CHAPTER V

G E O M O R P H O L O G Y

GENERAL

Naini Tal area, apart from its interesting geology is characterised by a number of unique geomorphic features that has intrigued the workers in the past. The region has striking topographic contrasts. Within a small area, on one hand there are scarps and ridges, rising thousands of metres high with corresponding narrow and deep valleys, and on the other, are numerous lakes characterising broad flat depressions. The hill-sides are fairly unstable and evidences of extensive rock-slide are encountered almost all around the

Naini Tal Lake. This landform assemblage has attracted the attention of many geologists, who have, from time to time tried to explain the origin of lakes, scarps and rock-slides. The author too, in the course of his investigations had the opportunity to critically examine these peculiar geomorphic features. He found that the geomorphic evolution of the Naini Tal area has been essentially controlled by the lithology and structure of the geological formations. In his opinion, the views and explanations of the various previous workers were inadequate, because in most cases, a proper understanding and interpretation of the structural peculiarities of the area, was not attempted.

In the following lines, the author has briefly discussed the geomorphic evolution of the Naini Tal and its neighbourhood and has suggested the likely origin of the lakes, scarps, ridges, valleys and rock-slides.

ORIGIN OF LAKES

Previous Views

The Naini Tal district of Kumaon is dotted with numerous lakes, situated in a belt, 16 km long and 5 km broad near the border of the "Sub-Himalayan Zone", restricted to a narrow belt of 5 km to the north of the

Krol thrust. It is significant that none of the lakes occur to the south of this dislocation. The number of major lakes is ten viz. Naini Tal, Khurpa Tal, Saria Tal, Sukha Tal, Lampokhra Tal, Bhim Tal, Puna Tal, Naukuchia Tal, Malwa Tal and Sat Tal; out of which the first five lie in the study area. The remaining five lakes lie to the east and south east in Bhim Tal area. The lakes, are of various sizes and depths, the important one being the imposing crescent-shaped Naini Tal lake. All these lakes lie at an altitude between 1602 m (Khurpa Tal) and 1934 m (Naini Tal) and are of fresh water type. The origin of these lakes, as has been mentioned before has aroused considerable interest of geologists and geomorphologists since as far back as ~~in~~ 1877.

Previous workers put forth diverse theories to explain the origin of the Kumaon lakes but none could satisfactorily do so.

Ball (1878) believed in origin by landslides, whereas Theobald (1880) strongly suggested glacial origin. Oldham (1880) invoked slipping of huge blocks of rocks, while according to Meddlicott (1881) lakes might have originated due to differential uplifts and subsequent subsidences along groups of fractures aided by solution action.

The Swiss geologists, Heim and Gansser (1939) regarded the Ayarpatha region as a very broken structural mass, and Gansser's idea was that the region south-west of the Naini Tal lake had been affected by late post-tectonic sagging, thus causing the breaking up of stratification. Auden (1942a) agreed with Heim and Gansser (1939) but said that much larger area should be shown as a slipped mass.

Thomas (1952) who approached the problem somewhat more systematically, suggested the following twofold broad division of the Kumaon lakes:

(1) The Naini Tal group,
(2) The Bhim Tal group.

He took into consideration the fact that the Naini Tal lake and its ancillary small lakes were situated amongst the outcrops of Krol dolomites and slates, while the Bhim Tal group of the lakes was situated amongst the Nagthat (Blainis of the author) quartzites, the green stones and the slates. According to him, the factors which conditioned the lake formation in Kumaon were (i) very recent earth movement and (ii) diversified lithology.

Thomas has suggested that the lakes of this size were but temporary geological features and their frequency in this small region must be connected with a very recent, rapid and irregular local movement. He believed that the irregular eroded surface of the Siwaliks over which the Krol nappe has moved must have contributed to the formation of surface irregularities.

<u>Present Author's Views</u>

The present author too has to offer his own opinion on this subject. On the basis of structural studies, he has observed that the Kumaon lakes have originated by a combination of structural and lithological factors. According to his findings, almost all the lakes including the Naini Tal and the Bhim Tal, are fault controlled.

Certainly, the lakes are not of glacial origin. The "barrier" at the SE edge of the Naini Tal lake claimed as glacial moraine by Theobald (1880) is in fact an accumulation of the slide-debris of Krol limestones that has come down from the north-eastern part of the Ayarpatha ridge. Furthermore, the region does not show any glacial features as cirques, U shaped valleys, erratics or any polished or striated rocks. The author also disagrees with Ball (1878) and Blanford (1894) who invoked huge landslips to explain the formation of lakes. Even the contention of Thomas (1952) that the Ayarpatha hill is a slipped mass from China peak, is not supported by the author's mapping. While the China peak rock is a Lower Krol shaly limestone, the one at Ayarpatha is dolomitic limestone of Upper Krol age. Also the argument of Thomas (1952) that the China peak and Ayarpatha hill contain identical trap rocks is not valid. In fact, the two mafic rocks are quite different in mode of occurrence and chemistry.

The author is of the opinion that the formation of the various lakes in this region could be attributed to the following two main factors:

(1) Subsidences of rock segments at fault intersections,

(2) Rock slides.

The author has discussed below the salient features of the origin of the various lakes in detail.

Naini Tal Lake

The Naini Tal Lake is situated in a valley like feature at an altitude of 1934 m above Mean Sea Level. It forms a 1.5 km long crescent-shaped water body along the Naini Tal Lake fault. In fact, the valley like feature which is occupied by this lake is a fault-line valley (Plate 5.1).

This lake is formed on account of the combined effects of the Naini Tal Lake fault, Khurpa Tal fault and Lariakanta fault. These faults have so developed that a rather big chunk of the Naini Tal synclinal nose has subsided. Due to intersection of the Naini Tal Lake fault and the Khurpa Tal fault the rock mass to the S and SW of the lake has gone down, while the portion to the N and E of the lake has subsided on account of the Lariakanta fault. Subsequent to the faulting, rock debris from the overhanging scarps have further added to the process of lake formation. The accumulated debris has acted as barrier to the water from escaping. The entire Talli Tal area comprises slide material mainly limestone boulders of huge dimensions.

The author believes that though the rock-slides were not the prime cause of the lake formation, they

PLATE 5.1

A full view of Naini Tal lake.
(From China peak

were quite important in their subsequent morphology. The lithology and climatic factors have aided the rock slides. Shaly and slaty rocks tend to be rather unstable on steep slopes, and in areas of sudden and heavy rainfall and intense frost action, incompetent and softer rocks would result into slides. It is quite obvious that the Naini Tal lake occupied a larger area in the past, but on account of the accumulation of slide material and perhaps recent uplifts of the entire terrain, the lake has shrunk to its present size. Its original extent is clearly recognised in the flat terrain comprising lake deposits in the WNW as far as Sukha Tal.

A most striking feature of the Naini Tal lake is that no major river or stream flow into it. The drainage map (Fig. 5.1) of the area reveals that no stream discharges into the lake from any direction except some transient 'rivulets' that discharge their water into it from the north during rainy seasons. On the other hand, the south-eastern edge of the lake provides the starting point of the Balia river which flows away from the lake SE in a south-eastern direction, following the course of the Naini Tal Lake fault. Inspite of this the lake has never been reported to go dry. Even in extreme dry periods a fall in the water level upto a maximum of 3 metres is observed.

The problem of the water replenishment in the Naini Tal lake is still not very clear. Perhpas, the highly cleaved and fractured slaty rocks of the China peak in NW and of the slopes in the N and NE which all tend to dip towards the lake, might be affording easy passage to rain-water into the lake. Also, it is not unlikely, that some underground channels in Krol limestones could be providing some water.

Sukha Tal

The Sukha Tal, a less conspicuous seasonal lake to the WNW of the Naini Tal lake, according to the author, is a part of the original Nàini Tal lake, now somewhat filled up by the rock debris and lake deposits and occupies a slightly higher elevation. It is seen to contain water only during and after the rainy season for a short period. The name 'Sukha Tal' itself implies a 'dry lake'. Obviously, it occurs just at the junction of the Naini Tal Lake fault and the Khurpa Tal fault. During rains it receives lot of water, but the most of it escapes to the Naini Tal lake.

The length of this lake in NNE-SSW direction is nearly 200 metres and the breadth is 100 metres in E-W direction. It is about 10 metres deep from the surrounding area but the water level never exceeds the 3 m mark. The huge boulders of dolomitic limestone lying unsystematically at the southern side of this lake are clear indications of a fault line valley (Khurpa Tal fault).

Saria Tal and Khurpa Tal Lakes

These two rather small lakes lie to the SSW of Sukha Tal along the Nihal valley, that follows the Khurpa Tal fault. The Saria Tal lies between the Sukha Tal and Khurpa Tal. The Sukha Tal occurs at the highest elevation, then comes the Saria Tal and finally the Khurpa Tal, which is relatively at the minimum altitude.

Of course, the lakes have developed on account of the damming of the fault line valley along the Nihal river at two points. But this damming is not only clue to rock slides. It is not adequate to invoke accumulation of rock debris by rock slides as the prime cause of lake formation. The author has found that the lakes have formed only at such points where the gradient of the valley has decreased, and this gradient reduction is seen to be due to the north dipping Krols which provide ideal shallow basin like depressions. The Khurpa Tal fault not only shows a strike slip movement, but it is also seen to show a down throw to the east. As a result shallow synclines (plunging with a few degrees to the west) abut against the massive upper Krol limestone. Once such structural basins were formed, the water flowing down the Nihal valley, started accumulating as small lakes, before overflowing and proceeding further down south. The large amount of sediments that was transported by the river comprised the scree material and slide debris added to the river from the over hanging cliffs. In due course, the lakes considerably shrank and at present they are seen as waterbodies within unconsolidated material.

As the Nihal river, which starts from the southern slopes of Hindi Bandi area and is fed by the underground water sources of Deopatha hill, the Saria Tal, in contrast to the Sukha Tal, is perennial. This lake is hardly one to two metres deep, one hundred metres in length and fifty metres in width. The Nihal river falls into this lake, overflows it through a small waterfall, and further continues southward. Rock boulders that have come down from the overhanging cliffs have considerably added to the process of damming and lake formation.

Khurpa Tal lake is situated nearly at the southern end of the Khurpa Tal Lake fault (Plate 5.2). It is 300 metres long, 100 metres broad and 10 to 20 metres deep. Its origin is nearly the same as that of Saria Tal, but this lake almost entirely is located within the unconsolidated sediments and rock debris, except along the western edge. It is interesting to note that the Nihal river at present does not meet the lake, and follows a course a little to the east, avoiding this lake. Evidently, this phenomenon is typically illustrative of recent uplift. Originally, this river must have been quite sluggish and flowing through Khurpa Tal and its deposits, but due to sudden uplift, it rejuvenated and one of its distributary channels started flowing within the unconsolidated material, carving out a steep gorge.

<u>Lampokhra Lake</u>

This water-body also is structurally controlled. It occurs at the intersection of Pokhra fault and a small

PLATE 5.2

A view of Khurpa Tal lake

syncline in the upper Krol limestones. This depression is hardly 100 metres in length, 50 metres in breadth and one to 3 metres in depth. It is a small seasonal lake, remaining dry for the most part of the year.

From the preceeding account it is seen that the various lakes in the study area, have a strikingly similar mode of origin and development. The main fact that emerges out is that all the lakes are situated in what is known as "fault-line valleys". Secondly, the dips of the strata and their tendency to form shallow synclinal structures has facilitated water accumulation. The lithology has also played its role by providing impervious bed rocks and affording suitable channels and planes for the replenishment of water.

Of course, the author would not like to belittle the role of rockslides in the process of lake formation. Almost all the lakes very clearly show huge boulders as well as fine scree material all cemented together and providing ideal barriers. For causing rock slides again the lithology, fracturing, heavy rains and frost action are important.

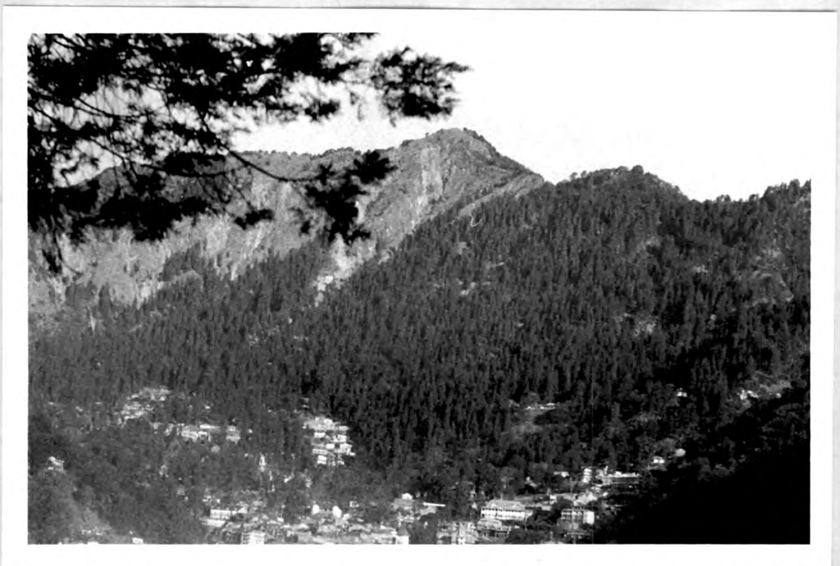
It is thus a unique combination of faulting, folding and climatic factors, that has given rise to Kumaon lakes, and to consider these lakes as temporary and very modern features as has been by Thomas (1952) is not very correct. These geomorphic features are fundamental and almost permanent.

SCARPS

The various scarps comprise another important geomorphic feature of the study area. Faults have played a very important role in the scarp formation too. Also, the lithology has contributed its own share. The author has found that the majestic scarps that overlook the Naini Tal lake and its neighbourhood invariably lie along the fault lines, and the lithological boundaries.

The most striking scarp is that of China peak (Plate 5.3) along its NNE-SSW flank. It follows the Lalpani fault. This scarp has developed on account of the subsidence of Lower Krol rocks of the north-eastern side of the Naini Tal lake. This subsidence has been facilitated by the Lariakanta fault. The slates and shaly limestones have been truncated across their strike. This fact has aided in the scarp formation. It is observed that frost action and heavy rains cause considerable rock-slides along its high cliffs, and as a result of this,

PLATE 5.3



A view of China peak scarp.

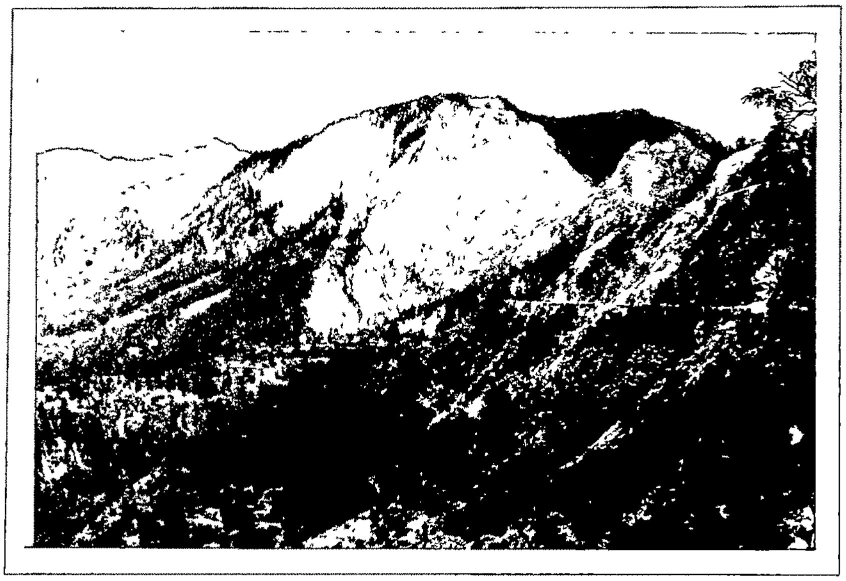
the scarp line is gradually receding westward without loosing its steepness.

Another equally important scarp is that of the Deopatha hill, which is again a fault scarp. Steep walls of this hill form the western face of the Khurpa Tal fault. The subsidence of the eastern side has resulted in this scarp. The rocks of this hill being hard dolomitic Krol limestones, have added to the steepness of the cliffs. These rocks are such that their weathering by frost action and rains results into craggy and steeply inclined surfaces. Had this limestone been not there, perhaps the fault scarp would have got eroded and smoothened out.

In comparison, the NW-SE scarp along the Lariakanta hill (NE of the Naini Tal lake) is much less steep. Though this scarp is also a product of faulting, the lithology of the rock types in its cliffs, has considerably subdued its steepness. Here, unlike the Krol limestones, quartzites and slates are less prone to form craggy and vertical slopes, and as such the cliff face of this scarp facing SW is comparatively less steep. The Lariakanta fault is a normal fault where the Lower Krol shales and shaly limestones to its west have gone down.

The Ayarpatha escarpment (Plate 5.4), on the other hand has an entirely different origin. Its E-W trend that marks the Lower and Upper Krol contact is definitely not a faulted one. This contact is a normal junction between the underlying slates and shaly limestones, and the author is not in a position to agree with the views of Thomas (1952) and Heim and Gansser (1939) that this junction is a thrusted contact. As has been already stated earlier, the author has found no evidences to consider the rocks of Ayarpatha to be identical to those of China peak. In fact, they belong to two different horizons, Upper and Lower Krol respectively. It is also not correct to say that folds do not exist in the limestones of the Ayarpatha. As regards the scarp formed along the contact of the Lower and Upper Krols, it is typically a phenomenon of differential response of the two rock types to the atmospheric agencies. This scarp has formed on account of (i) very gentle northerly dips, (ii) resistance of Upper Krol limestone to disintegration in contrast to the relatively rapid weathering of the underlying softer rocks, and (iii) the presence of large E-W vertical joints in the dolomitic limestones.

PLATE 5.4



A view of Ayarpatha escarpment.

It is worth mentioning that the heights of the different scarps, having originated primarily due to fault action, are indicative of the uplift and subsidence that occurred along the dislocations. In a way, the agents of weathering have not yet fully destroyed and smoothened out these height differences, and in this sense the fault scarps indicate relatively youthful topography.

ROCK SLIDES

Slope instability and rockslides are another salient features of the Naini Tal hill sides. Rock-falls and rock slides are so common here that hardly any year passes without a few major or minor catastrophies of this type. In fact, this phenomenon has now been attracting considerable attention of geologists and engineers, and attempts are being made to take all possible remedial measures.

The author has given some thought to the problem of rock-slides also and he has found that the instability of the area is again due to a combination of structure, lithology and climate.

Rock falls

The rock-falls comprise mainly sudden fall of huge boulders and chunks of hard rocks, mainly the Upper Krol limestone. These take place all along the steep cliffs and faces of the scarps. Big masses of rock near the edge of the cliffs get progressively detached by the action of rains, frost and heat, and then all of a sudden during a heavy downpour or sometimes even without it, they come tumbling down the cliff sections.

Rock slides

To the category of rock slides belong the movement of softer rock masses and of weathered rock mantles on steep slopes. In this type, the entire rock mass slides down under the effect of gravity. Such rock-slides are confined mainly to the highly cleaved and fractured Lower Krol rocks along the northern and north-eastern slopes facing the Naini Tal lake. Here too, the frost action might be important, but in almost all cases, rain water percolating below and lubricating the weaker planes, triggers off the sliding movement.

DRAINAGE

The drainage of the Naini Tal area is also controlled by the structural features. The overall stream pattern in the region can be regarded as rectangular or angulate and it reflects the control exerted by faults, cleavages and fold system.

The various major streams of the area follow the main faults. The Balia river flowing away from the Naini Tal lake follows the course of the Naini Tal Lake fault towards SE, and further beyond Jeolikot, where the Naini Tal Lake fault meets the Krol thrust, the river also takes a turn and follows the Krol thrust trend. The Nihal river which originates from Deopatha and Handi-Bandi follows its course along the Khurpa Tal fault.

To the NW of the Naini Tal lake, the China pass forms a small watershed, such that one stream starts from here and flows eastwards along the Naini Tal Lake fault to meet the Naini Tal lake. The other prominent stream (Lunwanta Gad) flows due west from this watershed following the course of the above fault. Lalpani Gadhera, a small stream flows due NNE and meets the Jakh river. Pangot river also flows due NNE following the course of the Pangot fault and meets the Jakh river.

In southern part, i.e. the south of the Ayarpatha ridge, the area almost entirely consists of the unconsolidated material, which has slid down from the southern side of the ridge (Plate 5.5). Three comparatively major streams flow from Ayarpatha ridge. They drop down from the limestone ridge forming waterfalls of nearly 30 metres high and then flow further south in the unconsolidated material. All these streams flow from Ayarpatha, meet the Nihal river near Krol thrust and then flow beyond it further south.

DISCUSSION

The author has dealt with the various geomorphic features and brought out their structural control. It is so evident that the geomorphic evolution of the Naini Tal area has almost entirely depended on the various faults and folds. A proper understanding of the fold and fault pattern,eliminates considerable confusion that has prevailed in interpreting the peculiar geomorphic characters of the area. Of course faults are there, but to invoke regional slides and thrusts to explain detached rock masses is rather far-fetched. Allowing for the normal subsidences along the down thrown fault blocks, the entire terrain has, according to the author remained in-tact and in place, and there is nothing mysterious or chaotic about its geomorphic evolution.

PLATE 5.5

A general view of the area to the south of Ayarpatha ridge.