CHAPTER V

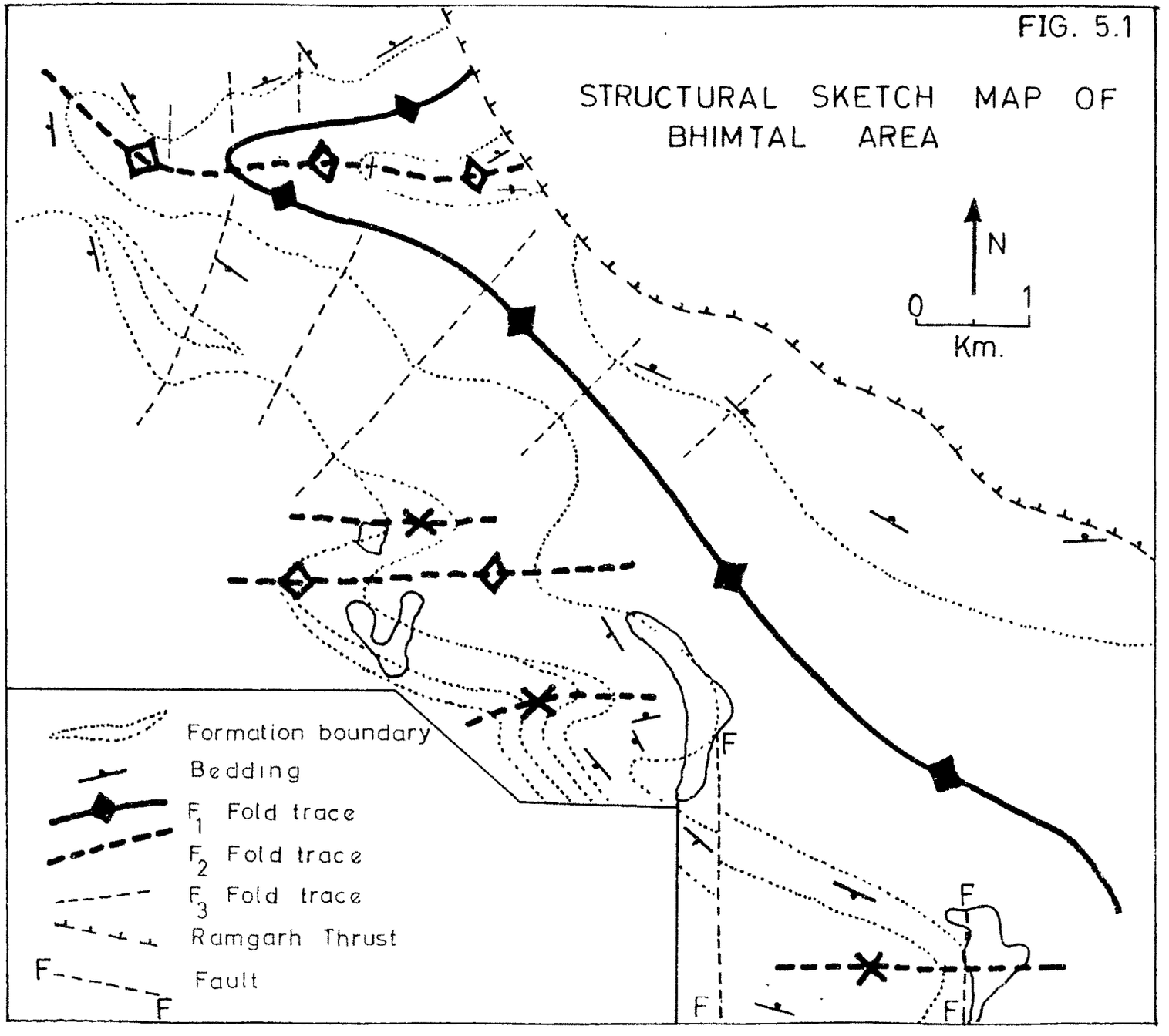
S T R U C T U R E

GENERAL

The anticlinal disposition of the quartzitic rocks of Bhowali and Bhimtal has been recognised by almost all the previous workers. But none in the past could provide structural details. The present author has now prepared a map, wherein almost all the major structural features of the area, have been duly recorded. The author has attempted to work out the existing structural pattern and the sequence of tectonic events that affected the area in the past (Fig. 5.1). In this task, he has taken much help

FIG. 5.1

STRUCTURAL SKETCH MAP OF BHIMTAL AREA



from the findings of the workers in the adjoining Garampani (C.P. Shah, 1973) and Naini Tal (Devendra Pal, 1973) areas.

In working out the structural geology of the area, the author has relied on a detailed mapping of the rock types, especially the quartzities. Though he paid due attention to the various planar and linear structural elements present in the area, but he could not utilize them adequately. The two main rock typed viz. quartzite and trap, are much jointed and fractured, and as such it was found difficult to decipher and sort out planar structures of successive generations preserved in them. Similarly, the quartzites show very few minor folds. The trappean rocks do contain small crinkles and puckers, but their occurrences are too sporadic to provide any conclusive information. The degree of exposure is also not adequate. On account of these reasons, the author was unable to attempt a systematic geometrical and statistical analysis of the structural elements.

Mapping and field study has revealed that the area has undergone three sets of folding and has been affected by one thrust. The various tectonic events show the following chronology:-

(1) Folding that gave rise to the main anticline (F_1),

(2) E-W folding superimposed over the anticline (F_2),

(3) Ramgarh Thrust,

(4) Gentle NE-SW flextures (F_3).

A perusal of the geological and structural sketch map of the entire Naini Tal-Bhimtal-Garampani region (Fig. 3.2) fully substantiates the tectonic pattern of the study area worked out by the author. The Bhowali-Bhimtal anticlinal structure (F_1) is seen refolded by a late E-W fold. The Ramgarh thrust that extends NW-SE in the north-eastern part of the study area is seen truncating the late F_2 structures also. It is thus most obvious that this dislocation developed after the E-W folding. The mapping has also revealed that the entire area, including the Ramgarh thrust, was subjected to yet another folding (F_3), which has given rise to the numerous NE-SW open flexures, imparting a certain waviness to the strike trends.

FIRST FOLDING (F_1)

Major Structures

The main regional anticlinal structure (Bhowali-Bhimtal anticline) belongs to this folding. The rocks that overlie the spilitic traps, very clearly show this

anticline. On account of the superimposition of late E-W folding the trace of the axial plane of the anticline shows a hook shaped trend. When traced from E to W, it extends WNW upto Bhowali, and thereafter takes a sudden bend and follows a east-north-easterly trend.

The trappean rocks occupy the core of the anticline. The quartzites and slates on the south-western limb show moderate southerly to south-westerly dips. The other limb to the NE, comprising quartzites dips due NE. Both the limbs show considerable variation in the values of dip and strike on account of the effects of late foldings.

Minor structures

Planar and linear structures related to the main F_1 anticline are sporadically recorded.

The most conspicuous planar structure is the axial plane foliation, that has developed in the slaty layers above the quartzites. But the development of such a cleavage is not universal; and its formation is seen to depend on the overall lithology of the beds. Very thin argillaceous layers in quartzites have on the other hand, developed cleavages due to flexural slip and are thus parallel to the bedding. It is not uncommon to come across

small folds where cleavages parallel to the bedding as well as the axial plane, have developed. This fact clearly shows that the mechanism of folding was a combination of a flexural slip and slip parallel to the axial plane (Fig. 5.2).

The trappean rocks, though conspicuously foliated and cleaved, do not reveal any distinct and well defined relationship with the fold. At most places, the cleavages suggest flexural slip, and as such dip parallel to the either limbs. At some places however, a strong and close jointing in traps with subvertical dips resembles a cleavage parallel to the axial plane. The traps are on the whole highly jointed and show several joint sets, and it is not possible to fully sort out in traps the planar structures related to this folding (Plate 5.1).

So far as the linear structures related to F_1 folding are concerned, they are 'b' type lineation and comprise (i) axes of minor folds and (ii) cleavage bedding intersection. Minor (F_1) folds are not very abundant, and are only sporadically recorded on the two limbs of the anticline, specially on the south-western limbs (Plate 5.2). In most cases, these minor fold axes show a moderate north-westerly plunge. This fold axis lineation is not so well defined within the trap. As regarding the cleavage-bedding

FIG. 5.2 Sketch of a sample showing the combination of a flexural slip and slip parallel to the axial plane.

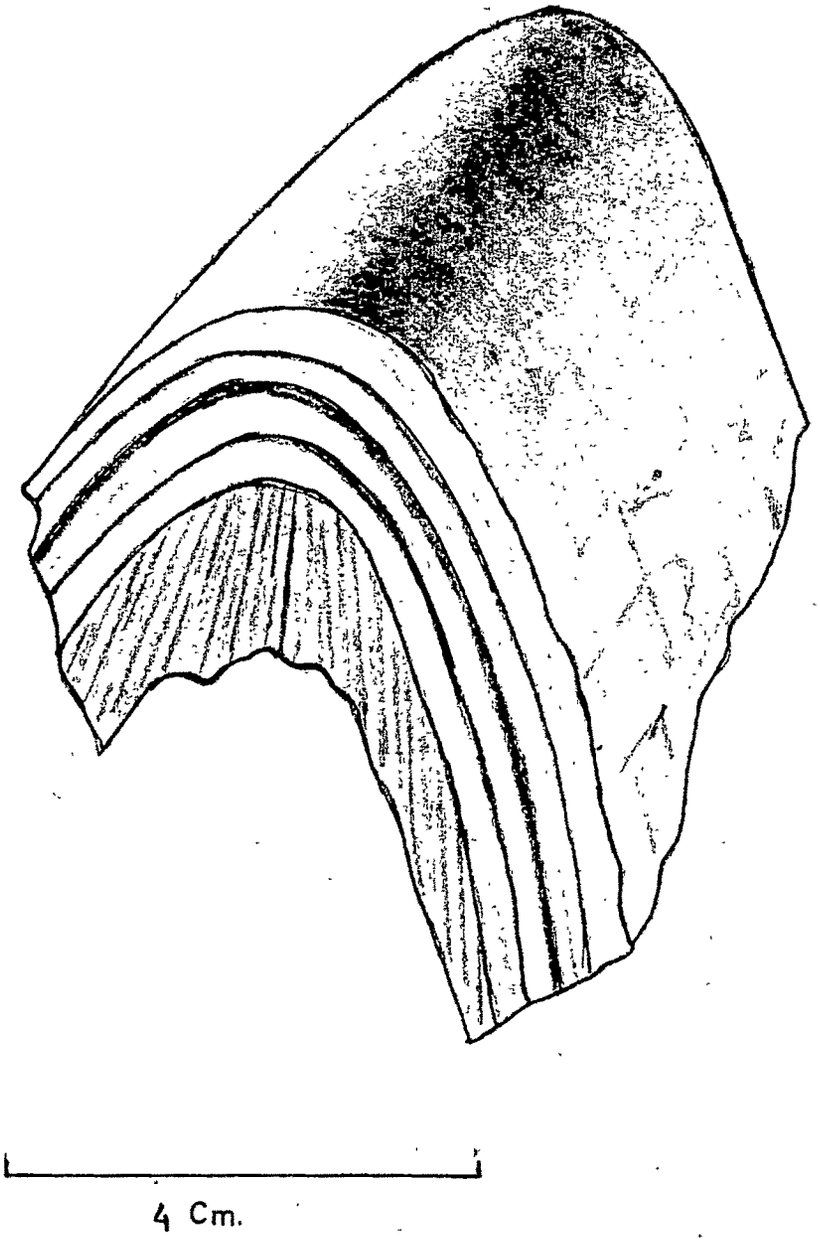


PLATE 5.1

Field photograph of foliated and jointed traps (Loc. Near Ghorakhal).

PLATE 5.2

Field photograph of a fold (F_1) in quartzite-slate. (Loc. West of Bhimtal near Bohrakun, on the road to Kathgodam).

intersection type, this also is well developed in the alternating quartzite-slate sequence in the south-western part. It also shows a north-westerly plunge.

SECOND FOLDING (F_2)

Major structures

Superimposed over the main F_1 anticline are a few antiform and synform of F_2 generation. In all there are three F_2 structures, of which one is quite big and has affected both the limbs of the F_1 anticline. It is this antiform that has imparted a hook-shape to the structure. Axial trace of the fold is almost E-W, extending eastward from Bhowali to Gorakhal. This F_2 fold has been designated as Bhowali-Gorakhal antiform. A complimentary synform of equal dimension, occurs to its north and lies outside the limit of the study area (see regional map Fig. 3.2). The Ramgarh thrust truncates this pair of synform and antiform. The author has also visualised two somewhat smaller F_2 folds to the south of the Bhowali-Gorakhal antiform. These have developed on the south-western limb of the F_1 anticline. Due to paucity of good exposures, he was unable to collect adequate field data to conclusively establish the existence of these

folds, but on the basis of whatever readings he could take in the neighbourhood, it appears that the two smaller folds comprising one more pair of F_2 synform and antiform, make an open Z shape.

Considering the foliation trends, and the geometry of the small crinkles associated with these folds, it is reasonable to assume that the axial planes of the two larger structures are subvertical and trend E-W. The fold axes plunge gently due west. Existence of these structure is further supported by the presence of numerous macroscopic F_2 flexures in the area to the south of Bhimtal, just outside the study area.

Minor structures

The effects of F_2 folding are abundantly encountered almost in all parts of the area, especially in the trappean rocks. The most important minor structural features are the crinkling, puckers and macrofolds. These are abundant in the hinge areas of the F_2 folds. The cleavage in the traps is seen extensively crinkled. The axial planes of these macrofolds are subvertical and show strikes that vary from WNW-ESE through E-W to ENE-WSW. The axes of these tiny folds show very gentle plunge either towards

WNW or to the E. The author has observed that the variation in the strike of the axial plane of F_2 crinkles and the plunge of the fold axis is due to the effect of the late NNE-SSW fold (F_3).

RAMGARH THRUST

Nature of the dislocation

Existence of this thrust has been recognised by many previous workers, but the present study has revealed for the first time, its proper place in the time sequence of the various tectonic events that affected this part of Kumaon.

The author's mapping supported by that of Shah C.P. (1973) in the Garampani area further north, has shown that the Ramgarh thrust cuts the F_2 folds. It is thus obvious that the dislocation constitutes the next major tectonic event after the second folding.

As it is today, this dislocation appears to be a high angled thrust, extending roughly NW-SE and dipping due NE. It has brought the older rocks over the Bhimtal Traps and the Bhowali Quartzites.

The various previous workers have not explained the true nature of this dislocation. Heim and Gansser

(1939), Gansser (1964), Pande (1950) and Valdiya (1962), all have considered this dislocation to be a folded continuation of the Almora thrust. According to Heim and Gansser (1939, p.28), the region between Bhowali and the South Almora thrust comprises a recumbent syncline overturned to the SW (Fig. 3.1).

Merh (1968, p.6) however, for the first time pointed out that the Ramgarh thrust and the Almora thrust were quite distinct dislocations, and the former did not constitute the southern flank of the synformally folded Almora thrust as postulated by Gansser (1964), nor do the rocks above the Ramgarh thrust form a syncline, recumbent or otherwise. Further Merh (1968) suggested that the Ramgarh thrust is a subsidiary dislocation related to the Krol thrust. In a subsequent paper written jointly with Patel J.P. (Merh et al.,1971), Merh postulated that this thrust which was of the nature of a regional reverse fault, had developed by the rupturing of a large anticline of the same generation as that of the synformal folding of the Almora thrust sheet.

But, the recent work including that of the present author has shown that this thrust is in no way related to the folding that gave rise to the Almora nappe synform

and the Bhowali anticline. There was a considerable time-gap between this folding and the formation of Ramgarh thrust. The Bhowali and Ratighat areas clearly show that this thrust truncates the E-W folds that were superimposed over the Bhowali-Bhimtal anticline.

The Ramgarh thrust as mapped by the author shows some fluctuation in its strike, though its general trend remains NW-SE. The dip of the thrust plane is difficult to measure but it varies from steep to moderate and is always to the NE.

Taking into consideration the findings of the workers in the neighbouring areas, the author tends to agree with Patel J.P. (1971, p.143) that the Ramgarh thrust originates from Krol thrust and that the two dislocations developed at a date later than F_2 folding.

Minor structures

Very conspicuous planar and linear structures have developed in the overlying rocks. These comprise (i) strain-slip cleavage (ii) slickenside and (iii) axes of tiny crinkles.

The strain-slip cleavage is related to sharp hinged monoclinal flexures (Plate 5.3), that have developed in the overlying phyllites perhaps due to a drag effect. These folds are seen to vary in size from mesoscopic to microscopic scale. The most characteristic features of these folds are their angular hinges and SW dipping axial planes. Extensive slipping along numerous shear planes (somewhat parallel to the axial planes of these flexures) has in turn, crinkled the schistosity and given rise to a crenulation/ strain-slip cleavage. The fractured axial planes of the monoclinal angular folds and the associated strain-slip planes comprise the dominant planar structures.

Extensive slickensides have developed due to the slipping of the foliae during the Ramgarh thrust movement. This slickenside lineation indicates the actual direction of slipping, and are of the nature 'a' lineation.

Axes of the tiny monoclinal crinkles and microfolds related to the drag folding comprise a distinct puckering and show widespread development in the vicinity of the Ramgarh thrust. These are distinguished by their very gentle SW dipping axial planes and strain-slip cleavage.

PLATE 5.3

Photograph of a specimen of highly sheared and crumpled granophyre resembling a phyllite and showing strain-slip cleavage.

THIRD FOLDING

This fold event has given rise to numerous gentle flexures whose axial planes strike NNE-SSW. The fold axes of these flexures however show plunge either to the NNE or SSW, depending on the dip of the two limbs of the F_2 structures. It is on account of this folding that the trace of the Ramgarh thrust tends to be sinuous.

In the present area F_3 flexures are not very conspicuous, on account of paucity of good and continuous exposures. Minor structures too, related to this fold event are sporadic, and are represented by stray crinkles in foliated traps.

This N-S to NNE-SSW folding has been recorded almost all over the Kumaon, and is seen affecting the rocks of Almora Nappe and Krol Nappe, as well as those of the autochthonous Siwaliks across the Main Boundary Fault (Vashi N.M.,1966; Patel J.P.,1971; Shah C.P.,1973; Devendra Pal, 1973). The present author took numerous traverses in the areas further north and he found that the effect of F_3 is quite prominent in the rocks of Almora crystalline.

FAULTS

The author has inferred two N-S faults that lie in the southern part of the area. On account of bad exposures, exact delineation of these faults is not possible, but it is quite evident, that one at Bhimtal and the other at Nakuchhiya Tal, are in some way responsible for the formation of these two lakes. The entire physiography of the broad valley is such that it reveals damming of a large river. It is not unlikely that these two faults as well as one other further east, were responsible for the formation of a big lake, which subsequently got filled up.

The two faults mentioned have been referred to as Bhimtal fault and Nakuchhiya fault. The two parallel faults are such that the middle trough portion has gone down.