The study area is located in the Lesser Himalayan segment of the Garhwal Himalaya. The area is drained by the Dhundsir Gad, a tributary of Alaknanda River. Present investigations have been carried out in the Dhundsir Gad. North Almora Thrust also known as Srinagar Thrust is passing through this area. The rock types present in the area are quartzite, limestone, phyllite, chlorite schist and micaschist, are low to medium grade rocks that have suffered multiple phase of deformation.

The Himalayan is folded and thrusted mountain range. First time this area has been geologically investigated in eighties. Due to its inaccessibility and severer climatic conditions very few old references are available. Medlicott (1864), Middlewiss (1885) and Oldham (1883) were the pioneers who gave the geological account for this region. Middlemiss presented a three fold classification of the Siwalik namely upper, middle and lower, which have been universally accepted. Late Sahni and Mathur (1964) have modified this classification. Later eminent geologist like McMohan (1877), Griesbech (1891), Pilgrim and West (1928), Auden (1934-1953), Gansser (1964), Valdiya (1965), Fuchs (1969), Rao (1968), Agrawal and Kumar (1973) and Ravi Sanker (1975) have made specific observations about Garhwal Himalaya.

The work of Heim and Gansser in Kumaun – Garhwal Himalaya is a landmark in the history of Himalayan studies. They independently gave a vivid account of the pilgrimage route of Badrinath and introduced the Main Central Thrust (MCT), which is separating the Central Crystalline from the Lesser Himalaya. Kumar (1971) has described the tectonic succession of the Garhwal Himalaya and suggested that along the Main Central Thrust, the crystalline are thrust over the Garhwal Group and the south dipping North Almora Thrust brings the Almora Dudhatoli crystalline over the rocks of the Garhwal Group.

Geology, tectonics, geomorphic process, and other structural attributes, which are generally affecting the development of landforms have been discussed in this chapter. A study of individual landforms, their origin and evolution through times have also been presented. The development of a drainage basin is controlled by the structure of rocks, climatic conditions, basin shape, drainage density, and biotic factors, the geologic and geomorphic history and recent diastrophism of the basin. The traces evidences such as
presence of narrow to very narrow gorge, valleys breaks in longitudinal profile, terraces, boulders, pebbles of various rocks (quartzite, granite, limestone, sandstone etc.) which through light on the gradations chronology of the area is being discussed. On the basis of above study various stages in the evolutions of the basin have been discussed. The Dhundsir Gad watershed falls between Jaunsar Berinag Nappe in the north and Krol Nappe in the south. Geological map of the area have been prepared (Fig.2). The lithology of the area is distinctly characterized by mineralogical composition, stratigraphic and structural framework, which are broadly confined to autochthonous and allochthonous zones (Sandaliya, 1984).

Geology of the Study Area

The study area falls in between the Pratapnagar and Badiyargargh zone. The present tectonic-stratigraphic sequences is based on Kumar & Agarwal (1975), Sandaliya (1984) and Kumar (1971). Following Table shows the tectono-stratigraphic sequences of the study area.

Tectonic Succession in the Dhundsir Gad

(After Kumar, 1971)

Central Crystalline

----------------------Main Central Thrust---------- ------

Garhwal Group - Calcareous Formation

- Quartzite Formation

---------------------------North Almora Thrust-----  ---------

Almora – Dudhatoli Crystalline

Kumar and Agrawal (1975) have classified the rocks of the Srinagar area into Garhwal Group, Chandpur Group and Dudhatoli Group. Garhwal Group of rocks separated by the Main Central Thrust in the north and consists of arenaceous and calcareous formation. The Dudhatoli Group is represented by the phyllites and quartzites, forming the northing limb of the Dudhatoli syncline. The rocks of this area have been subjected to three phases of deformation, namely (i) F1 (NW-SE), (ii) F2 (NE-SW) and (iii) F3 (NNW-NNE) (Sandaliya, 1984).
The south dipping ‘North Almora Thrust’ (NAT) is located about 5 km. northeast direction of Srinagar (Plate-3), along which the phyllite of the Dudhatoli group are thrust over the quartzite and argillocareous rocks of Garhwal group (Kumar and Agrawal, 1975). The Dhundsi Gar is a part of NW Srinagar consists of a series of ridges, ranges from 700 to 2300m. The autochthonous zone of Chandpur Group is consisting of limestone and phyllites. Along the NAT neo-tectonic activities have been reported. The Chandpur phyllites of Krol series override the subsequent gravels in the study area. In the study area number of minor faults and opening along the major joint sets indicating that this area is neotectonically active. Here major rock types have been described while for the terminology for the categorization of rocks of Rupke and Sharma (1974) has been adopted (Fig.2).

I. Crystalline Group

a. Chrapataya formation

(i) Biotite Gneiss: The Panduakhal-Gaddikhal top of the basin is composed of biotite genisses rocks. Some Quaternary deposits were reported in the upper valley. The medium to course grained biotite, quartz, feldspar bearing gneiss is greenish, grayish black in color. This gneiss is thrust over the Pratapnagar quartzite around hill top. The biotite gneiss is traversed by the veins of quartz measuring up to 5cm in thickness.

II. Chandpur Group

It consists of two formations namely Pauri formation and Pratapnagar formation:

a. Pauri formation

(i) Schistose phyllite: It is exposed along the NAT. The trend of the phyllite is NW to SE with the location variation from SWE to NNW. It shows well developed crenulation of strain-slip cleavage. The minor folds in this phyllites are mostly of recumbent to isoclinal types. The fractures of the folded schistose phyllite are represented by ramifications of the quartz veins (5 to 10 cm) in thickness (Sandaliya, 1984). This formation is exposed around Dang, Rampur and Sili villages of the study area.

(ii) Slaty phyllite: The slaty variety is well developed away from the NAT especially near Kandi and Khark Village (Plate-2). It is deep green in color and is harder than the schistose phyllite. It shows well developed fracture/slaty cleavage.
b. Paratapnagar quartzite formation

(i) Pratapnagar quartzite: A thick pile of fine to course grained greyish brown to gray quartzite is characterised by the presence of thin layer of the sericite quartzite, this quartzite schist and bands of dark grayish black to blue black slates. This quartzite is brown in nature than the ferruginous quartzite. The pratapnagar quartzite is comparatively more schistose, shows the development of vertical folds. Generally Pratapnagar Quartzite does not contain metabasic rocks. This quartzite is well exposed around the Silkakhall on the western part of the study area. The current bedding and ripple marks are the main sedimentary structures present in the quartzites. Quartz veins & slickenside were observed in Pratapnagar quartzite (Saklani, 1971) and is well exposed around Sarkeina.

A thick pile of fine to course grained quartzite characterized by the presence of thin layer of the sericite schists & bands of dark grayish brown ferruginous quartzite occur in the major portion of the catchment.

III. Garhwal Group or Calc Group

Broadly the northern boundary of Garhwal group defined by Main Central Thrust (MCT) and southern boundary is delineated by the North Almora Thrust (NAT). It is consists of quartzite and metabasic rocks. The rocks have suffered low grade metamorphism up to chloride grade. Generally the metabasic rocks are associated with quartzites. The metabasics are predominantly made up of chlorite and hornblende. Thin layer of white maroon quartzites (Plate-1) and gray phyllites are also associated with metabasic. The rocks of the calc group (Garhwal group) (Mehdi et.al, 1972) occurs as a window showing the tectonic contacts with the Pratapnagar quartzite in the north and Pauri phyllite in the south. Mainly ferruginous quartzite is predominant in this zone.

This quartzite can be differentiate from the ferruginous quartzite of the calc group as follows-

- The occurrence of metabasic rock is much less in the Pratapnagar Quartzite than ferruginous quartzite of calc group.
- The Pratapnagar quartzite is comparatively more schistose in nature than the ferruginous quartzite

In the area, number of lensoid bodies of limestone/marble and slate occur in the basal part of the quartzite.
a. Chamdhar formation

The rocks of the calc group (Garhwal Group) occur as a window having tectonic contacts with the Pratapnagar quartzite in the north and Pauri Phyllite in the south.

(i) Ferruginous quartzite: This type of Quartzite is well exposed around the central part of the study area mainly in Silkakhal, Phayalgaon, Klaflana, and Sili. In some localities the quartzites are thickly bedded, massive, course, gritty to fine grained and occasionally pebbly. At some places it is affected by the east-west trending lineaments parallel to the N.A.T. The ripple marks, graded and cross bedding are well developed at many places. This quartzite can be differentiated from the ferrogenous quartzite of the calc group (Sandaliya, 1984).

(ii) Limestone: The limestone belongs to the Chamdhar formation of calc group. This limestone is youngest rock type of the paraulocathaneous calc group and it is overlain by slate and quartzite. It is well exposed along the river sides on the valley slopes. In some places pinkish and banded variety of dolomitic limestone is also exposed. It contains brownish to cream coloured thin bands of shales and at many places it is folded also. (Sandaliya, 1984)

Metabsic rocks

The basic rock in the area occur as intrusives and flows. The intrusives are dykes and sills. Based on mineralogical and textural variations the various basic rocks can be classified as amphibolitic/basaltic in composition which have undergone metamorphism during the Himalayan orogeny possibly in its end phase. Generally the metabasics in their core parts are compact while at their peripheral parts these are schistose or crudely foliated. The metabasaltic flow occur in the rocks of the Calc Group near Silkakhal and Phayalgaon. At Phayalgaon the metabasic rocks occupies a 500 m. wide patch. These meta-volcanic are comparatively more developed in the Calc group than those of the other rock groups. The Metavolcanics with pronounced effects of metamorphism are amphibolite-schists and are frequently noticed in the ferruginous quartzite members of the Calc Group. The Metabagabbroic intrusions are confined mainly in rocks of the Crystalline group and Pauri Phyllite member of the Chandpur Group. Metavolcanics are also characterized by amygdaloidal structures. The main minerals of the basic rocks occur in variable amount are hornblende, chlorite, actinolite, plagioclase and iron oxides. The rocks are well jointed and on weathering are characterized by coating of iron oxides. The metavolcanics are pitted in appearance due weathering (Fig.2). The metabasics terrains are highly dissected by the
denudational processes and in those terrain gully erosion, landslide and slumping of high intensity were reported.

**Quaternary Deposition:**

Colluvial and alluvial deposits of quaternary age were observed during the geological survey throughout the study area which spread over along the valley side from 100m to 500m distance. The quaternary deposits are generally covered by dense forest cover. Big boulders resting over the scree or slide deposits and in the valley side slopes, probably of glacial origin are found here and there. Colluvial fans and scree materials are forming the repose slopes and formed due to gravitational forces or fluvial action covering a major portion of the bed rocks. Such types of terraces are good sites for the settlement and agriculture (Plate-6).

The area comprises different categories of slope, relative relief and latitudinal variations. This area has moderate to steep slopes. The Dhundsir basin presents a typical polycyclic landscape with a series of variegated erosions and depositional landforms. The erosional activities performed by the river are the accumulation of vertical corrosion as well as lateral planation along the entire stretch of the basins. Landslides are common on phyllitic rocks.

**Structure and Tectonics**

**Major structure**

The Dhundsir Gad basin lies in Garhwal Group of Lesser Himalaya. Lesser Himalaya was formed during the middle Eocene to Pleistocene age. Many thrusts, faults, gorges, deep valleys suggest that this area has undergone in the different phases of deformations during the Himalayan orogeny. Mainlay following major thrusts are found in the study area.

**Thrust:** The North Almora Thrust (NAT) is the main thrust of the study area. This thrust sheet exposed towards south of the Calc Group and is predominantly constituted by Pauri phyllites of the Chandpur Group. In the Srinagar area the NAT is also known as Srinagar fault (Mehdi et.al. 1972). It is generally low angle thrust, which at times acquire high angles also. It is south dipping thrust, striking in E-W or WNW to ESE direction with some local variation and the dip varies from 40°-60°. In the study area this thrust has been traced at Zirkoti and Gorsali villages. Along the NAT the phyllite of Chandpur Group is in tectonic contact with the arillocalcareous rocks of Calc Group. The Phyllite is intensively
folded, fractured and weathered along the thrust.

**Faults:** The study area is characterized by many transverse and tear faults. The faults have displaced the NAT in the southern area. There are following two transverse and two tear faults. The Dungarivya faults displaced the NAT at Zirkoti places. The Dhundsir Gad formed a deep gorge here. The Jamnirao fault is more prominent transverse fault trends from NW to SE direction.

**Minor Structures**

Some minor structural features were also reported in the study area during field investigation which play important role in the development of lower order drainage lines and landforms. The minor structural features includes (i) Planner structures such as bedding, cleavage, joints, (ii) Linear structures, (silicon sides or striations, boudinage structures, fold axis, lineation etc.) (iii) folds (minor and major) and (iv) Lineaments (major and minor). One of the minor fold is found at Koti village in the upper valley. Lineaments are the major tectonic minor features in the study area.

**Lineaments**

Lineaments are many lines on the maps and that are structurally controlled, which include photo geological images such as stream beds and ridges. The term can be used to refer to the lines representing beds, lithological horizons, mineral bandings, veins, faults, joints, unconformities, and rock boundaries (Nathani, 1999). Kumar and Agrawal (1975) have described three major phases of tectonic activity in the Garhwal region. The first phase is characterized by the major faults and fold axes with NW to SE trend. The second phase by the fold axes of NE-SE trend, and the third phase with faults and fracture zones against the NE-SW trend. Sandiliya and Prasad (1982) have also described the lineaments zone of Garhwal Himalaya and they have described the four phases of tectonic activities. Both major and minor lineaments have been marked on the map (Fig.3) and there are three major trends in the Dhundsir Gad (Plate-3&4).

(i) **NW-SE Trending Lineaments:** The major right bank tributaries of the Dhundsir Gad followed the NW-SE trend of lineaments. The Thapli Khad also follows the same trend. This trend is displaced by the N-S trend of lineaments. This trend is representing the second phase of tectonic activities of upliftments. The development of stream appears to follow the fault and synclinal axis of folds and ridges. The boundaries of different structural units
and faults are demarcated with the help of these lineaments. The North Almora thrust follows the NW-SE trend of lineament in the Dhundsir Gad Basin.

(ii) **NE - SW trending lineaments:** The Dhankur Gad and Nagailagair Gad follow the NE-SW trend from source to confluence with Dhundsir Gad. The lower left bank tributaries follow the same trend. This trend is displaced by the N-S trend lineament.

(iii) **N-S trending lineaments:** The youngest trend of lineaments is N-S direction, which displaced all the old trend of lineaments. From Phalgaon to Kandi Village, the Dhundsir Gad follows the N-S trend of Lineament. At this place the NE-SW trend is displaced. Before the confluence at Dhundprayag, later tectonic phases disturbed the course of river in many places and it flow in zig-zag shape.

Out of these major trends of lineament in the Dhundsir Gad, there are many minor trends which follow the second and first order of streams. Some minor lineaments have been also demarcated along the small local faults of the rocks. Lineaments play an important role in determining the course of the drainage in any region. The major streams follow the synclinal axis of folds. The thrusts and faults have changed the course of the river at numerous places, and the river become sinuous in nature. The Dhundsir Gad generally follows the N-S trend of lineament. The fourth order tributaries of Dhundsir Gad follow the NE-SW trend of lineaments, while the NW-SE trend of lineaments are follows by third order streams.

**Geology and Landforms**

Local geological setting of the region has been controlled by both erosional and depositional landforms. Developments of slope elements, evolution of drainage pattern, mass wasting activities, all are controlled by the character of the bed rock and its structural configuration. The phyllitic terrain is easy to erode than the quartzite terrain which is harder and steeper. Rounded to sub rounded topography can be observed in the phyllitic terrain, while conical hills, scarps and cliffs are very common on the quartzite terrain. The water divides of quartzite terrain are rounded and subsurfacial while the water divides of phyllitic terrain are narrow and sharp due to extensive mass wasting processes. The stream courses also narrow and deeper in the quartzitic terrain in comparisons to phyllitic terrain. The offset drainage, drainage anomalies and drainage pattern are controlled by bed rocks character and structural features. Mostly rectangular, trellis and dendritic drainage pattern are very common in the study area, while the angular, obsesequent and braided pattern are very common in phyllitic terrain with moderate to gentle slope. The stage of geomorphic
development, channel course, sinuosity etc. are suggesting that quartzite terrain is more resistant to erosion and other mass wasting processes rather than the phyllitic terrain. The slope is gentle to moderate in phyllitic terrain while the slope is moderate to steep in the quartzite terrain.

**Evolution and Development of the Basin**

An attempt has been made to trace out the probable morphogenesis of the present landscape. Dhundsir Gad basin has been largely determined with the help of its geologic and tectonic history. In the present study morphology of the area is mostly analyzed with the help of topographical maps and fieldwork. In the origin time of Dhundsir Gad basin the fold was formed in the evolution of Himalaya in Eocene-Pleistocene times. Before Cambrian period, the area formed a part of the tehtys geosyncline where sedimentation took place in relative calm. This sea received deposits of that time contributed by the river of the either sides of the continent. Deposition of turbidite, which later composed the Chandpur and Garhwal formation and igneous activity firstly affected the central part of the basin. After some time these sediments were changed in chlorite schists, quartzite, slate, phylliet. It remains as basin of deposition of the upper Eocene Period. In this period the first Himalayan took place uplifting the part of tethyan geosyncline, and it was the beginning of the Himalayan drainage.

(i) **First stage**: This stage characterizes the alignment of the N-W to the S.E. ranges of the area under study. The entire area lying in the eastern and western part of the study must have been occupied by high range of above 2000 meters. There the mountain ranges area, at present, well defined as water parting. The Dhundsir Gad basin follows the N.W. to the S.E. fault line and the tributary streams developed on both the sides of the major streams.

(ii) **Second stage**: In this stage the Dhundsir Gad basin, following the fault line, had under gone deep erosion, as a result of which the river had developed its valley at a fast rate. The tributary streams, like Udar Gad and Chauni Gad also developed along the local fault lines. The active erosion has resulted into the existence of a number of mountain ridges and spurs. The important tributary streams came into existence and also developed during this stage. These are Tola Gad, Udar Gad, Serkana Gad, and other tributary of the river. The important mountains ranges and ridges that come into existence are Maniknath-Ka-Danda, Nagraj Dhar. Kaprali Dahar, and forming W-E mountain range. Landslides and other tectonics movements must have severely been experienced during this stage.
(iii) **Third stage**: The processes of the valley widening. Lengthening and deepening had been very conspicuous during this stage. The excessive processes of down cutting had resulted into the existence of the deep valleys with vertical cliffs. The area of metamorphic terrain the intensity of the down cutting is higher in the valleys developed over the non-resistant areas. Due to processes of active and lateral cutting in the area of metamorphic terrain, the valley walls were worn back, to a great extent, by the successive operation of weathering, rock wasting under action of gravity, and its eventual removal by the river. In the ingenious terrain the development of the stream remained very slow in comparison to metamorphic terrain, for the terrain was much resistant. The processes of valley widening had been more active in the lower course of the Dhundsir Gad basin. Some tributary streams such as Taula Gad, Sirsed Gad developed in this stage.

(iv) **Present stage**: The present landscape is, however, the result of the continued processes of sculpturing, of chiseling by the agents of erosion. The drainage system has been well developed in the metamorphic terrain and therefore, it is highly dissected. These processes have also modified the magnitudes of the slope in the basin. The present landscapes are mainly the result of the resents processes of denudation (Fig. 4). The main geomorphic features present in the area are escarpment, ridge, spurs, cliffs, waterfalls, terraces, alluvial conical hills and planner surface.

**Soil Type**

In a watershed eco-system, soil characteristics play a significant role in soil forming processes, run of control, infiltration, percolation of ground water and the susceptibility of the soil to erosion. Scientific data of the study area related to soil is not available. The principal sources of information available is on the basis of settlement reports, field investigations and first hand information on the soil characteristics. Each type of soil has given a local name. The soils in the Dhundsir Gad basin have been almost entirely derived from Quartzites and phyllites. Quartzite is hard, massive and brown at middle part of the study area. In the higher altitude (2000m) where oliva to oliva gray soils is also reported. Near the confluence with Alaknanda River, medium textured sandy loam soils were reported. The fineness or coarseness of soil depends upon the physical and chemical properties of the minerals. The particles of intermediate size viz. sand and clay form a silty soil. A mixture of sand, clay and silt is known as loam soil.

Among the important physical properties of soil is the texture. Soil texture involves the size of individual particles and their subsequent arrangement into groups. These
properties determine nutrient-supplying ability of soil solids and the supply of water and air necessary for plant and root development activities. Soil texture classes can be determined by different combination of sand, silt and clay. However, on the basis of investigations the soils of the watershed can be classified into the following division.

(i) Clay soil (River bed): Generally, this soil is formed by the fluvial processes. The largest areas of clay soil are found in river terraces / Gadheras, near springs, colluvial fans valleys where rivers have deposited eroded material. This soil type is good quality, in which intense agriculture practices is being practiced by local people having excellent yields crops of paddy, wheat and pulses. This soil at some places is mixed with gravels and rock fragments. Soil of this group has found mainly from the sediments deposited by the rivers Dhundsir Gad and his tributaries.

(ii) Loam clay (Stream valleys): These soils are found in valley areas i.e. Dang, Phayalgaon, Kharak and Koti. They comprises the smallest area of the watershed and is most danced populated part of the study area. Almost all crops can be grown on this soil but wheat, paddy, pulses and maize give buffer yields. The loamy soil is loose and lacking in cementing clay. The physical conditions are such that they can be worked very easily. They contain lime, potassium, phosphorus while the content nitrogen is low. The soils of this region have a tendency to become heavier as one proceeds from north to south.

(iii) Silts sand (forest and hill): Nearly 66% of the total area of the watershed is under forest cover. These soils have been formed by the decomposition of growing vegetation and fallen leaves of trees. The formation of these soils mainly depends upon the vegetation cover, local climate and rock types. In the study area this soil has very little agricultural value. Mainly inferior crops like Kodu, Jangora, Marcha and Fafer/Kotu etc. are grown on it. These soils are without humus and are the product of weathering of rocks. Big fragments of rocks and gravels are the main characteristics of these soils. This type of soil is found mainly of two types- one which is found in acidic condition and contains high quantity of acidic humus and low quality of bases. The other type is containing higher proportion of bases and forms under slightly acidic to natural conditions. This type of soil is very poor and is widely spread over the watershed and sparsely populated. The largest areas of loam silt are found on gentle slopes where it covers river beds.

(iv) Skeletal soil: On higher altitudes skeletal soil is found which contains a large number of gravels and rock fragments. This type of soil is less productive. Only Marcha and Ogal are grown on it. Sagoria Mittee which comprises the highly cultivated and manured land is
found in the immediate vicinity of the homestead. Moderately steep to steep slopes are occupied by Okhar land all over the catchment. The fine particles of the soil are removed by the erosion and weathering processes to produce rocky land.

The soil profile as such depends upon the slope, vegetation and landuse condition of the area. Near the springs and seepage zone, where the land is partially irrigated, fine to medium grained sub-matured soil is found. Gully erosion is very serious problem.

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