CHAPTER V

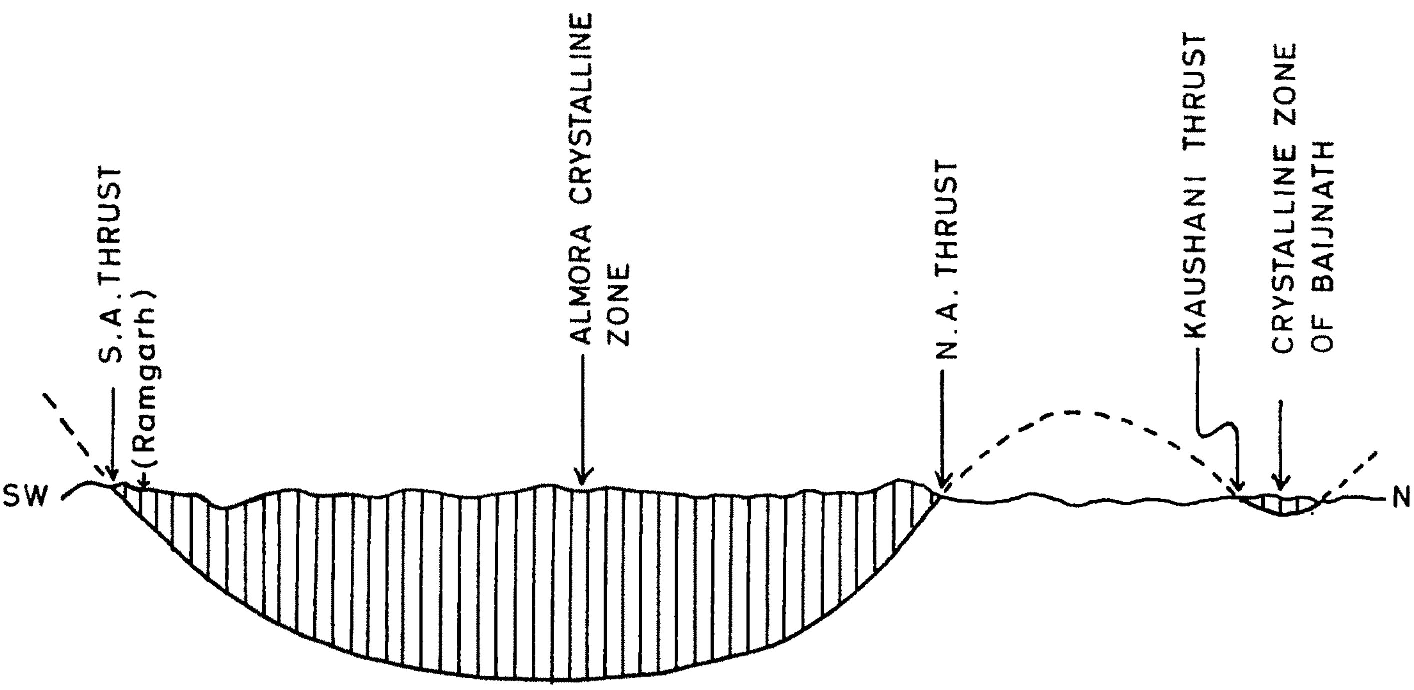
CHAUKHUTIA-MANWA DEVI GROUP

(KROL NAPPE)

GENERAL

The rocks of this Group, though stratigraphically younger than the Karchuli Group, structurally lie below the latter. A perusal of the section prepared by Heim and Gansser (1939) for this part of Kumaon (Fig. 5.1) shows that they have taken the tectonic contact (running in the study area along the Khastari Gadhera) between the Karchuli Group (Almora Nappe) and the Chaukhutia-Manwa Devi Group (Krol Nappe) as the south-west dipping Almora Thrust, designated it as North Almora Thrust and connected

Fig.5.1



SECTION FROM RAMGARH TO BAIJNATH SHOWING THE FOLDING
OF ALMORA THRUST AFTER HEIM AND GANSSER (1939)

it the north-east dipping thrust at Kaushani further north-east, comprising two limbs of an antiform. The rocks of Chaukhutia to the east of the Khastari Gadhera, according to them, occupy the antiformal core and comprise a part of the Krol Nappe. The author has found that this interpretation may not be fully valid, and his investigations have revealed that some of the pre-existing concepts regarding the North Almora Thrust and the stratigraphy of the Krol Nappe rocks need revision.

According to the mapping of the author, the thrust that separates Krol Nappe rocks of Chaukhutia-Manwa Devi Group from the Almora Crystallines, has been pushed beneath the former due to the dislocation (along the Khastari Gadhera), a major reverse fault that dips steeply due east (Fig. 5.1a).

The rocks of the Chaukhutia-Manwa Devi Group, show following depositional sequence:

Quartzites (including Subgraywackes)
Chlorite schists (foliated spilites, tuffs etc.)
---------------Unconformity---------------------
Dolomitic limestones
Slates and quartzites

The above sequence forms a NNW-SSE anticline which has been so truncated along its crest by the reverse fault (Khastari Fault) that the western limb has been thrown down. As a result, the two limbs of the antiformal structure do not correspond.

SLATES AND QUARTZITES

This lowermost formation immediately to the east of Khastari fault is ideally exposed around the Ganai village and to its E and NNE. It comprises a sequence of interbedded slates and quartzites.

The slaty layers vary in thickness from a few centimeters to as much as a couple of meters. They are finegrained, show a well developed slaty cleavage and are of brownish yellow, purple grey and grey colour. The variation in colour is so rapid and frequent that sometimes a single specimen may possess all the colours. This variation in the colours is attributed to the different degrees of oxidation of iron in the slates. The factor controlling the colour is the ferrous and ferric iron content in them. According to Pettijohn (1964, p.347) "the red slates contain no more iron than do those which are black, gray or green. The colour differences reflect only the state of oxidation of the iron. Red shales are so coloured because of the presence of finely divided ferric oxide (hematite). In the green and black shales the iron is largely in the ferrous state".

The slates are highly cleaved and jointed. Under the microscope, their thin sections show a very fine-grained foliated mass in which tiny specks of muscovite, chlorite, sericite and quartz are recognized. The development of cleavage is due to the parallelism of mica and chlorite and streaky quartz.

The interbedded quartzites are of dull brown and light pinkish colour, medium to finegrained, and form 1 meter to 30 meters thick layers. The slaty cleavage is always parallel to these quartzitic layers. Sedimentary structures like current bedding or ripple marks are significantly absent.

In thin section, the quartzites are seen to consist of mostly quartz grains embedded in a foliated argillaceous matrix. A few scattered flakes of muscovite and grains of magnetite are the only other minerals. The quartz grains show a considerable variation in the degree of roundness varying from subrounded to subangular. It is significant that the individual quartz grains are free from strain shadows or any obvious shearing effect, and this is indicative of the fact that during deformation the strain was mostly taken up by the argillaceous matrix.

DOLOMITIC LIMESTONES

The slate-quartzite sequence is overlain by a thick carbonate horizon, comprising beds of dolomite and dolomitic limestone with interbedded slates and quartzites. In its upper part, the limestone is seen to contain stromatolites. As compared to Someshwar and Dwarahat, the development of stromatolites in Chaukhutia area is much restricted, and rather sporadic. The carbonate formation is approximately 3 km wide and is seen to show the following sequence:

Limestone generally greyish green,
(with slaty layers) showing algal structures.

Cherty quartzite

Limestone greyish green, pink white,
very fine grained with slaty layers.

The unusual thickness of the above formation is due to repeated folding so clearly recognised in the field. It has been observed that on the whole, the limestone below the cherty quartzite, is very fine-grained, while that above is crystalline and granular. Of course, no hard and fast demarcation is supposed to exist on these lines.

Thin sections of the various samples of limestones, reveal following textures:-

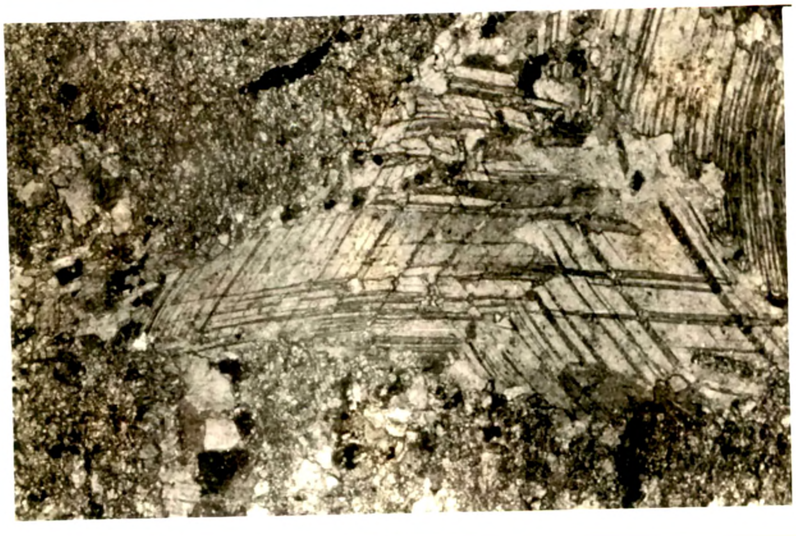
1. Very finegrained where it is not possible to identify any mineral (Plate 5.1).

2. Finegrained granular with streaks and patches of coarse crystals. Here the main mass consists of tiny grains of carbonate (mostly dolomite) with occasional needle of a mica (muscovite) and dustry grains of iron oxide (goethite). Irregular streaks and patches of well developed crystals of calcite are seen interspersed (Plate 5.2). A few samples show a little bigger grain size and these are calcite rich. Occasionally, the presence of thin streaks of cherty silica are recorded (Plate 5.3). The limestone in the vicinity of the (cherty) quartzite layers, contain sporadic grains of quartz in association with calcite (Plate 5.4).

PLATE 5.1

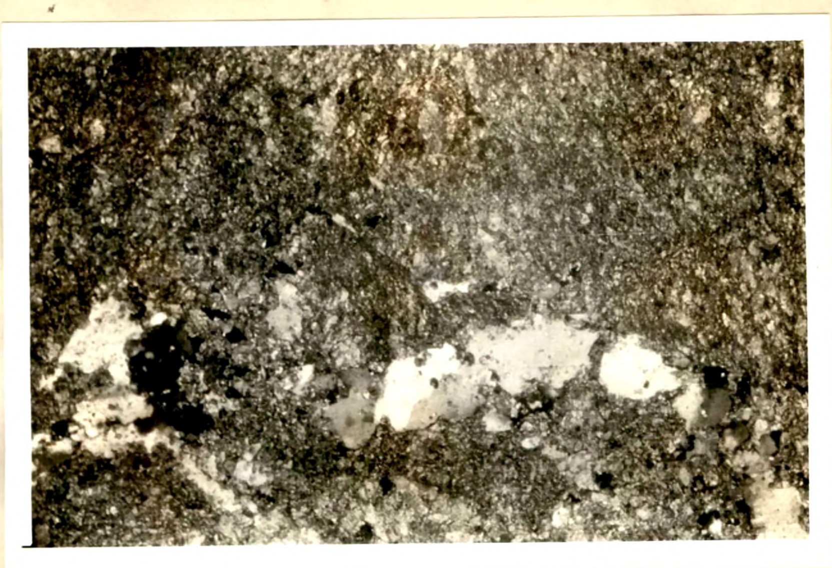
Very fine grained dolomitic limestone.
(Photomicrograph: Cross nicols, X75)

PLATE 5.2



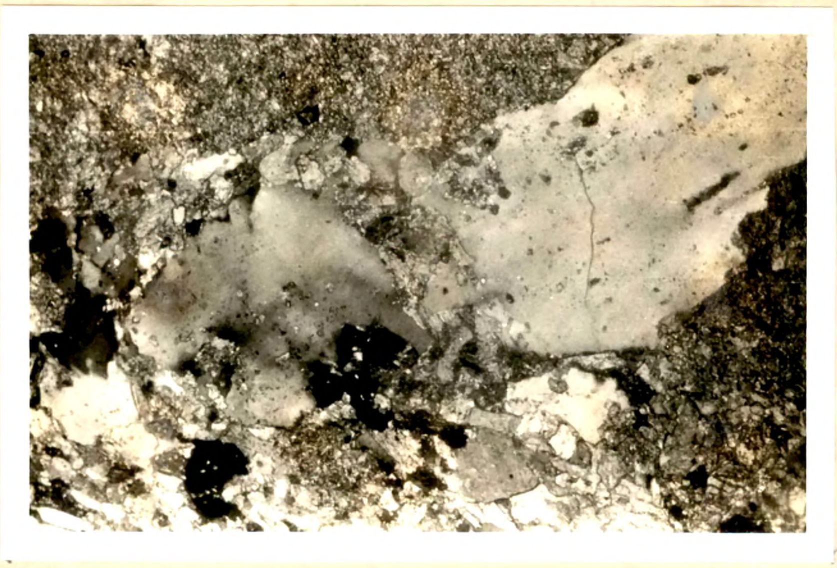
Dolomitic limestone showing streaks and patches of well developed calcite crystals.
(Photomicrograph: Cfoss nicols, X75)

PLATE 5.3



Limestone showing thin streaks of cherty silica.(Photomicrograph: Cross nicols,X75)

PLATE 5.4



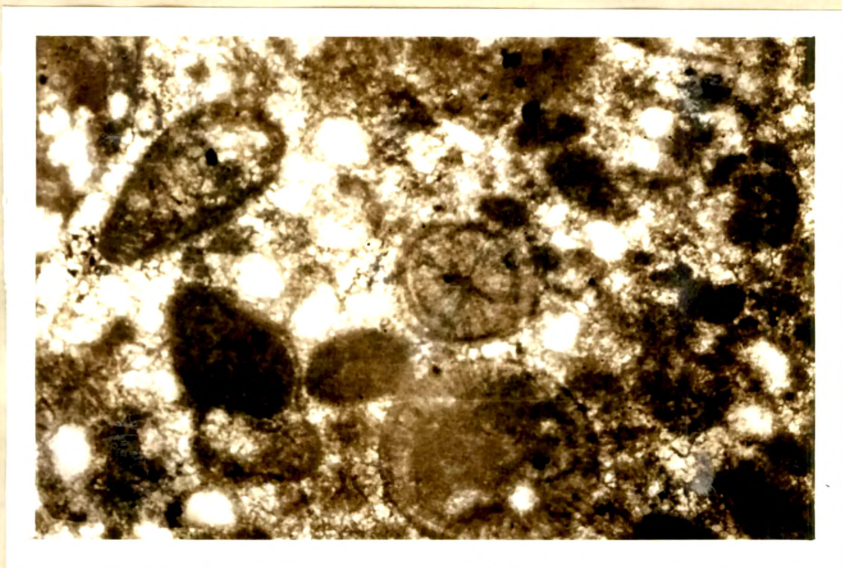
Limestone with sporadic quartz grains and calcite. (Photomicrograph: Cross nicols,X75)

3. A fine oolitic texture, wherein the oolites - round as well as elliptical are seen embedded in a crystalline calcareous matrix (Plate 5.5a, 5.5b). The oolites are mostly dusty and almost opaque, but at many places reveal a radiating structure comprising needles of aragonite.

X-Ray Diffractometer Patterns of a few selected samples (Table 5.1, Fig. 5.2) have revealed that most of the carbonate rock is rich in dolomite, while in a few, calcite predominates. The author has observed that the very fine, almost non-crystalline variety, is dolomitic while the fine to mediumgrained crystalline rock is calcite rich. In all the varieties, muscovite mica and goethite are observed. The quartz content is variable depending on the presence and absence of chert as detrital grains.

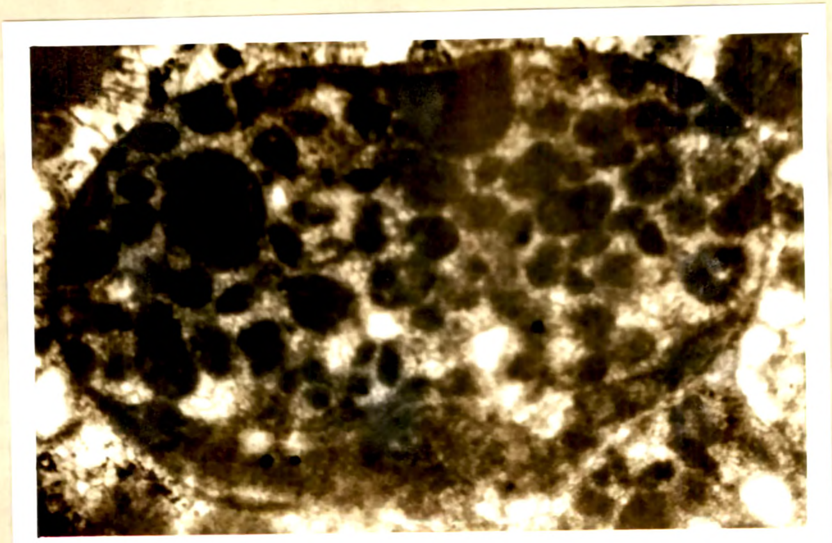
The finegrained cherty quartzite layers that occur in between limestone beds, form a very conspicuous rock horizon, extending almost all along the strike. In hand specimen, the rock is seen to be a milky white very fine grained quartzite. Under the microscope, it reveals a cherty aggregate of fine silica and tiny grains of quartz. In close association occur streaks and patches of calcite, but in a very subordinate quantity (Plate 5.6).

PLATE 5.5a



Dolomitic limestone showing oolitic texture. Radiating needles of aragonite in oolites. (Photomicrograph: Cross nicols, X75).

PLATE 5.5b



Dolomitic limestone showing oolitic texture. Pellet or bigger oolite comprising smaller oolites. (Photomicrograph: Cross nicols,X75)

Table 5.1 : X-ray diffractometer data of Dolomitic limestone

Sr.No.	2θ	d(A°)	Intensity	hkl	Mineral identified
Sample No.21					
1.	26.68	3.34	S	101	Quartz
2.	31.08	2.88	VS	104	Dolomite
3.	33.68	2.66	W	130	Goethite
4.	35.48	2.53	W	202	Muscovite
Sample No.22					
1.	31.08	2.88	VS	104	Dolomite
2.	33.68	2.66	VW	130	Goethite
3.	35.48	2.53	W	202	Muscovite
Sample No.23					
1.	26.76	3.33	S	101	Quartz
2.	29.60	3.02	VS	104	Calcite
Sample No.24					
1.	26.76	3.33	S	101	Quartz
2.	31.04	2.88	VS	104	Dolomite
3.	33.68	2.66	W	130	Goethite
4.	35.40	2.53	W	202	Muscovite

Note: VS = very strong; S = strong; W = weak; VW = very weak

Dolomite = 31°, 2θ
Calcite = 29.4°, 2θ
Quartz = 26.68°, 2θ
Muscovite = 35.40°, 2θ
Goethite = 33.36°, 2θ

Fig. 5.2.

X-RAY DIFFRACTION PATTERN OF DOLOMITIC LIMESTONE.

SAMPLE NO: 21. (ACCORDING TO VESIRORA; KOROLER 1965)

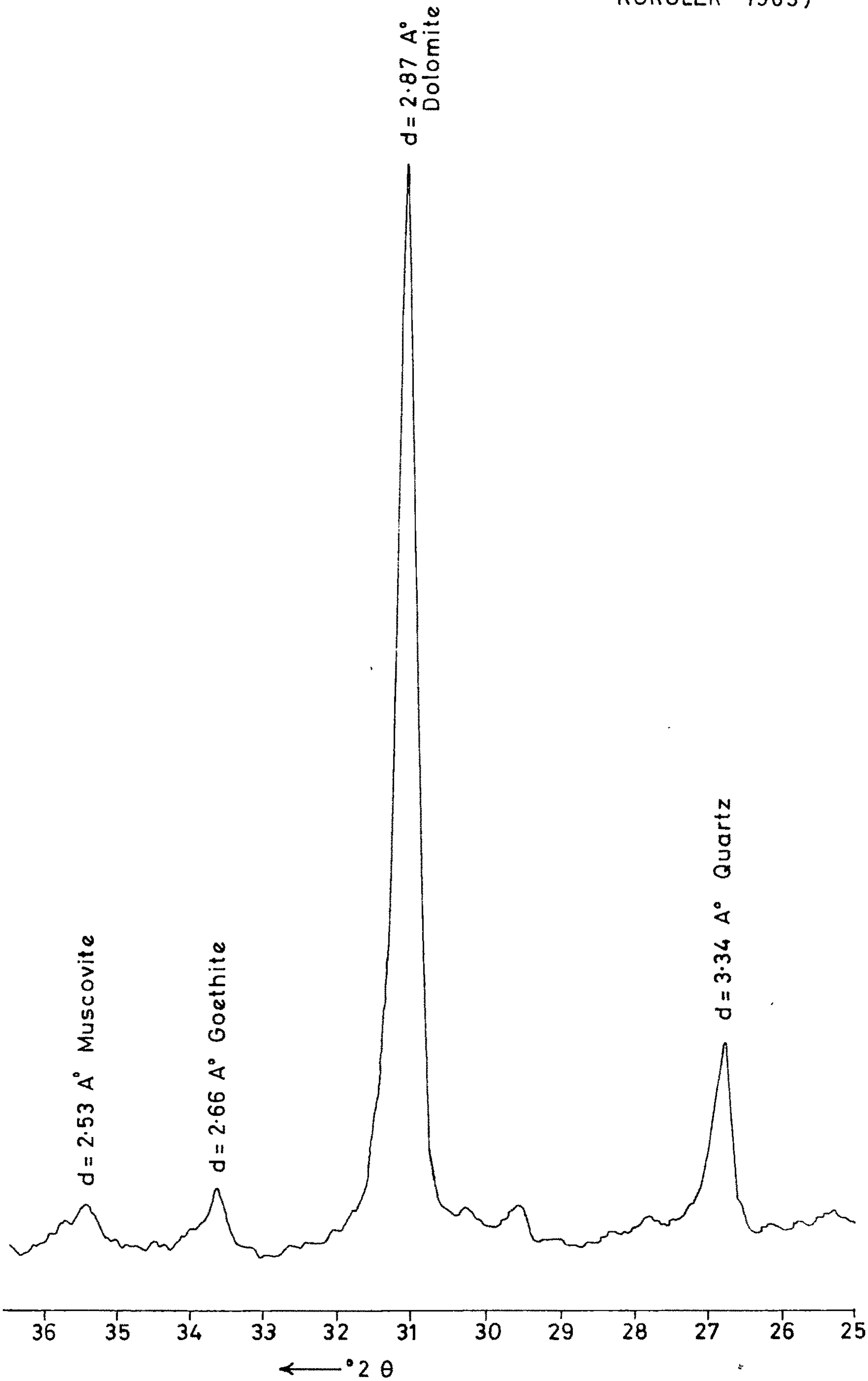


Fig. 5·3

X-RAY DIFFRACTION PATTERN OF DOLOMITIC LIMESTONE
SAMPLE NO:22. (ACCORDING TO VESIRORA KOROLER 1965)

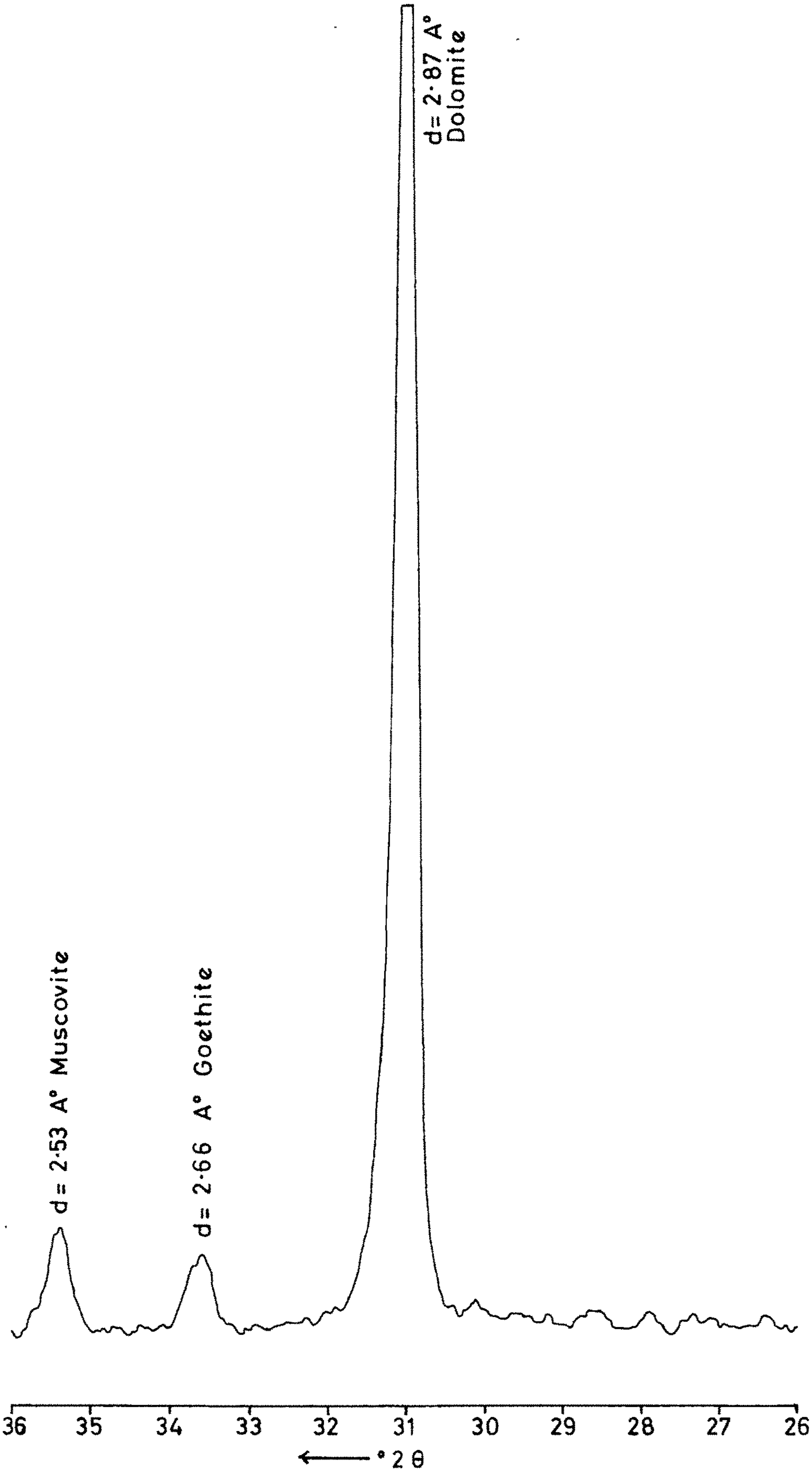


Fig. 5.4

X-RAY DIFFRACTION PATTERN OF DOLOMITIC LIMESTONE. 81
SAMPLE NO:23 (ACCORDING TO VESIRORA; KOROLER 1965)

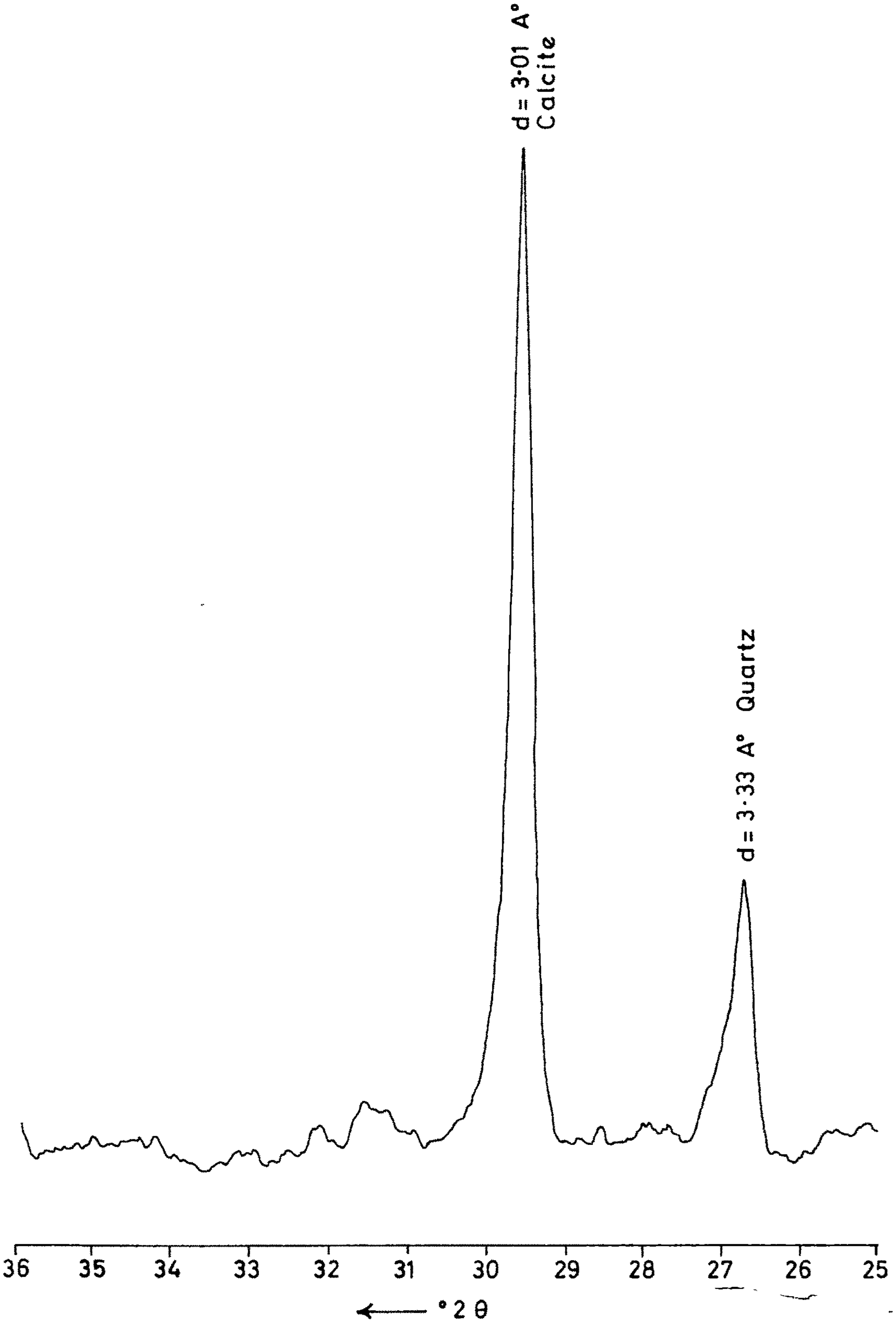


Fig . 5. 5

X - RAY DIFFRACTION PATTERN OF DOLOMITIC LIMESTONE.
SAMPLE NO: 24 (ACCORDING TO VESIRORA; 82
KOROLER 1965)

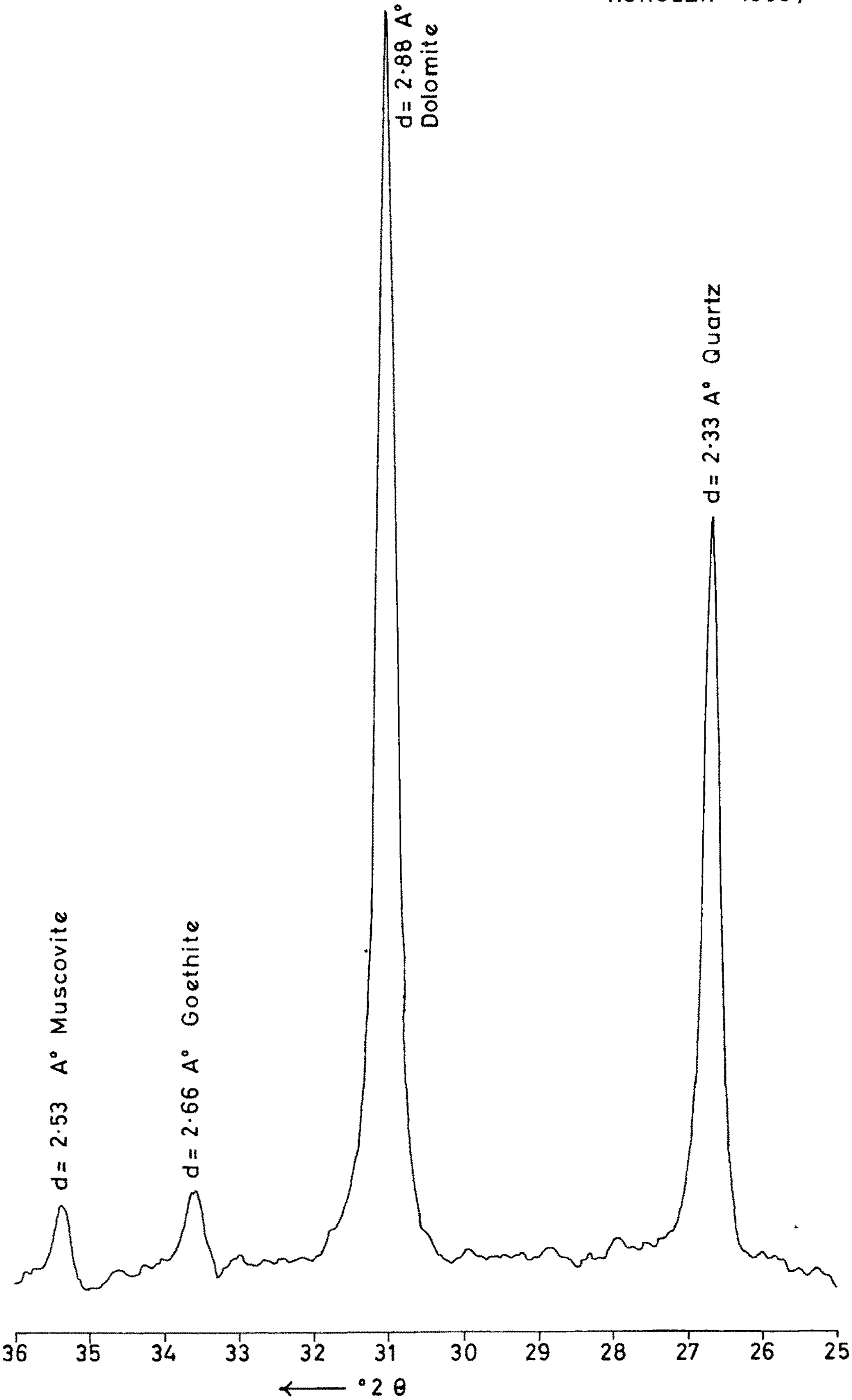
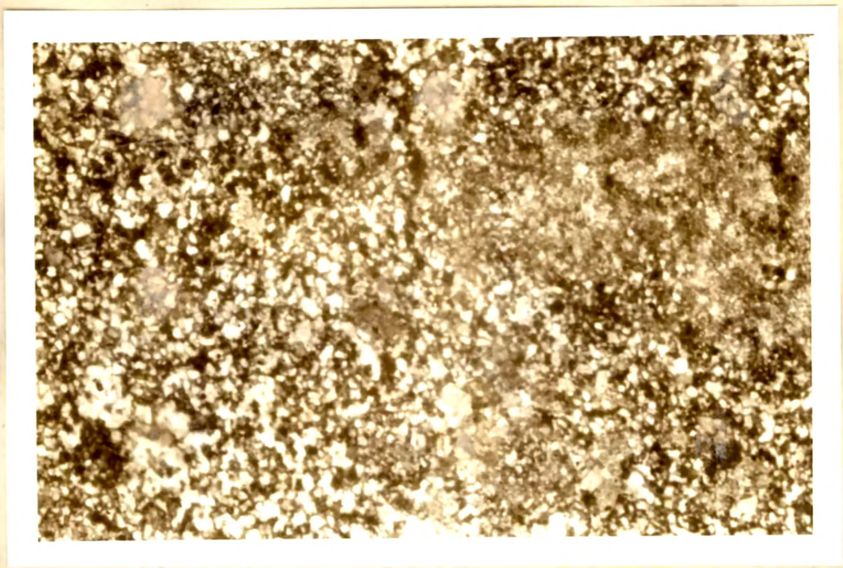


PLATE 5.6



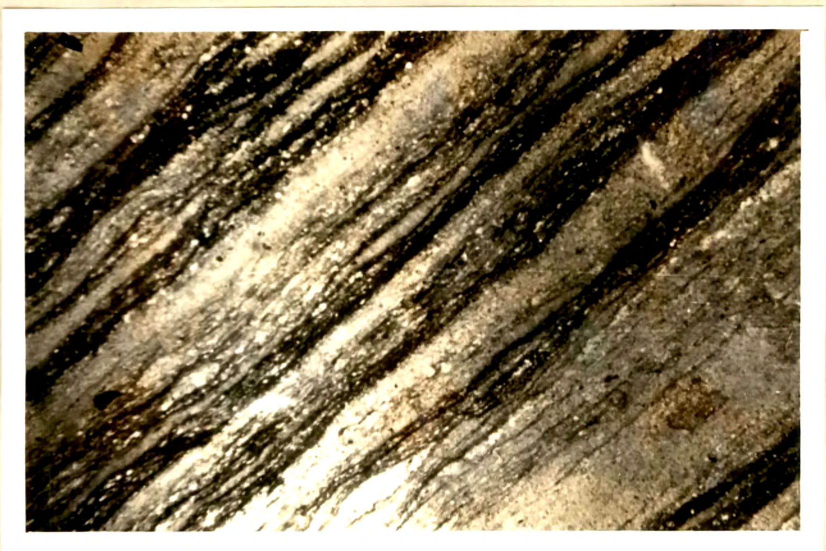
Cherty quartzite showing streaks and patches of calcite. (Photomicrograph: Cross nicols, X75)

The limestones contain numerous slaty layers. Of these the cream coloured and purple slates are calcareous and represent an originally marly sediment. The grey variety of slates, which do not show any $CaCO_3$ content are nearer to argillites and typically show very distinct original sedimentary laminations. An interesting feature of all these varieties of slates, is the frequent occurrence of tiny chevron folds shown by the lamination, the slaty cleavage always marking the axial plane of the folds. The author has observed that these tiny folds reflect the bigger macroscopic folds which are seen in the enclosing limestone.

Under the microscope, they show very finegrained texture, consisting of dark and light coloured laminae. The dark laminae consist of almost opaque black material difficult to identify. The light coloured layers are also difficult to sort out, but they seem to be made up of a cryptocrystalline mass of quartz, sericite and some chlorite. Patches and streaks of calcite grains are frequently recorded (Plate 5.7).

The stromatolites are, as stated earlier, sporadic and restricted to the upper part of the carbonate horizon. These algal structures are of considerable importance. The stromatolitic variety is of greyish white colour and

PLATE 5.7



Slate consisting of light and dark coloured laminae. (Photomicrograph: Polarised light, X30).

shows less well defined stratification. Siliceous or cherty material is associated with them in the form of nodules or veins or in the interareas between the columns. The bedding planes are rather uneven and mostly marked and identified by the zones of stromatolites. In cross sections, the lines joining the convex surfaces of the stromatolites could be taken as the depositional bedding.

The principal stromatolitic structure observed in the area is Collenia found in various sizes and forms (Plate 5.8). The stromatolites show a laterally linked hemi-spheroidal column form and can be favourably compared with those of Collenia described by Logan et al. (1964). In plan, the stromatolitic laminae show rounded to oval parallel sections indicating a concentric vertical stacking. The diameter of stromatolites varies from 4 cm to 6 cm. They are identical with the types 'Collenia-Columnaris' described by Misra and Valdiya (1961, p.80) from the Calc-Zone of Pithoragarh, Dixit (1968, p.87) from the Giricchina area and by Munshi (1971) from the Someshwar, Southeast of Chaukhutia.

The orientation of the stromatolites clearly indicate that the beds are uninverted and to postulate a regional inversion of sequence (Valdiya, 1962) is not valid.

PLATE 5.8

Field photograph of limestone showing the stromatolites. (Loc. near Tarag Tal)

CHLORITE SCHISTS (SPILITIC ROCKS)

These strongly foliated metabasics rest unconformably on the limestone. In the northeastern part, these rocks are scarce but in the south and southeast they are quite conspicuous. In the southeastern corner of the area, these chloritic rocks are seen to rest directly over the limestone and further east they continue beyond Dwarahat and Someshwar. At Someshwar, Munshi (1971) has reported a horizon of slates and quartzites intervening between the chlorite schists and limestones. Obviously, northwestward, these slates and quartzites gradually pinch out and at Chaukhutia, the chlorite schist comes in contact with the limestones.

In the study area, the chloritic rocks, tend to pinch out, such that the overlying subgraywackes come directly over the limestone at most places. It is however interesting to note that a few lenses of chlorite schist also occur within the overlying subgraywackes.

The detailed investigation of these chloritic rocks by the author has revealed that at most places, these comprise metamorphosed basalts and tuffs of spilitic affinity. A very critical petrographic study, has enabled the author to classify the chlorite schists of the area into following three spilitic varieties:-

Foliated diabase

Foliated basalt

Foliated tuff.

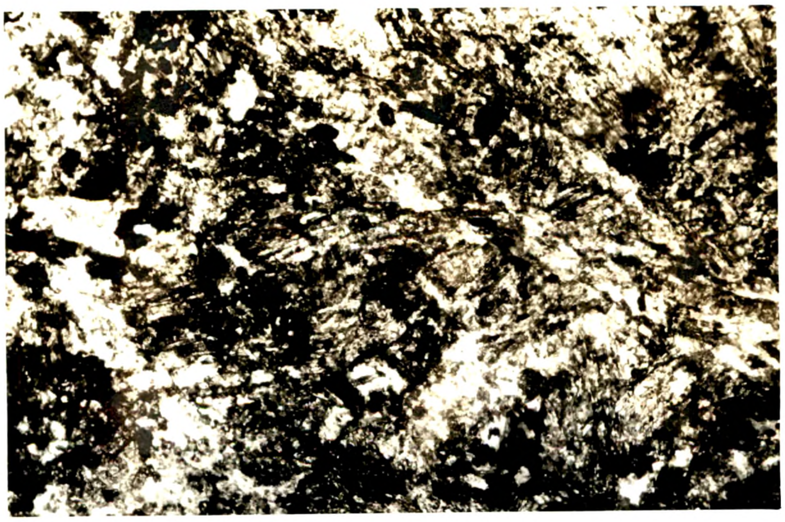
In hand specimen, it is not easy to distinguish between the above three varieties. However, in thin sections they are easily recognised. Of the three above varieties, the tuffs appear to be predominant.

It has been found that the coarse diabasic spilite occur as stray lensoid layers within the tuffaceous varieties, or as lenses in the overlying subgraywackes. The author could collect only two samples from the study area, from a lensoid body within the quartzites. But further southeast i.e. from Dwarahat and Someshwar areas, the author has recorded the coarse variety in larger proportion. It appears that the so called amphibolites reported by earlier workers are in fact, spilitic diabases. Similarly, the typical basaltic rocks too have been found to be scarce, though the author has recorded one very distinct occurrence from the study area. He, however, is of opinion that some of the highly foliated and streaky varieties could have been originally basalts but are now highly cleaved with original igneous textures having been destroyed.

Petrography

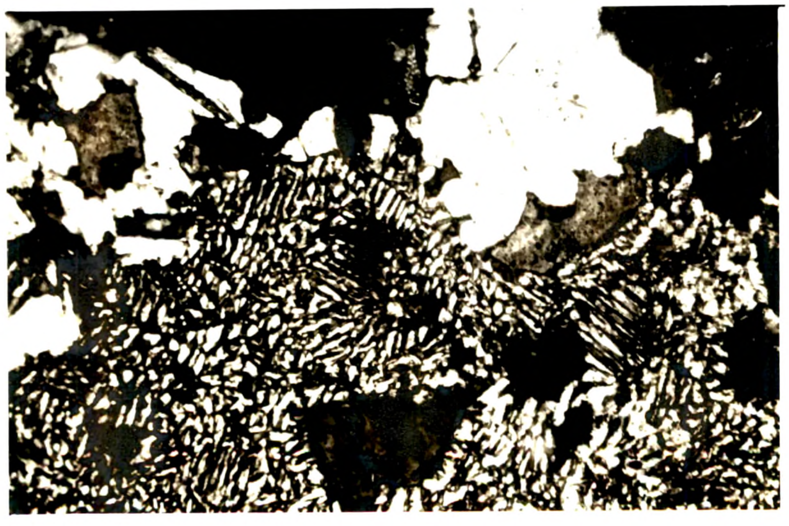
Foliated diabase: This coarse grained variety in hand specimen is seen as a dark greyish green rock with a tendency to show a marked foliation. Thin sections reveal much more. Under the microscope, the rock is seen to comprise a rather confused assemblage of broken and altered felspar and some relict pyroxene, embedded in a foliated chloritic and uralitic mass (Plate 5.9a). A relict intersertal texture is faintly observed. Of the two samples studied, one is quartz-free, while the other contains a fair proportion of quartz either as discrete cuspate interstitial grains or in granophyric intergrowth with the felspar (Plate 5.9b). Felspar is a plagioclase partly altered to saussurite but shows the usual twinning on the Albite law. Due to alteration it is difficult to precisely identify its nature, but with the help of Michel Levy method, it is found that while the quartz-free variety contains a plagioclase that

PLATE 5.9a



Texture of foliated diabase showing broken and altered felspar embedded in chlorite and uralite. (Photomicrograph: Cross nicols, X75)

PLATE 5.9b

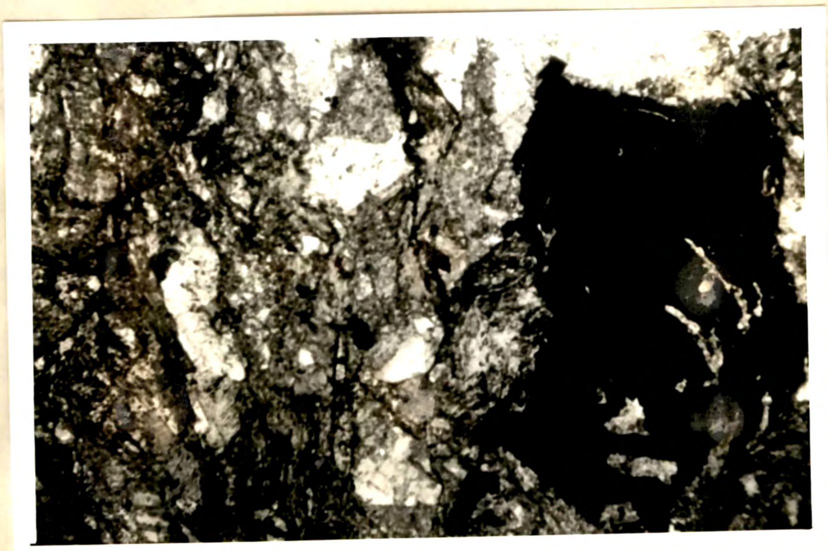


Plagioclase in diabase, showing granophyric texture. (Photomicrograph: Cross nicols, X160).

is almost an oligoclase (An_{8-12}) while the one in the quartz-bearing variety is more sodic and could be taken as albite. Most of the felspar laths are broken and sometimes aligned along the foliation.

The mafic constituents of the rock, now comprise chlorite and uralite, epidote. Chlorite occurs as streaks and tufts of light green to colourless needles and flakes. These are generally isotropic or show very low order bluish grey polarisation colours. Uralite forms well developed prismatic laths tending to be fibrous at both ends. Light green and pleochroic, this mineral occurs in close association with chlorite. It is recognized by its characteristic pleochroism in shades of green, second order polarisation colours and oblique extinction angle. Epidote is seen to form conspicuous and anhedral grains, occurring individually or in clusters of two or three. It shows typical pale green colour, faint pleochroism and one set of distinct cleavage. Quartz as stated already, when present occurs either in granophyric intergrowth with plagioclase or as interstitial grains. It also forms very finegrained almost crypto-crystalline patches at places. The remaining minerals are tiny grains of sphene and skeletal crystals of ilmenite with leucoxene (Plate 5.10).

PLATE 5.10



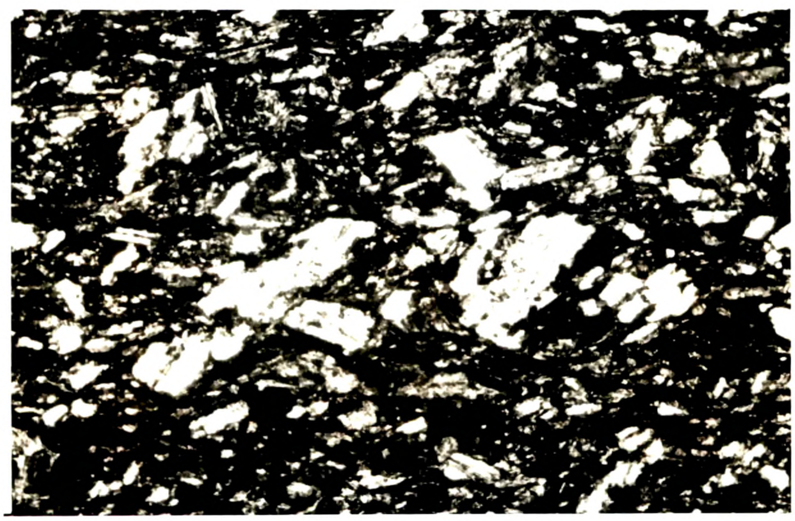
Diabase showing skeletal crystals of ilmenite with leucoxene. (Photomicrograph: Polarised light, X30)

Foliated Basalt: Only one undoubted occurrence of this rock has been recorded. In hand specimen it is seen as a dark greenish grey aphanitic rock. Under the microscope it shows a somewhat trachytic texture, wherein stubby laths of plagioclase are seen embedded in chlorite-uralite groundmass (Plate 5.11).

The phenocrysts show a distinct parallelism which appears to be an original flow phenomenon. The felspars are quite fresh, show invariable lamellar twinning. On the basis of the extinction angle on the twin lamellae and the low refractive index (lower than Canada Balsam) this plagioclase is estimated to be nearer to alkali (An_{10-13}). The groundmass consists of a foliated aggregate of needles and tufts of uralite and chlorite. While the uralite shows a bluish green colour, the chlorite is generally light green almost colourless. The former shows the usual polarisation colours of second order while the latter is isotropic. Interspersed in the groundmass are fine streaks of cherty silica. Small grains of sphene and magnetite are seen scattered throughout the mass.

Foliated Tuffs: These are finegrained dark greenish to greyish-green strongly cleaved rocks. Hand specimens

PLATE 5.11



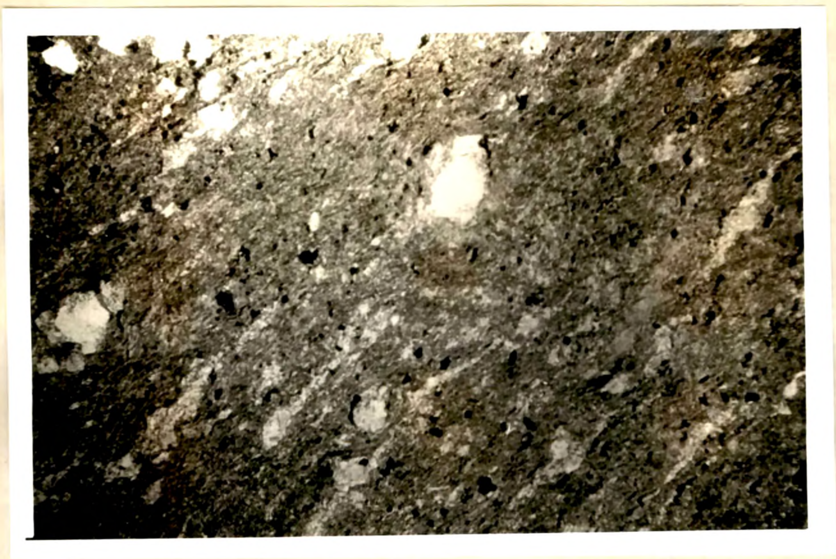
Foliated basalt showing trachytic texture.
(Photomicrograph: Cross nicols, X75)

do not reveal anything, but under the microscope, the true nature of these rocks become quite clear. On the basis of the study of a number of thin sections, the author has been able to divide these chloritic rocks into two main varieties.

1. Tuffs with subordinate quartz and chert (Plate 5.12).
2. Tuffs with a high proportion of quartz and chert (Plate 5.13).

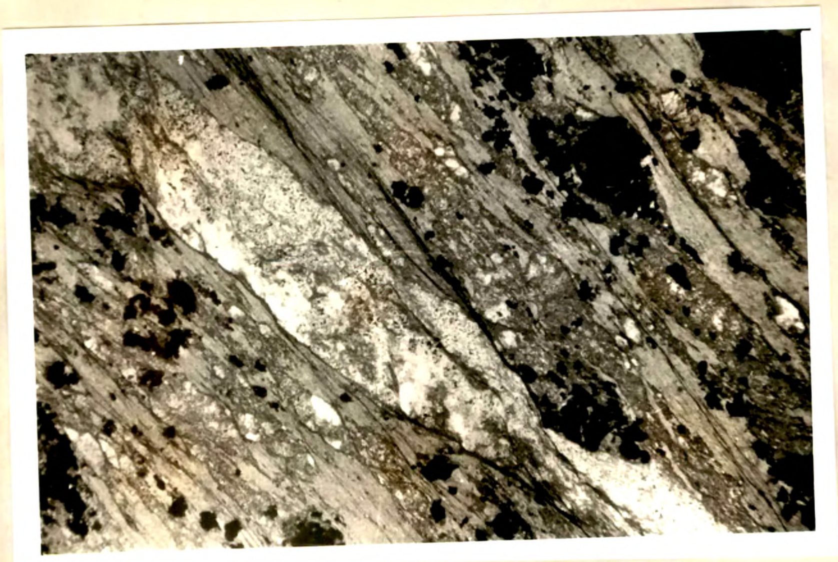
The first variety is seen to comprise a very finegrained foliated mass of uralite and chlorite with thin streaks of iron oxide. In some sections, uralite dominates while in the other chlorite is more. Occasionally a little sericite is also recorded at tiny streaks in close association with chlorite and uralite. Uralite occurs as fibrous aggregate, showing a light bluish green colour, distinct pleochroism and oblique extinction. Chlorite is either very finegrained and almost isotropic or fine elongated shreds, pleochroic from brown yellow to light green (X = brown yellow; Y = green; Z = green; X, Y = Z). Occasional grains of quartz and frequent streaks of fine cherty silica are common. Iron oxides are magnetite and leucoxene.

PLATE 5.12



Tuff with subordinate quartz and chert.
(Photomicrograph: Polarised light, X30)

PLATE 5.13



Tuff with high proportion of quartz and chert. (Photomicrograph: Polarised light, X30)

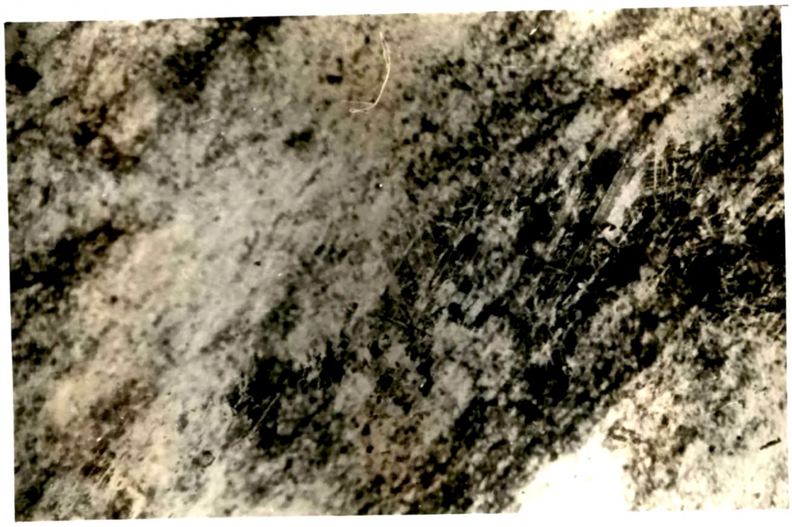
The siliceous tuffs are typically rich in cherty layers, which occur in alteration with chloritic and palagonitic streaks. In this variety uralite is not recorded. The siliceous layers consist of well developed quartz grains gradually merging into very fine chert. The chlorite is typically pleochroic from light brown to green, but shows very low polarisation colours. Palagonite occurs as elongated lensoid patches of yellow colour and under cross nicols,it shows very fine spherulitic aggregates. The author has recorded in one section, deformed patches of volcanic glass (Plate 5.14). A couple of thin sections have revealed veins of prehnite that are seen changing to sericite. Prehnite is recognised by its mode of occurrence, cleavage and polarisation colours.

The author has also recognised a variety of tuff which can best be termed as keratophyric tuff. It is rather more siliceous and less chloritic. The quartzose lenses occasionally have preserved broken and deformed sodic plagioclase (Plate 5.15).

Tuffites

These are transitional rocks and show an increased percentage of clastic sediments in relation to volcanogenic

PLATE 5.14



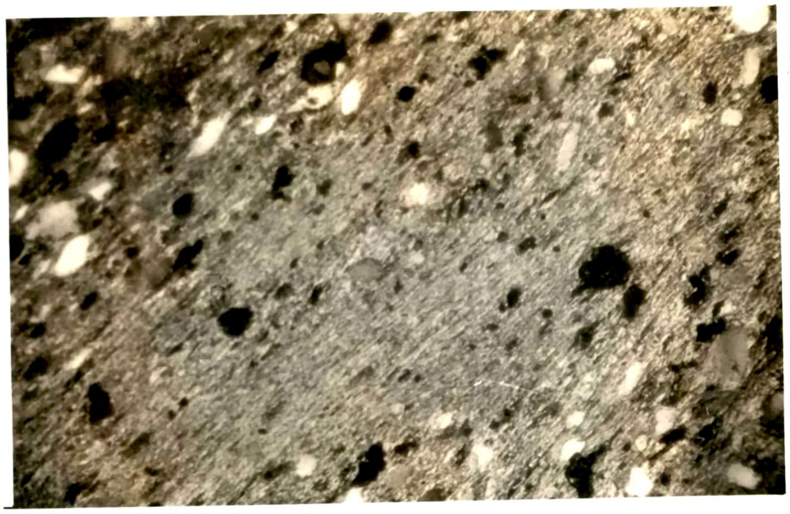
Siliceous tuff showing deformed patches of volcanic glass. (Photomicrograph: Polarised light, X30).

PLATE 5.15

Siliceous tuff showing broken and deformed sodic plagioclase. (Photomicrograph: Cross nicols, X30) material. These occur in close association with tuffs and also as intercalations in the overlying quartzites, and are recognized in the field by their typical laminated structure. The volcanogenic material is seen to be of light green colour while the clastic layers are greyish white.

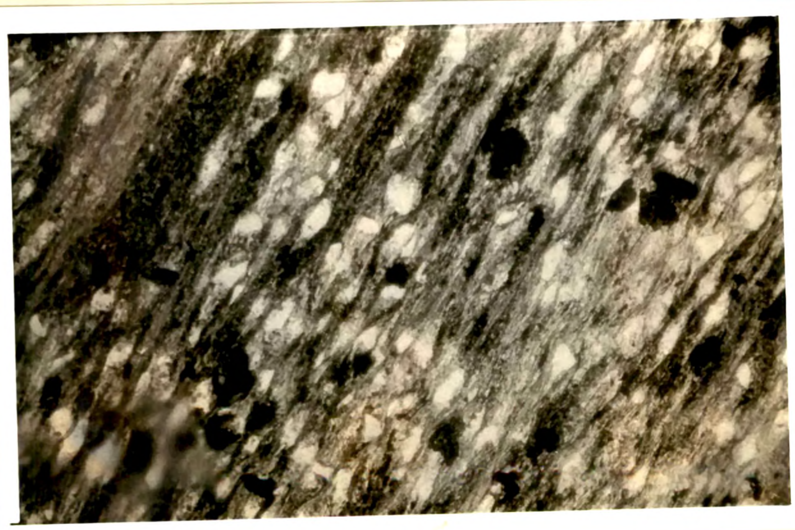
Thin sections reveal an overall foliated structure with alternating layers of tuffaceous and clastic layers. The tuffaceous layers are finegrained sericitic and chloritic resembling phyllite (Plate 5.16). The clastic layers are almost exclusively quartzose and are made up of equigranular quartz grains with small needles of sericite and biotite (recrystallised from chlorite of the matrix). Another, but less common variety of tuffite is that in which the lamination is not so well marked, and its thin sections show a uniform scattering of quartz grains in a fine foliated volcanogenic matrix. The matrix consists of sericite and chlorite (Plate 5.17). The relative proportions of quartz grains and the matrix material is variable, and this variation in the matrix imparts a distinct layering. The latter variety is more common as intercalations in the quartzites.

PLATE 5.16



Taffaceous layers in tuffite resembling phyllite (Photomicrograph: Cross nicols, X30)

PLATE 5.17



Tuffite showing a uniform scattering of quartz grains in a foliated volcanogenic matrix. (Photomicrograph: Polarised light, X30).

QUARTZITES

These arenaceous rocks, come over the spilitic horizon. Only a small portion of these rocks, lie within the area in the NE. But, these rocks are of considerable significance, as they comprise a very important 'quartzitic' formation extending all over the Inner Lesser Himalaya of Kumaon from W to E, above which the Baijnath thrust sheet is supposed to be resting.

In hand specimen, these rocks are seen to be of dirty white to brown colour, with very little stratification. From a study of thin sections, they are found to be impure quartzites of the nature of medium to finegrained subgraywackes. The predominant mineral is quartz which occurs as subrounded to subangular grains embedded in a fine grained matrix that consists of quartz, sericite and sometimes chlorite (Table 5.2). The deformation and metamorphism being quite feeble, the original sedimentary textural characters are considerably preserved. The degree of sorting is moderate to poor and so is the roundness (Plate 5.18). It is interesting to note that though these arenaceous rocks have been subjected to some deformation, they have at most places preserved their original texture. Thin sections clearly show that the stresses were mostly

Table 5.2 : Quartz and Matrix Relation of Quartzites

	Quartzites					
	H	I	J	K	L	M
Quartz grains	78.49	83.13	78.34	84.67	75.14	95.46
Matrix	21.48	16.85	21.62	15.30	24.79	4.50
Total Percentage	99.97	9.98	99.96	99.97	99.93	99.96

absorbed by the incompetent matrix, resulting into development of sericite and feeble foliation.

Occasional layer in the subgraywackes, are found to be exclusively made up of sutured quartz aggregates. Obviously, these represent local accumulation of clear quartz concentrates which have been subsequently welded together by recrystallisation during the metamorphism (Plate 5.19).

CHEMISTRY OF SPILITIC ROCKS

The chemical data also supports the spilitic nature of the chlorite schists. The author has chemically analysed representative samples of diabase and spilite, and a critical study of the analyses has revealed a relatively high Na_2O and low K_2O in comparison to the normal basaltic rocks (Table 5.3). The chemical data when plotted on Kuno's diagram (Fig. 5.7), very distinctly shows the alkaline nature of the rocks. The Simonen's diagram (Fig. 5.8) based on the Niggli values [Si as abcissa against (al + fm) - (C + alk) as ordinate] reveals that the basic rocks both basalts and diabases, fall within the spilitic field.

PLATE 5.18

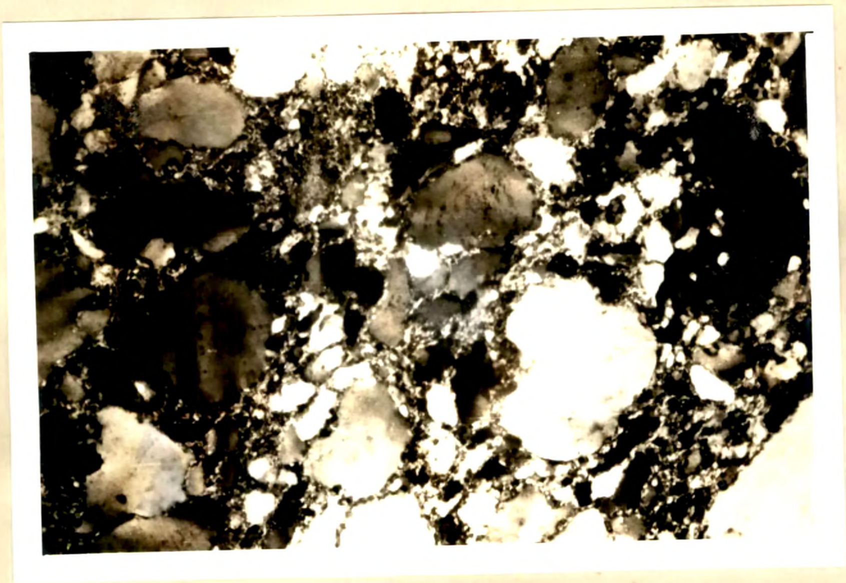
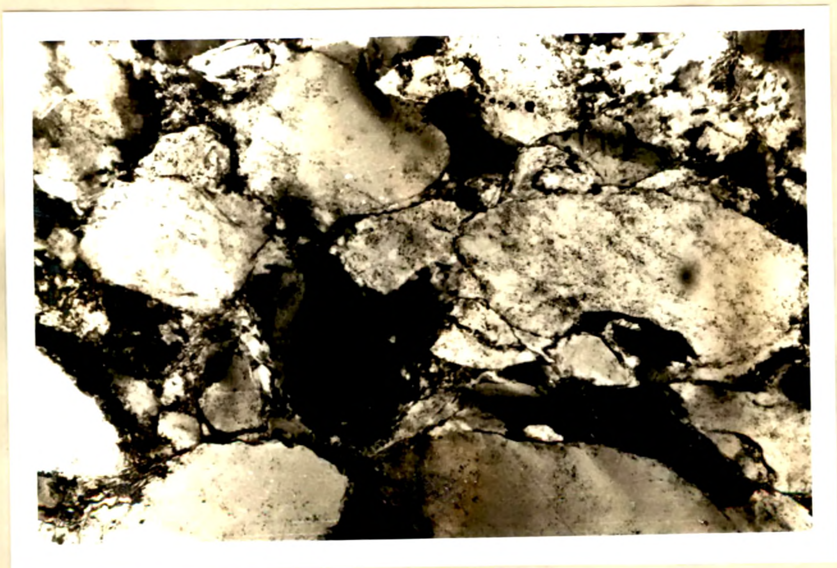


PLATE 5.19



Texture of subgraywacke
(Photomicrograph: Cross nicols, X75)

Table 5.3 : Chemical analysis of chlorite schists (spilitic rock)

(Weight per cent)

Oxides	1	2	3	4
SiO_2	51.07	50.68	48.93	48.48
Al_2O_3	15.64	14.43	15.34	15.04
Fe_2O_3	4.55	4.22	3.51	3.98
FeO	8.56	9.40	12.40	11.80
Na_2O	4.65	4.70	5.68	5.16
K_2O	1.49	1.63	0.21	0.31
MgO	6.19	7.86	6.65	6.71
CaO	4.80	3.99	4.80	5.36
TiO_2	0.29	1.18	0.32	0.43
P_2O_5	0.02	0.02	0.07	0.73
MnO	0.02	0.04	0.02	0.02
Loss on Ignition	2.13	2.33	2.28	2.62
Total	99.41	100.48	100.21	100.64

contd...

Table 5.3 (contd.)

Oxides	5	6	7	8
SiO_2	52.66	48.34	51.87	50.32
Al_2O_3	16.54	16.41	14.83	16.58
Fe_2O_3	2.91	2.58	4.01	4.23
FeO	9.68	8.40	9.32	8.48
Na_2O	3.01	4.95	5.02	3.74
K_2O	1.10	1.37	0.98	1.12
MgO	7.26	7.30	8.51	8.99
CaO	3.22	5.52	2.80	5.94
TiO_2	0.38	1.74	1.36	0.28
P_2O_5	0.32	0.01	0.14	0.01
MnO	0.01	0.06	0.02	0.01
Loss on Ignition	3.02	2.71	2.05	1.13
Total	100.11	99.39	100.91	100.84

contd...

Table 5.3 (contd.)

Oxides	9	10	11	12
SiO_2	52.03	51.67	50.58	52.61
Al_2O_3	16,42	15.22	16.33	16.18
Fe_2O_3	3.66	4.76	3.58	4.22
FeO	9.76	8.92	6.80	10.68
Na_2O	3.95	5.96	5.69	4.28
K_2O	0.53	0.90	0.93	1.87
MgO	8.91	6.09	8.39	5.07
CaO	3.01	4.94	5.52	4.06
TiO_2	0.25	1.19	1.34	0.72
P_2O_5	0.51	0.33	0.07	0.04
MnO	0.01	0.01	0.02	0.07
Loss on Ignition	1.31	0.21	1.45	1.08
Total	100.35	100.20	100.70	100.88

contd...

Table 5.3 (contd.)

Oxides	13	14	15	16
SiO_2	52.46	51.56	50.22	53.07
Al_2O_3	16.73	17.37	15.53	14.92
Fe_2O_3	4.22	4.95	2.44	3.04
FeO	7.40	8.56	10.20	6.40
Na_2O	2.43	3.64	4.02	4.68
K_2O	0.95	0.53	0.99	0.53
MgO	7.71	8.87	8.61	8.87
CaO	3.52	2.52	5.66	4.66
TiO_2	1.18	0.21	1.31	2.24
P_2O_5	0.20	0.32	0.70	0.05
MnO	0.05	0.06	0.02	0.01
Loss on Ignition	2.85	1.67	1.19	2.23
Total	99.70	100.26	100.89	100.70

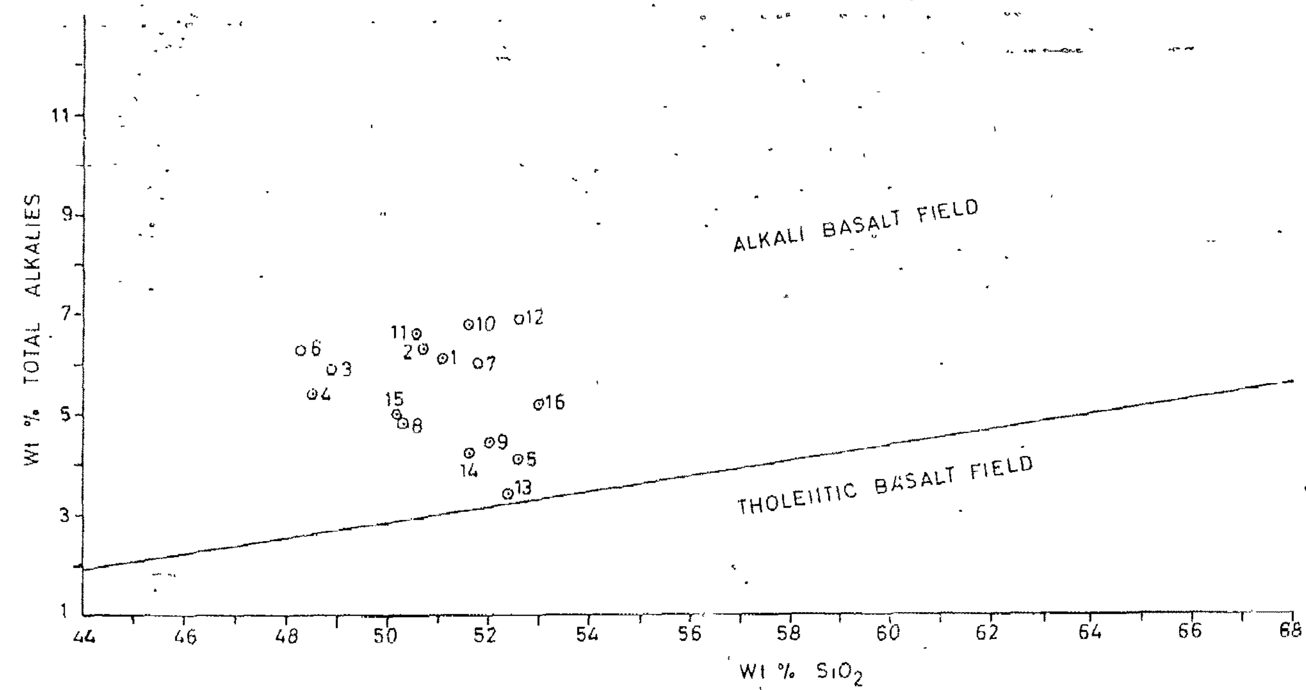
Table 5.4 : Niggli values of chlorite schists (spilitic rock)

	1	2	3	4	5	6	7	8	9	10
Si	129.33	123.54	116.76	114.29	138.92	114.81	127.58	114.15	126.57	127.37
al	23.25	20.61	21.49	20.79	25.63	22.93	21.39	22.18	23.50	22.04
fm	50.00	55.55	53.01	53.75	55.85	47.29	57.82	53.74	58.69	49.41
C	13.07	10.23	12.32	13.44	9.02	16.52	7.37	14.29	7.88	13.02
alk	13.68	13.61	13.18	12.02	9.49	13.25	13.42	9.80	9.93	15.53
(al+fm) - (C+alk)										
	46.50	52.32	49.00	49.08	62.97	40.45	58.42	51.83	64.38	42.90

	11	12	13	14	15	16
Si	118.73	138.11	143.09	126.32	117.23	133.69
al	22.54	25.04	26.97	25.00	21.29	22.05
fm	49.30	50.08	57.24	59.12	54.20	53.32
C	13.80	11.18	10.36	6.62	14.01	12.39
alk	14.37	13.70	5.43	9.26	10.50	12.24
(al+fm) - (C+alk)						
	43.67	50.24	68.42	68.24	50.98	50.74

Fig: 5.6

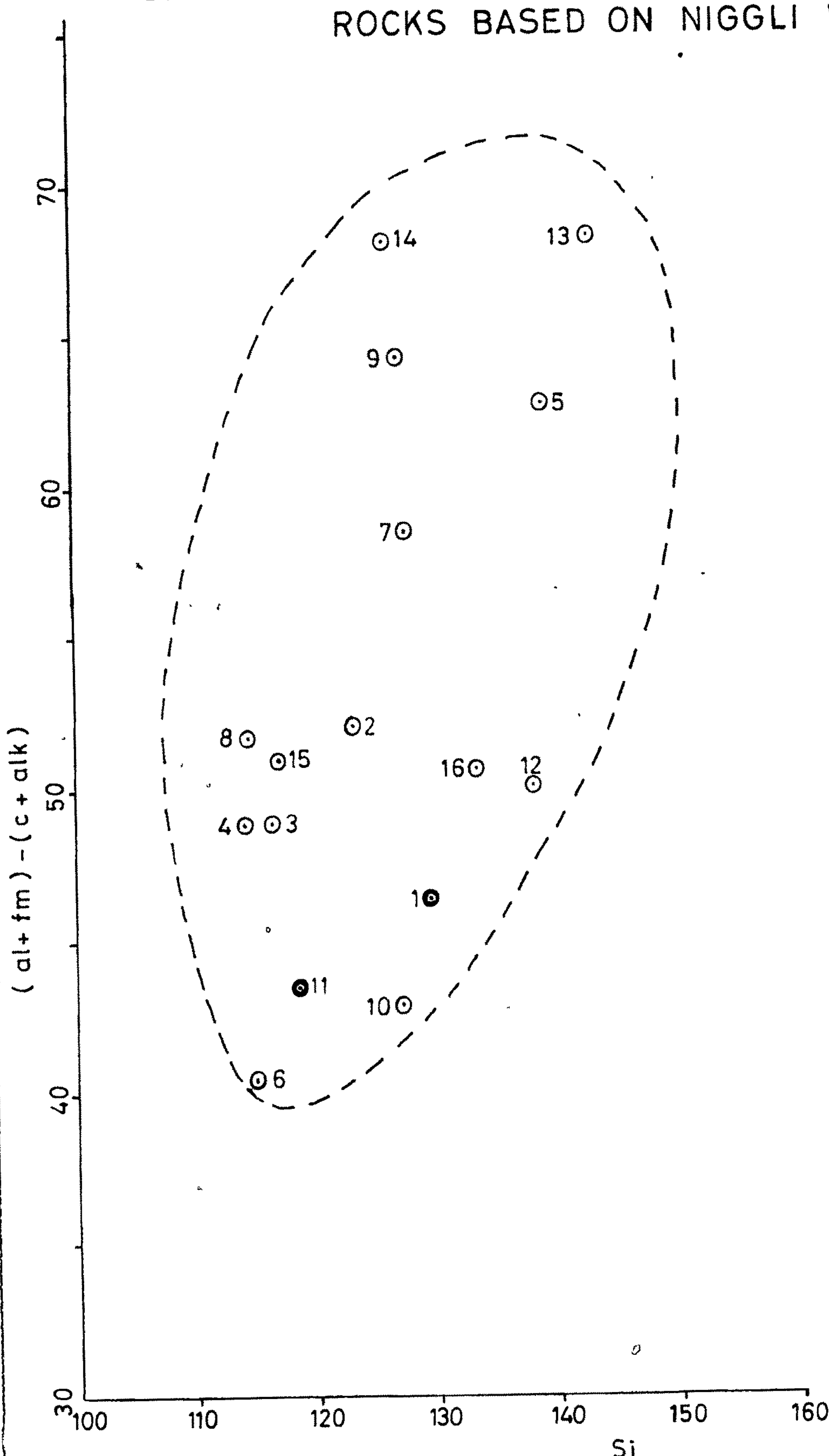
KUNO'S DIAGRAM SHOWING THE ALKALI BASALTIC FIELD FOR THE SPILITIC ROCKS OF THE CHAUKHUTIA AREA (AFTER KUNO - 1959)



⊙ SPILITIC ROCKS

Fig. 5.7

SIMONEN'S DIAGRAM OF SPILITIC ROCKS BASED ON NIGGLI VALUES



⊙ SPILITIC ROCKS (Basalt)

● SPILITIC ROCKS (Diabase)

The author has deliberately not entered into the controversy of the origin of these rocks. Spilites are problematic rocks and ever since the term was introduced by Bonnard in 1819 (Vallance, 1960, p.8) it has remained controversial. The controversy, whether the spilites are of primary or secondary origin, is yet unresolved. From the available data, the author is contented to report that the original magma that gave rise to spilites must have been alkaline. How this alkaline magma was derived is a problem that requires an exclusive study beyond the scope of the present study.

Earlier workers have reported the occurrence of metamorphosed basic rocks and tuffaceous layers in quartzites (subgraywackes). About this interbedding of chloritic layers in quartzites in this part of Kumaon, Gansser (1964, p.236) has written "locally and mostly associated with quartzites, there are thick sections of tuffaceous beds altered into chlorite schists with some epidioritic intercalations representing actual flows. Tuffs and flows were most likely submarine." Valdiya (1962) who has termed the succession above the dolomitic limestone at Pithoragarh as Berinag quartzites, has also reported a similar association. He has written

(1962, p.35-36) that, "The quartzites are interbedded conspicuously with chlorite schist and schistose amphibolite. These basic schists sometimes acquire considerable thickness and constitute a very important part of the quartzite zone. It is remarkable that in no place are the basic rocks found to cut across the adjacent sedimentaries".

As regards the Chaukhutia and its neighbourhood, Mehdi et al. (1972) reported the intercalations of penecontemporaneous basic flows of spilitic nature in the quartzite considered equivalent to the Berinag formation.

The present author's investigations have clearly shown that the chlorite schists are definitely of spilitic affinity. It is obvious that lensoid bodies of chlorite schists, comprise spilitic lava flows and related tuffaceous beds, representing a geosynclinal volcanism that accompanied deposition of the quartzites and subgraywacke.

METAMORPHISM

Metamorphically, the rocks of this Group are less interesting. They are feebly metamorphosed, though the different lithological types do show textural and mineralogical variations in their response to the metamorphism. The shearing stress seems to have played a dominant role in bringing about the metamorphic changes.

The metamorphic characters of the rocks on the eastern limb of the Chaukhutia anticline can be summarised as under:

(1) In the lowermost slate-quartzite sequence, the slaty layers represent originally argillaceous sediments which now have been metamorphosed a little to a very finegrained foliated mass. The quartzite layers in this sequence are more interesting. The quartz grains do not show any metamorphic effect, having retained the original clastic shape, but the argillaceous matrix is seen to have developed distinct slaty cleavage.

(2) The dolomitic limestone show few metamorphic changes, except the recrystallisation of $CaCO_3$ into distinct streaks and patches of calcite. The slates within the limestones show some change. These rocks have also preserved the original sedimentary laminations, but the distinct slaty cleavage is the indication of metamorphism.

(3) The spilitic rocks have been changed over partially to chlorite schists. The foliation is characterised by chlorite, uralite sericite and streaks of finegrained quartz. The overall metamorphic grade is low, of green-schist facies.

(4) The overlying quartzites and subgraywackes also show effects of metamorphic changes only in the matrix. The clastic quartz grains are seen to be still preserving their original shapes. The matrix is however foliated and slaty.