CHAPTER 4

P E T R O G R A P H Y

The rock types of the Almora and Baijnath nappes consist of (i) migmatitic gneisses with lenses of quartzite (ii) sills of epidiorite and (iii) phyllonites bordering the thrust zone. The gneissic rocks, showing different degrees of shearing, present considerable difficulty when it comes to describing them because they can neither be lumped into a homogeneous lithological group and described together, nor can they be separated into distinct rock types with well defined megascopic, textural and mineralogical differences which may distinguish one type from the other.

GNEISSES

As already stated earlier (Chapter 3) the gneisses which comprise a major part of the two nappes in the area, show extensive mylonitization along several imbricate shear zones. All stages of shearing and alteration of various constituent minerals are present, and for the convenience of petrographic description, the following three categories have been worked out:

(1) Almost unmylonitised gneiss,

(2) Partly mylonitised gneiss,

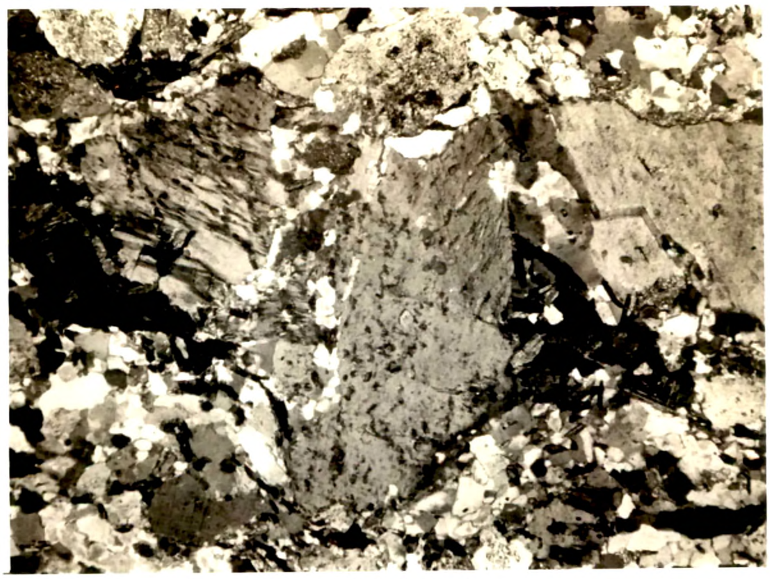
(3) Almost totally mylonitised gneiss.

To the above list may be added one peculiar rock comprising partly or fully mylonitised gneiss with elliptical or spindle shaped bodies of quartz-felspar-tourmaline.

Unmylonitised gneiss

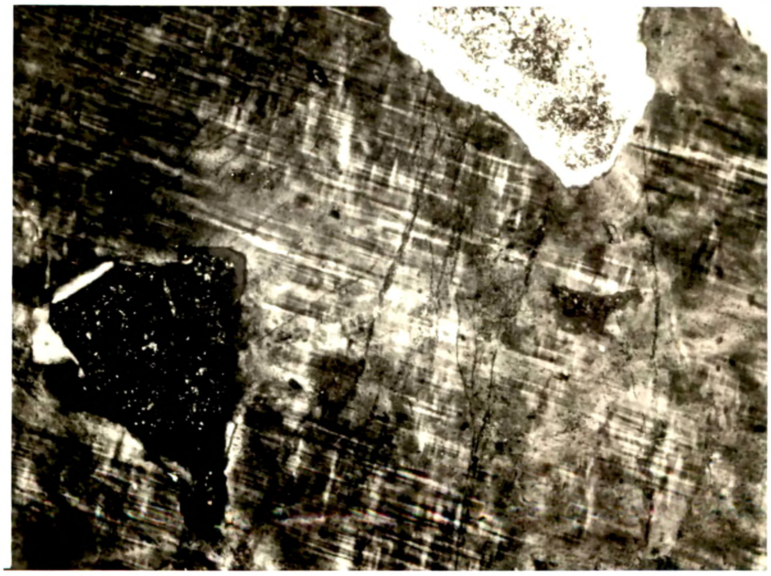
This rock in hand-specimen can be described as a porphyroblastic gneiss with bigger augen-shaped and sub-rounded felspars embedded in a coarse foliated groundmass. In thin section, the texture is seen still better. Porphyroblasts of potash felspar and plagioclase occur in a gneissic granoblastic aggregate of quartz, felspars and micas (Plates 4.1 and 4.2).

PLATE 4.1



Texture of unmylonitised gneiss.
(Photomicrograph: Crossed Nicols X30)

PLATE 4.2



Microcline porphyroblast with inclusion of plagioclase in unmylonitised gneiss.
(Photomicrograph: Crossed Nicols X80)

The minerals present are quartz, potash felspar, plagioclase, biotite and muscovite with some accessory and secondary minerals.

Quartz occurs in grains of variable sizes, and forms (i) stray porphyroblasts, (ii) sutured aggregates of interlocking grains with felspar and micas, and (iii) thin veins of fine grains. The first two modes of occurrence are typically original while the last one indicates granulation due to incipient shearing. Bigger quartz grains show strain shadows while the finer aggregates are free from the strain effects and indicate recrystallisation.

Potash-felspars are both microcline and orthoclase, though the former predominates. Both varieties occur as porphyroblasts and also in the main gneissic mass. The microcline typically shows the cross-hatching while orthoclase is identified easily by its carlsbad twin. Inclusions of sericitised plagioclase are quite common. In most cases, the porphyroblasts are strained and broken, and quite often streaks of quartz have penetrated along the fractures. The felspars in the groundmass occur in close association with quartz and micas - showing considerable interlocking.

Plagioclase(An_{26-30}) is always present, and in some samples dominates over the potash felspar. In such cases, it also forms distinct porphyroblasts. Otherwise, its mode of occurrence is as anhedral and subhedral grains in the granitic groundmass. It also occurs as inclusions within the potash felspar porphyroblasts. Some plagioclase porphyroblasts indicate their partial replacement by microcline. The grains show twinning on albite law, and the extinction angle measured on the twin lamellae ranges from 8° to 12°.

The plagioclase porphyroblasts show alteration to mica and saussurite wherever affected by the shearing.

Biotite and muscovite both are present but their content is rather subordinate, and in some specimens only biotite is present in appreciable proportion. It always forms small flakes and scales of greenish brown colour, arranged in small streaks and tufts. The biotite is rarely fresh and in most sections it is seen to be chloritic. Muscovite has a two-fold origin; stray flakes, occurring in association with biotite, represent the original muscovite, while in many samples, a new muscovite derived from the recrystallisation of sericite is also recorded.

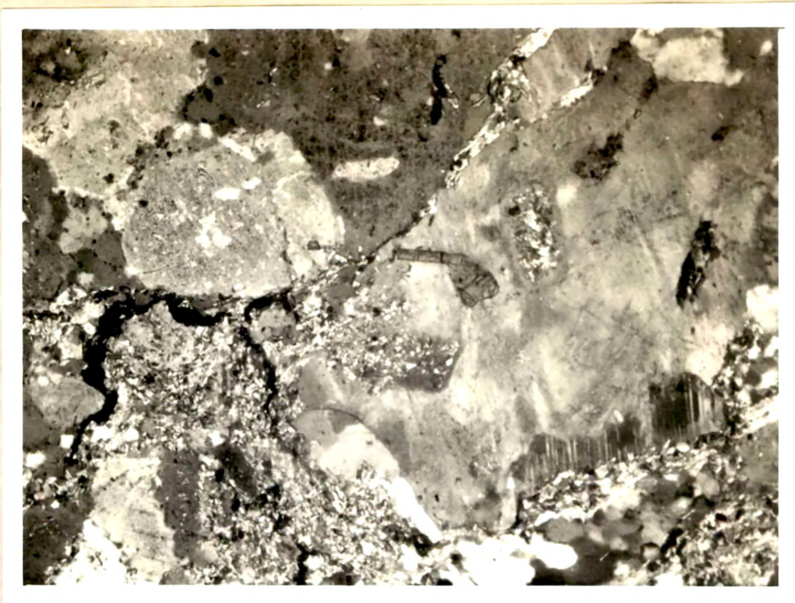
Accessory minerals are magnetite and hematite which occur as small anhedral grains.

Secondary minerals are sericite, epidote and chlorite derived by the alteration of felspars and biotite respectively.

Partly mylonitised gneiss

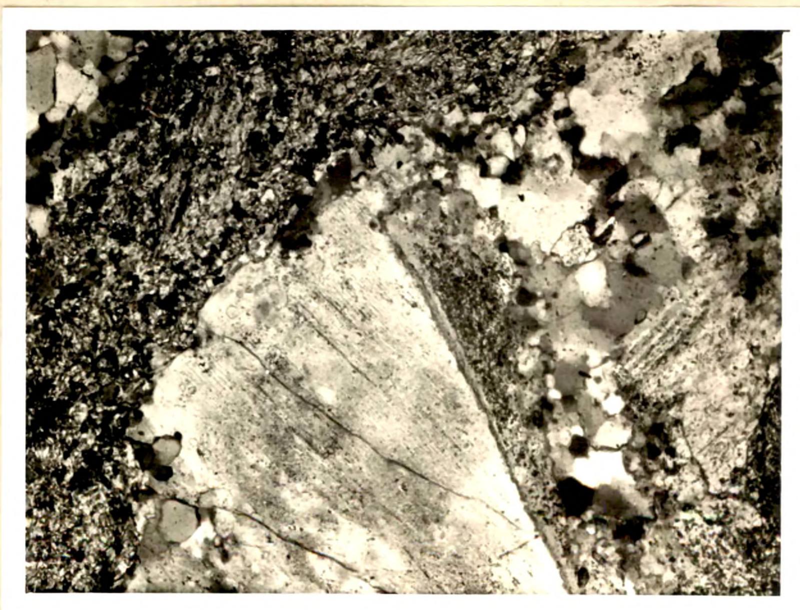
This rock an intermediate variety in which the effects of shearing are such that original nature of the rock is fully discernible, yet the alteration products are quite conspicuous. In hand specimen, the rock is seen as a sheared and partly granulated rock with a streaky and "sub-augen" porphyroblastic structure. Under the microscope, the main mass as well as the porphyroblasts are seen traversed by numerous planes of shearing along which alteration and granulation has taken place. The structure is such that the original felspar porphyroblasts have been broken, drawn out and partly altered. The relicts of porphyroblasts better referred to as 'porphyroclasts', as well as those of the gneissic groundmass, still reveal the original porphyroblastic nature of the gneiss (Plates 4.3, 4.4 and 4.5).

PLATE 4.3



Texture of a partly mylonitised gneiss showing a broken porphyroblast.
(Photomicrograph: Crossed Nicols X80)

PLATE 4.4



Texture of a partly mylonitised gneiss showing increased crushing and granulation.
(Photomicrograph: Crossed Nicols X30)

PLATE 4.5

Texture of a partly mylonitised gneiss showing an advance stage of crushing and granulation. (Photomicrograph: Crossed Nicols X30)

The original mineral composition of the rock is already discussed. Due to shearing, a number of new minerals have developed, and in the existing state, the minerals recognised are: quartz, potash-felspar, plagioclase, biotite, chlorite, muscovite, sericite and epidote.

Quartz shows much variation in its size, shape and mode of occurrence. It is seen as irregular grains big to small. Originally bigger and porphyroblastic grains, are now seen broken and strained. The peripheries of, and the cracks in such grains are crowded with small granules of quartz. In addition, numerous lenticular streaks of fine granular quartz criss-cross the entire mass.

Potash-felspars are again both microcline and orthoclase, recognised by their low R.I. and typical twinnings. These occur as broken, strained, somewhat drawn out and partly altered grains. The alteration is mostly to sericite, which forms streaks and aggregates. The sericitisation is initiated along the margins and cracks.

Plagioclase (An_{26-30}) also shows crushing, granulation and alteration. Porphyroclastic relicts are conspicuous and well preserved, and still reveal the original lamellar twinning of the plagioclase. Alteration is fairly extensive and it either fully or partly shows saussuritisation and sericitisation.

Biotite is much subordinate and occurs as streaky clusters of small flakes. It almost universally tends to be chloritic and greenish brown in colour. Pleochroism is distinct but not so well marked ($X > Y = Z$; X = light green; $Y = Z$ = dark greenish brown).

Chlorite is always present and is after biotite. It is seen as small irregular streaks either as individual flakes or in clusters. It is of usual green colour and is recognised by its feeble pleochroism and low polarisation colours.

Muscovite and sericite occur in close association, and most of the bigger flakes of muscovite are obviously recrystallised from sericite. Sericite has formed streaky aggregates at the expense of felspars. Some muscovite flakes occurring in association with biotite could be the original muscovite of the gneisses.

Epidote is quite common, forms tiny granules and appears to be a secondary mineral released during the alteration of plagioclase.

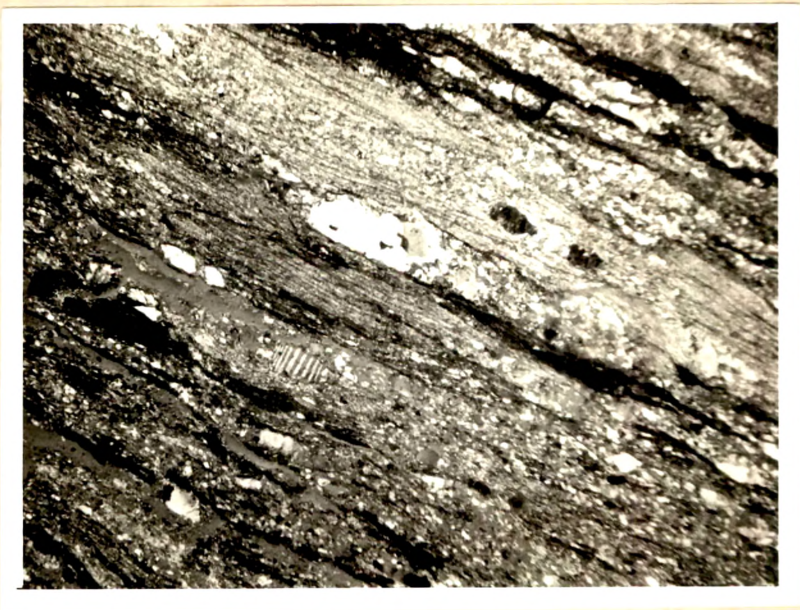
<u>Totally mylonitised gneiss</u>

This rock confined to several narrow zones parallel to the foliation represents almost completely sheared and altered gneiss. In hand specimen it is seen as light grey streaky rock with small elongated patches and porphyroclastic augens. The thin sections of this mylonitised rock show a fine-grained highly foliated mass of chlorite, sericite and quartz in which streaks and lenses of granulated quartz and altered felspars are embedded (Plate 4.6). While some specimens show straight foliation, the others are crumpled.

<u>Quartz</u> occurs as (i) augen shaped porphyroclasts, (ii) lens shaped aggregates of interlocking grains, and (iii) fine granules in close association with micaceous minerals. Quartz content is variable, depending upon the amount of quartz in the original rock. The porphyroclasts mostly show strain effects. These bigger partly crushed grains are surrounded by rims of tiny quartz granules (Plate 4.7).

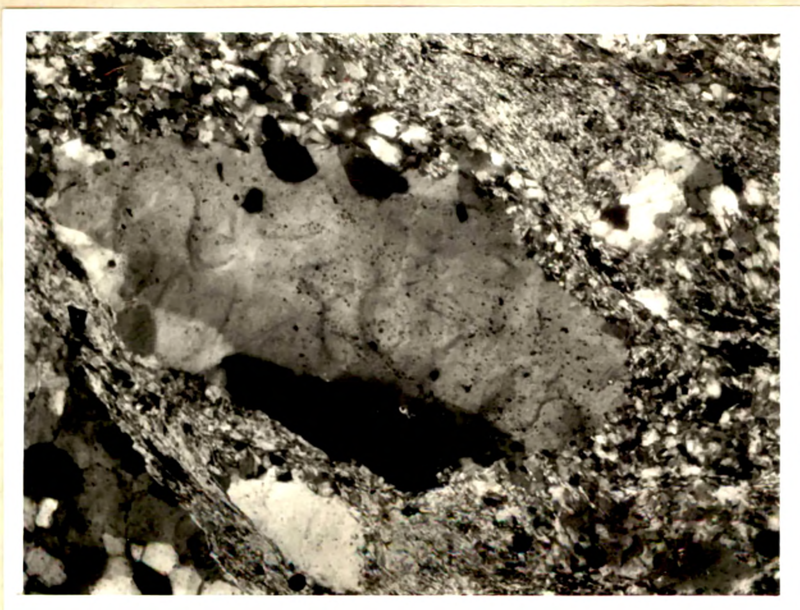
<u>Felspars</u>, both potash and plagioclase are recognised but they are invariably in a high state of alteration. Most of the bigger grains are seen as elongated and

PLATE 4.6



Texture of a totally mylonitised gneiss.
(Photomicrograph: Crossed Nicols X30)

PLATE 4.7

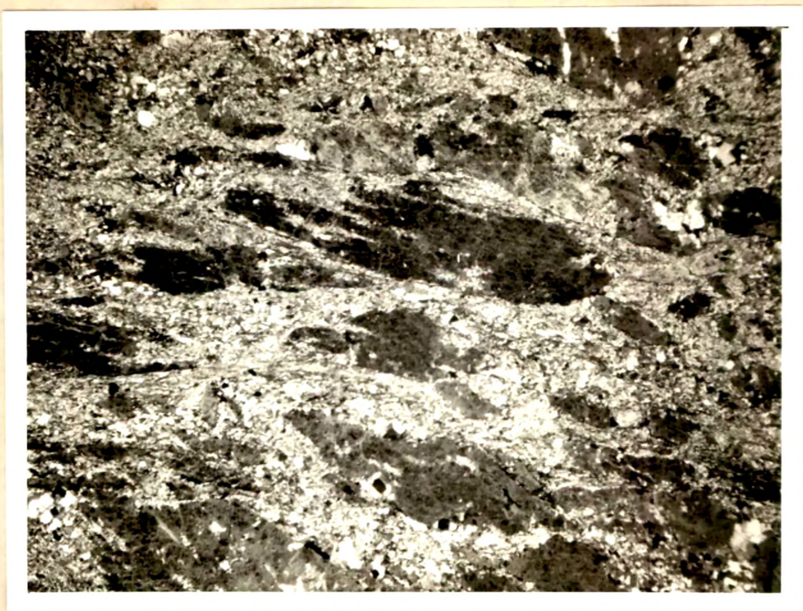


Porphyroclast of quartz showing strain shadow and rims of fine quartz granules in mylonitised gneiss.
(Photomicrograph: Crossed Nicols X80)

altered relicts with irregular boundaries (Plate 4.8). While the potash felspar has altered to a sericitic mass, the plagioclase has given rise to saussuritic material. The original nature of the felspars can hardly be made out in case of potash felspars. However, the plagioclase quite often shows the lamellar twinning still partly preserved. The felspar of the groundmass appears to have been totally altered to a foliated sericite and saussurite mass.

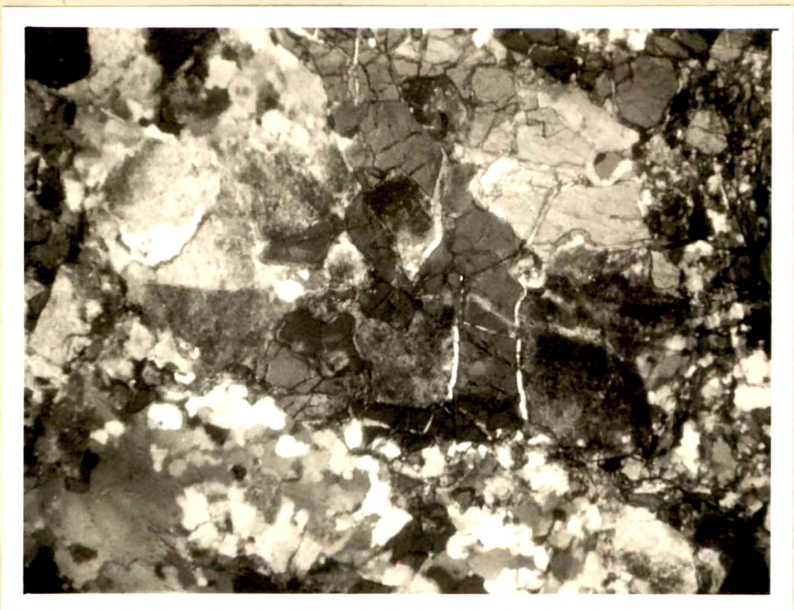
Chlorite, sericite and saussurite are the dominant secondary minerals, derived by the alteration of felspars and biotite of the gneiss. These vary in relative proportions, depending on the original felspar and biotite contents of the gneisses. Chlorite, a derivative from biotite, forms tiny flakes and streaks, occurs in linear clusters, shows green colour and low birefringence. Sericite is after potash felspar, and forms foliated mass of tiny scales. At places, late recrystallisation tends to give rise to muscovite at the expense of the sericite. Such recrystallisation is more common in puckered varieties. Saussurite represents alteration product of plagioclase, and comprises a confused mineral aggregate in which tiny granules of zoisite and quartz are recognised.

PLATE 4.8



Altered and drawn out relict of felspar in mylonitised gneiss.
(Photomicrograph: Crossed Nicols X30)

PLATE 4.9



Plagioclase with included fragments of tourmaline.
(Photomicrograph: Crossed Nicols X80)

Iron ore mostly magnetite and hematite, occurs as tiny opaque grains, uniformly scattered through the foliated mass.

Quartz-felspar-tourmaline rock

This rock forms striking elliptical and spindle shaped bodies in mylonitised gneiss, and show their post-shearing growth. In hand specimen, these bodies are seen to consist of an outer shell of quartz-felspar enclosing a tourmaline rich core. In thin sections, the rock shows a fine to medium grain with abundant quartz-felspar intergrowth. The grain size variation is very striking. The minerals are quartz, plagioclase, potash-felspar and tourmaline.

Quartz occurs as highly sutured grains and shows much variation in grain size. It occurs as conspicuous grains intergrowing with felspars and also as patches and veins of fine aggregates.

Felspars are both potash and plagioclase (An_{25-30}) and both occur almost in equal proportions. Both intergrow and also enclose each other. The potash felspar is an oligoclase and shows both carlsbad and albite twinning (Plate 4.9).

Tourmaline is confined to the main core and forms irregular grains. It shows intimate intergrowth with felspars and quartz (Plate 4.10). It is recognised by its typical patchy brown, olive and slaty blue colour and pleochroism (colourless to pale green).

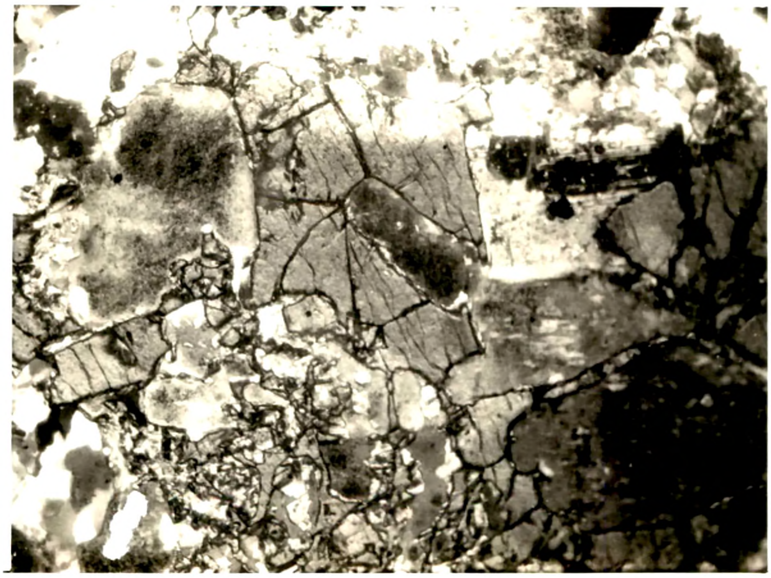
QUARTZITES

Petrographically the quartzites are of little interest. In hand specimens, these are seen as creamy white, fine-grained rock - sheared and somewhat friable. Thin sections reveal a 'granulitic' texture such that somewhat flattened grains of quartz form an interlocking mosaic. The entire quartzose mass is traversed by closely spaced microscopic shear planes (Plate 4.11). Apart from quartz, the rock contains muscovite and biotite in very subordinate amounts.

Quartz is the main constituent and occurs as irregular flat grains, which show considerable interlocking. Strain shadows are rather uncommon and this fact suggests recrystallisation during stress.

Biotite and muscovite occur as tiny and stray flakes interspersed in the granulitic mass. Sometimes these also form fine streaky clusters. Obviously, these two micas represent the original argillaceous content.

PLATE 4.10



Tourmaline showing intergrowth with plagio-
clase.
(Photomicrograph: Crossed Nicols X80)

PLATE 4.11

Almora nappe quartzite showing granulitic
texture and parallel shear planes.
(Photomicrograph: Crossed Nicols X30)

Chlorite and sericite are the alteration products after biotite and muscovite respectively. These appear to have formed during the shearing of the quartzites.

PHYLLONITES

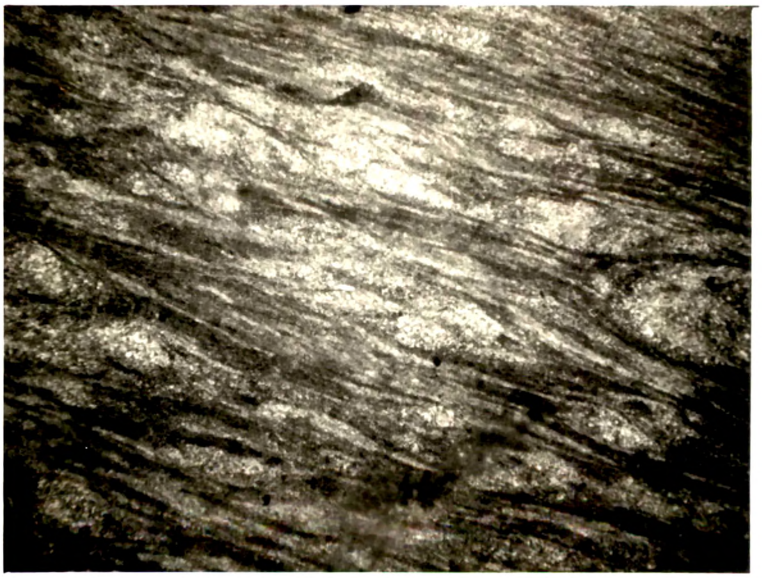
These highly sheared rocks confined to the vicinity of the thrust, resemble phyllites in hand specimen. Highly cleaved and finegrained, the phyllonites are light grey or greenish grey, somewhat sheeny rocks. In thin sections, the phyllonites show a fine-grained foliated mass of tiny specks of chlorite, sericite and quartz interspersed in the foliated mass are lenticular aggregates of quartz granules. Iron ores show a uniform scattering throughout the rock. While most of the phyllonites show a straight foliation, (Plate.4.12A) some are seen crinkled with a strain-slip cleavage. This crinkling is obviously a drag phenomenon and suggests micro-folding of the earlier shear cleavage (Plate 4.12).

Quartz mostly occurs as fine granules intimately mixed with chlorite and sericite. Also it forms pods of fine granules, indicating intense crushing of originally bigger grains. It also forms veins of somewhat bigger grains and these either represent original quartzose portions or introduced quartz during shearing.

PLATE 4.12

Crinkled phyllonites with a strain-slip cleavage.
(Photomicrograph: Crossed Nicols X80)

PLATE 4.12A



Texture of uncrinkled phyllonites
(Photomicrograph: Crossed Nicols X80)

Chlorite and sericite can not be studied separately, as these occur intimately in close association. Chlorite rather dominates over sericite, and is recognised by its green colour, feeble pleochroism and low interference colours. Sericite forms colourless scaly aggregates.

Iron ore is mostly magnetite and hematite of which the latter predominates. These form discrete grains scattered all over the chlorite-sericite mass.

EPIDIORITE

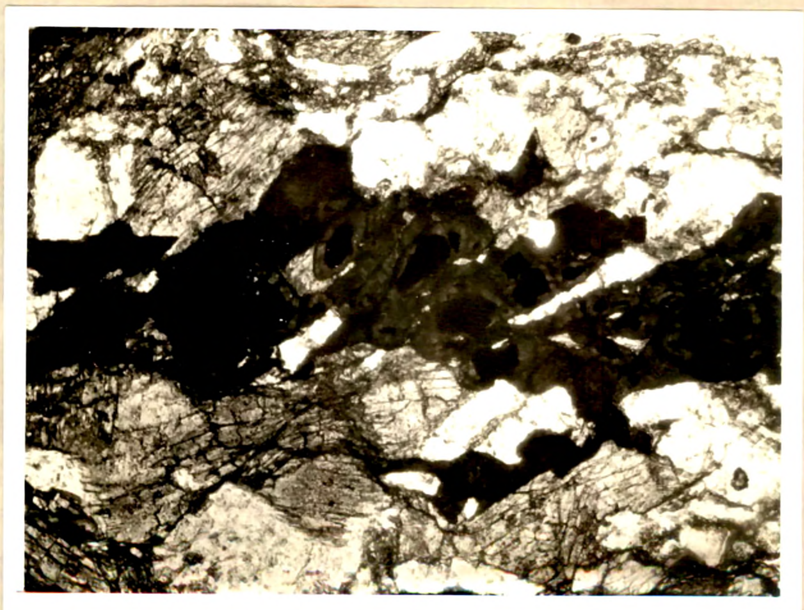
This rock occurring as narrow bodies conformable with the foliation, represents a post-thrusting igneous mafic activity. It is a dark brown or dull grey rock, which under the microscope shows a well marked relict sub-ophitic texture. Tabular laths of partly altered plagioclase are seen embedded in a hornblendic or chloritic material. The original constituents of the rock must be plagioclase and pyroxene. While the plagioclase is still preserved, the pyroxene has totally altered to hornblende, chlorite and epidote (Plate 4.13).

Plagioclase (An_{30-40}) forms rectangular or prismatic subhedral laths and shows both carlsbad and albite twinning. Alteration to saussurite is always there but its degree varies.

PLATE 4.13

Texture of epidiorites.
(Photomicrograph: Crossed Nicols X30)

PLATE 4.14



Leucoxene patches with ilmenite cores in epidiorites.
(Photomicrograph: Polarised light X80)

<u>Hornblende</u> is after the original pyroxene and forms rather big xenomorphic grains of light green colour. It typically shows the amphibole cleavage and pleochroism ($X < Y = Z$; X = pale greenish; Y = yellowish green; Z = green). Its alteration to chlorite and epidote is common.

<u>Chlorite</u> is an alteration product of hornblende and is most abundant in the specimen of the sill occurring in the gneiss. It forms felted masses of light green colour, faintly pleochroic and with low polarisation colour.

<u>Epidote</u> occurs in two ways. Either it forms clusters and streaks of tiny granules around the hornblende and plagioclase, or it forms distinct clusters of well formed crystals. The bigger grains show typical yellowish green colour and second order polarisation colours. Extinction on (110) is about 10°.

<u>Ilmenite-leucoxene</u> occur as stray patches. The ilmenite forms small grains within opaque white masses of leucoxene (Plate 4.14). These appear to be an original constituent of the mafic rock.