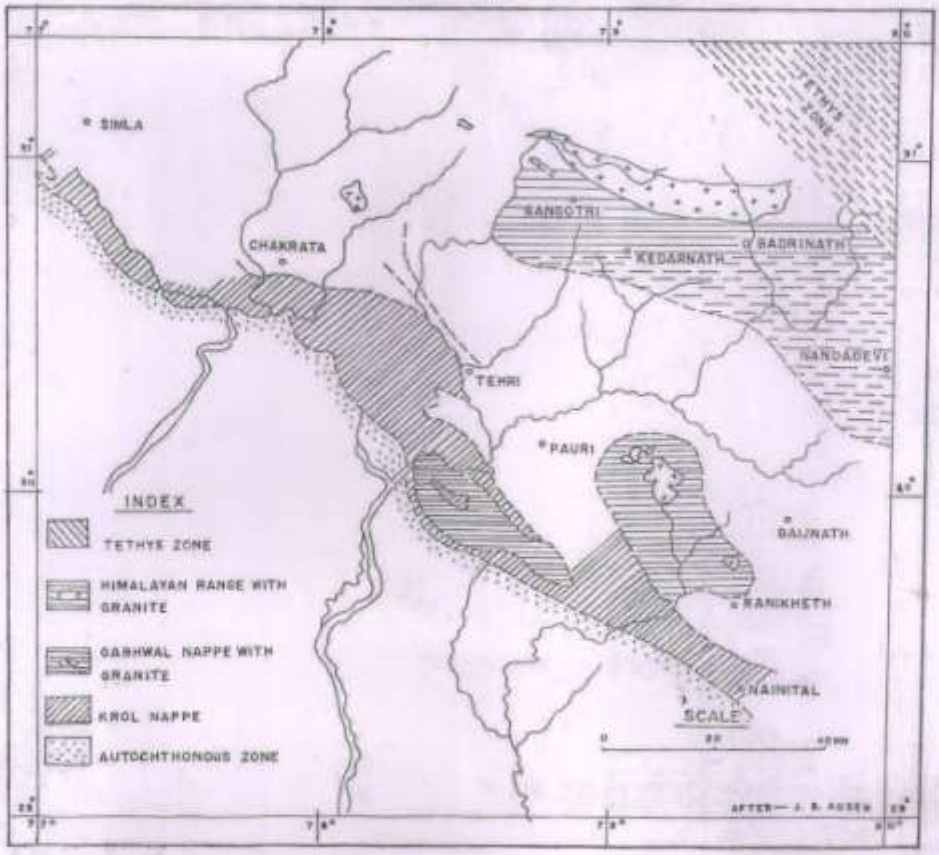
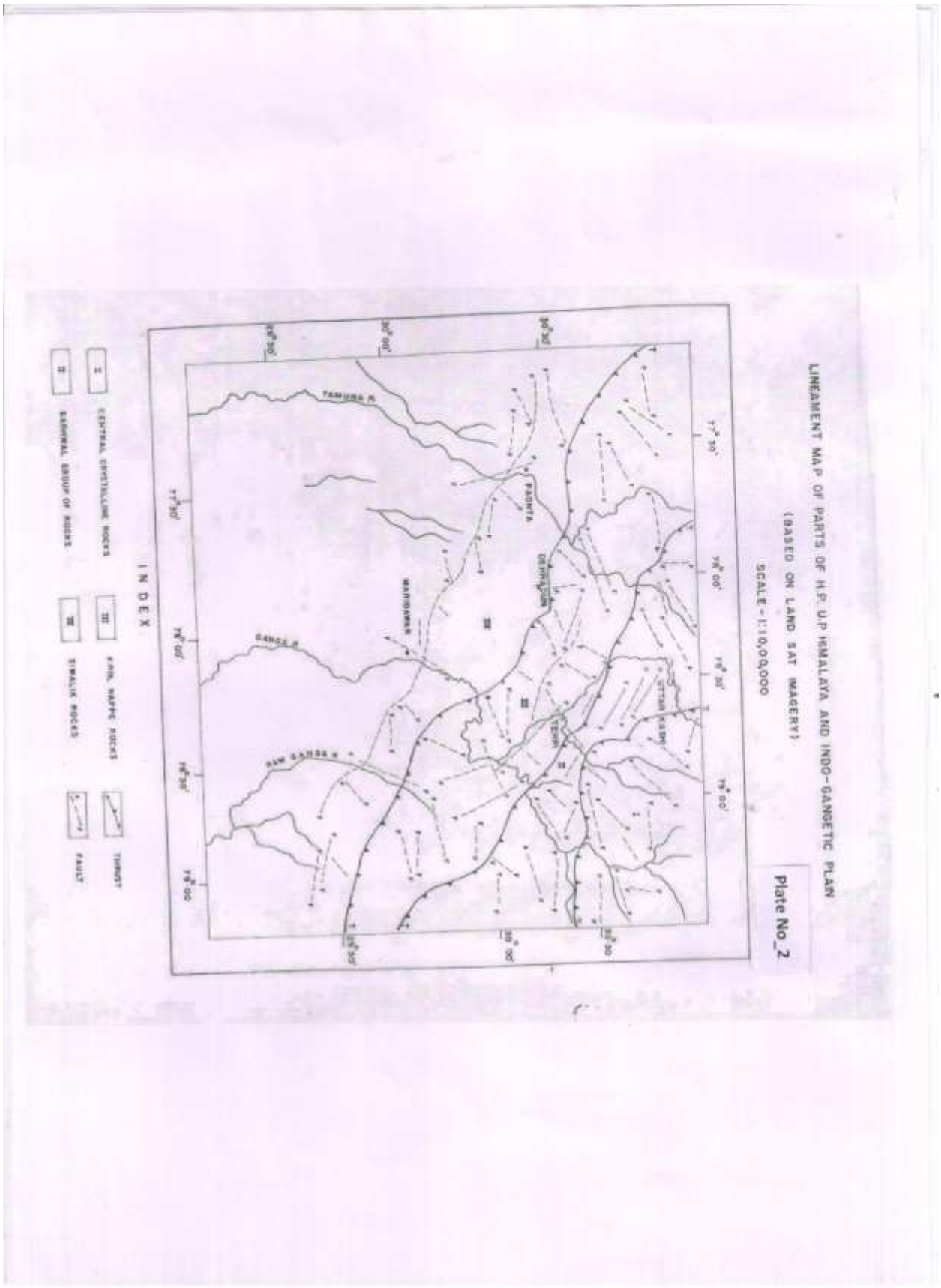


Plate No_1

TECTONIC MAP OF THE GARHWAL HIMALAYA

(SKETC MAP)




LINEAMENT MAP OF PARTS OF H.P. U.P HIMALAYA AND INDO-GANGETIC PLAIN
(BASED ON LAND SAT IMAGERY)
SCALE - 1:10,00,000
Plate No_2
INDEX
I CENTRAL CRYSTALLINE ROCKS
II KARWAL GROUP OF ROCKS
III KAMLI MAPPE ROCKS
III SIWALIK ROCKS
THRUST
FAULT
YAMUNA R.
GANGA R.
RAM GANGA R.
MAHSHWAR
DEHRADUN
TEHRI
UTTAR KASHI

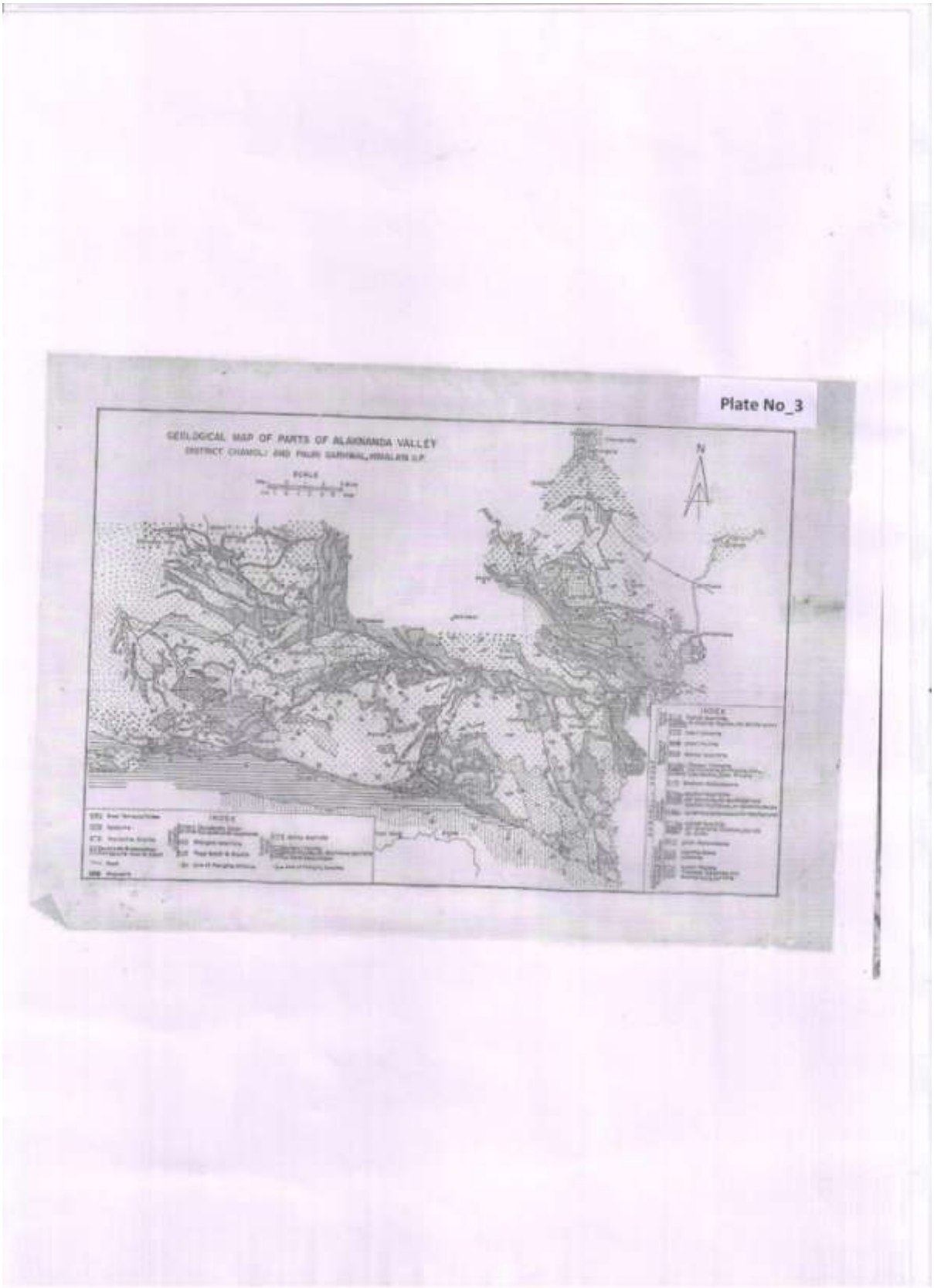
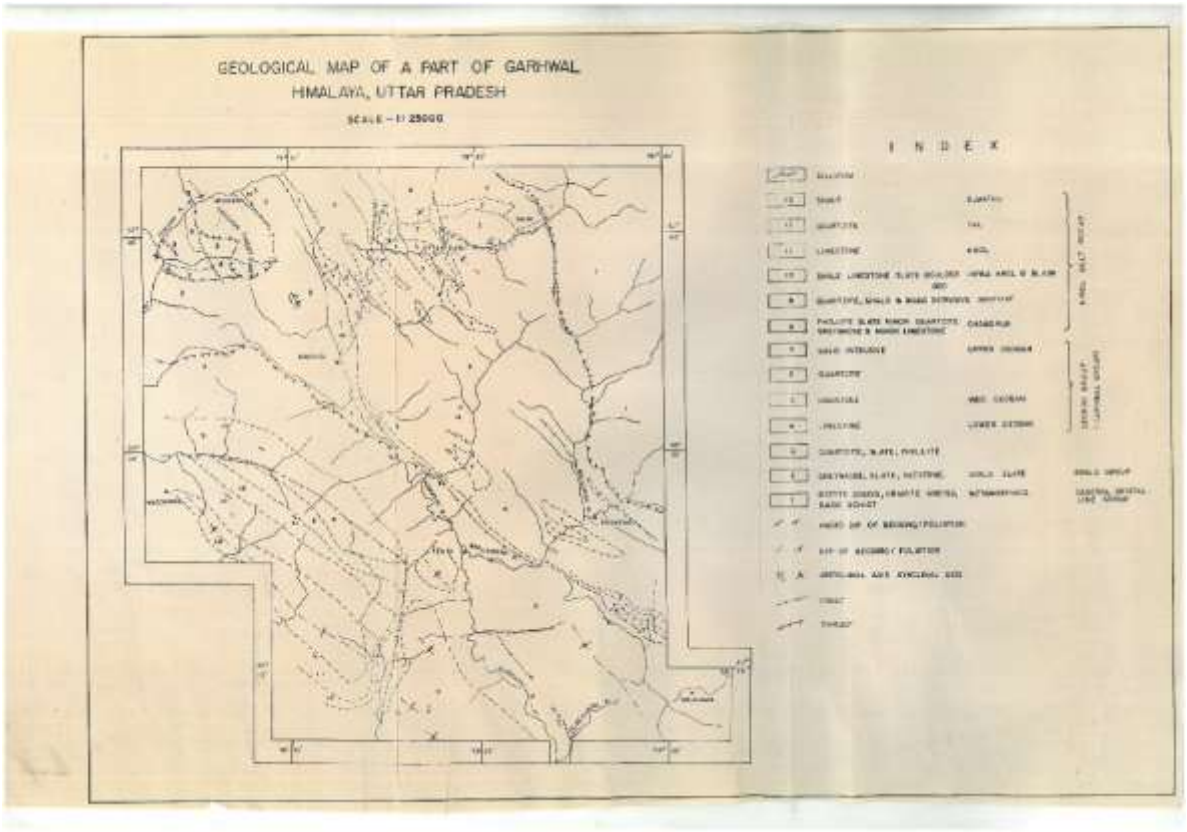


Plate No_3
GEOLOGICAL MAP OF PARTS OF ALAKNANDA VALLEY
N



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