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GEOLOGY AND PETROGRAPHY OF METAMORPHIC ROCKS IN MAUJI AND RESHIAN AREAS, DISTRICT MUZAFFARABAD AZAD KASHMIR, PAKISTAN

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ABSTRACT

Geological mapping was conducted in 13 km² area in Mauji and Reshian, District Muzaffarabad, Azad Kashmir. The work has involved detailed petrographic studies. Metasedimentary rocks in the Mauji-Reshian area consist of graphite, pelite and arenaceous schists with minor gypsum and calcareous bands belonging to the Salkhalas. These rocks are intruded by biotite granite gneiss and numerous dolerite dykes. The metasediments have been metamorphosed under the greenschist facies conditions. An almandine garnet schist has developed probably in the aureole around the biotite granite gneiss.

The mineralogical assemblage of the schist together with the presence of gypsum and calcareous bands in the area is indicative of flysch type deposits as a result of sedimentation under shallow water marine conditions. The graphite schist is characterizd by extremely fine grained quartz averging 50 um in size, abundant carbonaceous material and ubiquitous presence of pyrite suggesting a black shale origin for these rocks.

INTRODUCTION

Field work was conducted by the one of the authors (M.A.R.) in the Mauji and Reshian areas in District Muzaffarabad during summer of 1974. It comprised geological mapping and the collection of samples. The area was mapped on a scale 1:16000. Location of the area is shown in the index map (Fig. 1).

The mapping was conducted by foot traverses using topographic sheets as base. Geological contacts were marked as far as possible by traverses in different directions but the accuracy is limited by the difficulty of accessibility and vegetation in the area.

The geological maps of Mauji and Reshian areas are presented in Figures 1 and 2 respectively. The maps show the distribution of metasedimentary sequence of rocks together with the distribution of gneissic bodies, dolerite dykes and gypsum bands.

Thirty one thin sections were examined in detail for modal composition of various mineralogical assemblages. Emphasis was given to the observation of textural features and genetic relationships. The work provides geological maps of Mauji and Reshian areas, the classification of rock types and the metamorphic zones in the Mauji-Reshian region together with the detailed petrographic description. An attempt has also been made to interpret the petrogenesis based on the data provided.

Previous Work

Middlemiss (1910) and Middlemiss and Bion (1913) were the first to establish the stratigraphic relationship in the Kashmir region. Wadia (1931, 1961) made a compilation of the Himalayan geology including his own investigation on the Kashmir region. Gansser (1964) has provided an excellent description of the geology of the Himalayas which includes the geological setting and the structure of various sections of the Himalayan range. No work has been done on the detailed geology and structure of Azad Kashmir region.

REGIONAL GEOLOGY

The area lies in the Kashmir region of the Lower Himalayas. The rocks in this region are mainly known as Salkhala Series (Wadia, 1931). These rocks are regarded as the oldest and form a basement in the region. They have been correlated with the Jutoh Series of Simla, the Vaikritas of the Central Himalayas and the Dharwars of the Penninsular shield (Wadia, 1961). The lower Himalayan region is separated by the Main Boundary Fault from the foothills of the Salt Range and Potwar basin containing sequence of Tertiary formation (Gansser, 1964).

Northwards, the lower Himalayas are transgressed by the young fossiliferous formations in the Tibetan region. Westwards the region is flanked by the Kashmir-Hazara syntaxis (Wadia, 1931) which is mainly responsible for aberrant tectonic trends in this region.

The stratigraphic sequence in the Azad Kashmir region is based on the relationship of the exposed younger rocks with the Salkhala Series rocks. Since the latter are overlain by the Precambrian to early Cambrian Dogra Slates, their age must be Precambrian (Gansser, op cit).

The most prominent structural feature in the region is the Main Boundary Fault which is regarded as a major north dipping thrust fault at the southern limit of the Lower Hamalayas separating it from the Murree or Siwalik formation (Gansser, op. cit). Calkins and Matin (1967) have traced this major fault from the Kunhar River to Muzaffarabad and southwards along the Jhelum river.

LOCAL GEOLOGICAL SETTING

Metasedimentary Rocks

The metamorphic rocks of Mauji and Reshian areas form the continuation of the same sequence of metasedimentary rocks in the area and can be divided into the following three lithological types:

(i) *Pelitic Rocks.* The rocks show widespread distribution in the area. They are characterized by the presence of very fine micaceous minerals with well-developed foliation and microscopic banding. The pelitic rocks display metamorphism ranging from chlorite to almandine zone.

(ii) *Quartzitic Rocks.* The quartzitic rocks are also very fine grained with minor micaceous minerals. They occur as intercalated bands within pelitic rocks which grade into the quartzitic rocks. For the purpose of field mapping the pelitic and quartzitic rocks were regarded as one lithological unit. Quartzitic rocks show chlorite grade of regional metamorphism.

(iii) *Graphitic Rocks.* The graphitic rocks are predominent in the Mauji-Reshian area. They consist of segregated bands of carbonaceous-rich material, on microscopic scale. Graphite schist grades gradually into the pelitic and quartzitic rock while its contact with the granitic gneiss is sharp.

Biotite Granite Gneiss

In Mauji, gneissic rocks are exposed in a body about 150 metres thick following the trend of foliation of the graphite schist (Fig. 1). There are also minor gneissic bodies of thickness about 60 and 70 m trending NW-SE within the pelitic schists. Southwards, in Reshian the gneiss attains a thickness of about 450 m and extends NW to Mauji (Fig. 2). The extension of the main biotite granite body in the Mauji-Reshian area appears to be related to a major granite gneiss body exposed along the river Neelam, NW of the village of Mauji.
village of Mauji.

The various lithological units of rocks in the area are arranged in the stratigraphic succession as shown in Table 1.

TABLE 1. SUCCESSION OF SALKHALA SERIES IN MAUJI AND RESHIAN AREAS

Rock Unit		Thickness in metres
3.	Dolerite Dykes	10–25
2.	Almandine Schist	30
	Biotite Granite Gneiss	50–400
1.	Metamorphic Schistose Group	
	Quartzite	600
	Chlorite and Quartzitic Schists	550
	Graphite Schists	115
	Biotite Schists	30–45

Structure

The graphite schists show a high degree of folding with minor brecciation of the rock. Shearing is also commonly present along the axes of folds, the shear zones vary in thickness from 1 cm to about 1 m. A major shear zone is located in the Mauji area, and is filled with breccia which consists of graphite schist fragments with goethite matrix.

Minor structures are exhibited by small scale folds in the pelitic schists which contain quartz infills in the crests and along other areas of low pressure. The pelitic schists show well-developed schistosity parallel to the foliation.

The area shows isoclinal type folding of chlorite schist, graphite schist and biotite schist, the axis of the major fold passing through the biotite schist. Furthermore, the almandine schist is developed in contact with the gneiss (Figs. 1 and 2). The chilled contact of gneiss together with hornfelsing, toughness and development of somewhat criss-cross foliation in the almandine schist probably indicates the latter's development as a result of contact metamorphism due to intrusion of the granite body.

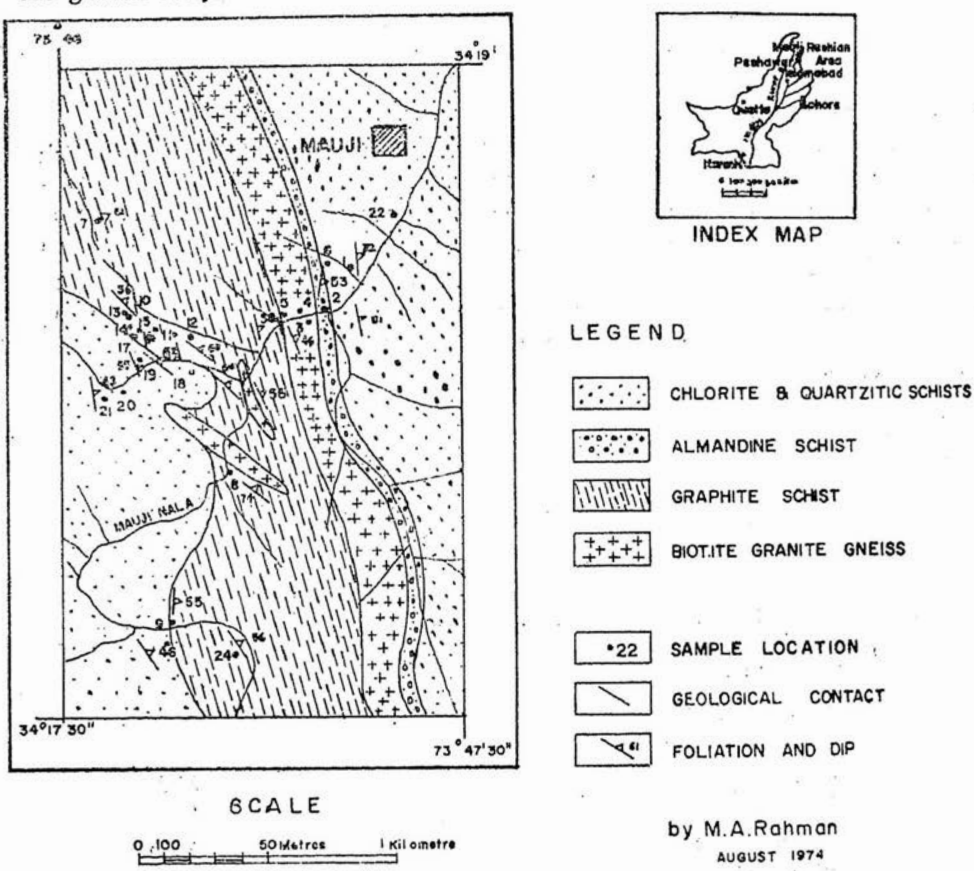

Fig. 1. Geological map of the Mauji area, Azad Kashmir.

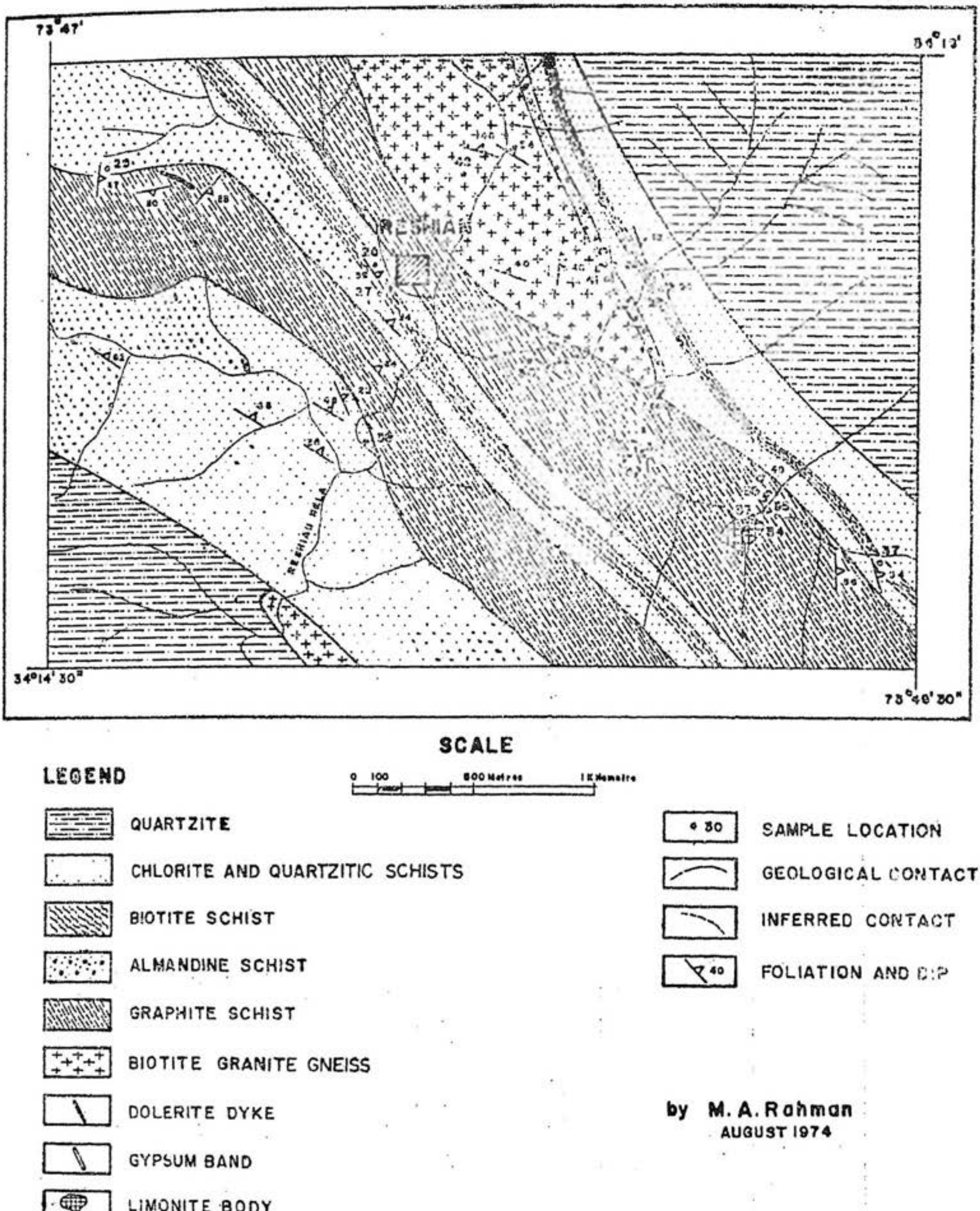

Fig. 2. Geological map of the Reshian area, Azad Kashmir.

PETROGRAPHY

Chlorite Schists

The chlorite zone rocks essentially consist of quartz, albite/oligoclase, prochlorite and muscovite in variable proportions with minor amount of magnetite, apatite and sphene. At some places, presence of schorlite is also noted. Modal composition of mineral constituents of chlorite schists is given in Table 2.

TABLE 2. MODAL COMPOSITION OF CHLORITE SCHISTS BASED ON VISUAL ESTIMATES

Sample No	Quartz %	Albite/ Oligoclase An_9–An_{12} %	Prochlorite %	Muscovite %	Zoisite %	Schorlite %	Sphene %	Apatite %	Magnetite %
1	50	15	25	5	—	—	1	2	2
6	60	15	8	12	—	—	1	1	3
19*	65	—	7	15	4	3	1	1	2
38	78	—	10	5	—	2	—	1	4

* In addition to the listed constituents, this chlorite schist contains limonite 2%.

TABLE 3. MODAL COMPOSITION OF QUARTZITIC SCHISTS BASED ON VISUAL ESTIMATES

Sample No.	Quartz %	Perthite %	Albite/ Oligoclase An_8–An_{14} %	Sericite %	Muscovite %	Schorlite %	Siderite + Goethite %
20	62	8	5	12	7	2	3
21	65	10	4	8	3	5	4

Quartz is present as very fine subhedral to anhedral grains elongated parallel to schistosity often forming interlayers with chlorite as segregated bands. Albite/oligoclase (An_9–An_{12}) is present as fine subhedral to anhedral, irregularly oriented grains generally intergrown with quartz and showing minor alteration to sericite. Twinning on albite law is characteristic. Zoning is occasionally present. Prochlorite is present as pale green, short and tabular flakes. Muscovite flakes are colourless, sometimes forming thin segregated layers parallel to the schistosity.

Minor amounts of sphene and apatite are invariably present. Opaque grains of magnetite as subhedral elongated grains are present cross-cutting the micas. Tourmaline as schorlite variety is occasionally present as olive coloured, prismatic grains.

Quartzitic Schists

The quartzitic schists consist of quartz, sericite, perthite, muscovite and albite/oligoclase (An_8–An_{14}) in variable proportion with minor amounts of tourmaline and siderite associated with goethite. The modal composition of the quartzitic schists is given in Table 3.

Quartz is present as subhedral to anhedral, fine grained and generally elongated parallel to schistosity. Sericite is present as minute flaky agregates generally oriented parallel to the schistosity. Relict perthite grains show presence of lamellar growth of plagioclase in potash feldspar. Albite/oligoclase (An_8–An_{14}) are subhedral showing characteristic twinning on albite law. Goethite impregnates the rock along the schistosity.

The quartzitic schists as well as graphite, biotite and almandine schists, which are being further described, have all indicated the presence of muscovite of second generation which is generally developed at an angle to the foliation. This muscovite is characterised by the larger size and higher birefringence (Fig. 3).

Graphite Schists

The graphite schists show fine layering often folded and disturbed by brecciation (Fig. 4). Quartz is present in finely segregated layers of 0.1 mm and shows parallel and elongated S-shaped structures with wavy extinction around euhedral and elongated pyrite grains. Carbonaceous material is present in segregated and somewhat folded layers parallel to the schistosity. Pyrite grains are partly or wholly altered to goethite occasionally forming pyrite pseudomorphs. They form veins along the schistosity and along fracture cross-cutting the foliation. Furthermore, goethite fills spaces in brecciated areas and as matrix in graphite schist breccia.

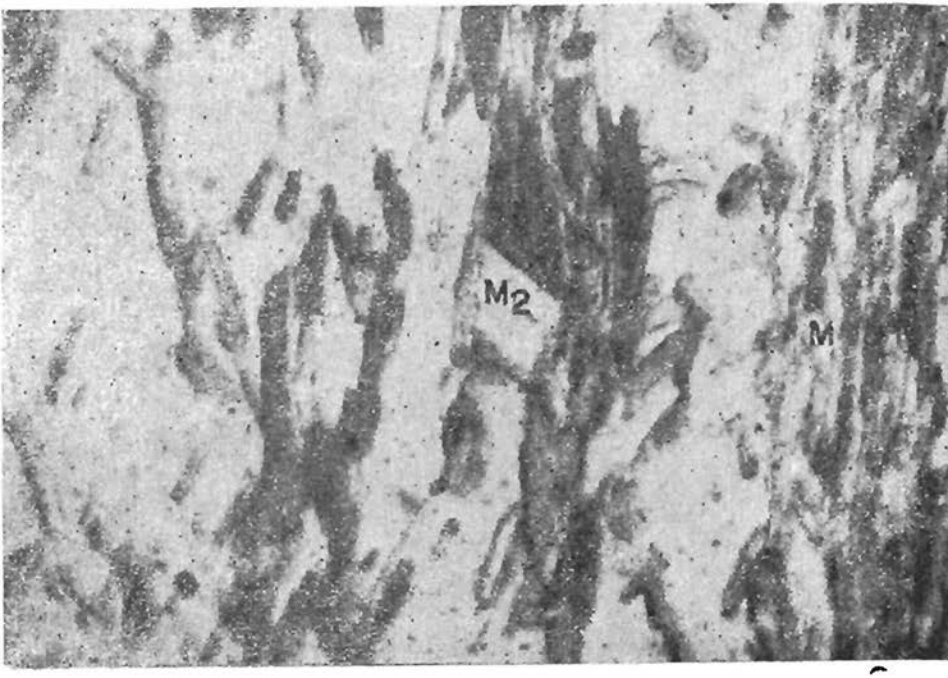

Fig. 3. Muscovite (M) with muscovite of second generation (M_2) developing across foliation in the biotite schist. Biotite is present as dark grey flakes. X80. Polarized light.

Graphite schists essentially consist of carbonaceous meterial, quartz and sericite with minor amounts of opaque minerals and muscovite in varying proportions both in Mauji and Reshian areas. In Reshian area, the graphite schists also contain minor amounts of epidote, rutile, tourmaline and apatite. Tables 4 and 5 give the modal composition of the schists from the Mauji and Reshian area respectively.

Quartz is present as 10 to 100 mμ anhedral grains elongated parallel to the schistosity. Segregated quartz bodies are also present in irregularly elongated shapes. Quartz upto 0.5 mm is also present as veins along schistosity, bent and folded with foliation. Carbonaceous material is present as less than 10 mμ cryptocrytalline grain aggregates finely dispersed and irregularly shaped segregated bands of 10 to 100 mμ thickness (Fig. 4). Sericite is presnt as colourless flakes 100 to 300 mμ irregularly distributed in schists.

In Mauji, pyrite as euhedral to subhedral grains, are irregularly disseminated alng foliation but in Reshian, the schists show the presence of goethite pseudomorphs after pyrite. In Reshian area, the graphite schists are also characterized by

Fig. 4. Graphitic schist showing folding and brecciation. White areas indicate presence of quartz bands. X80. Polarized light.

the presence of albite porphyroblasts commonly altered to sericite. Inclusions of carbonaceous material and opaque minerals are commonly present within albite porphyroblasts. Zoisite is present as colourless to pale coloured, short euhedral aggregates. Rutile is present as fine, pale-coloured, prismatic aggregates. Schorlite is present as a greenish yellow, lath-shaped grains disseminated into the rock. Apatite is present as minute prismatic grains and as six-sided sections. Biotite is present as prismatic porphyroblastic aggregates showing subparallel orientation.

A second generation of muscovite shows porphyroblastic growth upto 200 mμ in aggregates cutting across the foliation. The graphite schists show concentration of sulphide minerals and is characterised by the association of calcite and chlorite.

Biotite Schists

Biotite schists consist mainly of quartz, muscovite, biotite, epidote and prochlorite. Minor amount of schorlite is present at some places. Magnetite is variably present and apatite rarely. Table 6 lists the modal composition of the biotite schists.

TABLE 4. MODAL COMPOSITION OF GRAPHITE SCHISTS FROM MAUJI AREA

Sample No.	Quartz %	Carbonaceous material %	Sulphides %	Sericite %	Goethite %	Muscovite %	Voids %
7	28.1	63.5	4.5	1.2	—	0.4	2.3
8	42.3	48.8	5.4	0.6	1.3	0.2	1.4
9	21.9	59.7	6.6	1.0	10.8	—	—
10	31.2	61.5	—	0.6	—	—	6.7
12	23.0	69.5	1.2	2.2	0.6	—	3.5

TABLE 5. MODAL COMPOSITION OF GRAPHITE SCHISTS FROM RESHIAN AREA

Sample No.	Quartz %	Carbonaceous material %	Sericite %	Geothite %	Micro-cline %	Musco-vite %	Epi-dote %	Rutile %	Tour-maline %	Apa-tite %	Voids %
32	24.8	65.9	5.6	3.6	—	—	—	—	—	—	—
35 A	58.2	22.7	4.4	7.4	1.0	3.8	1.0	0.3	0.2	0.5	0.5

Quartz is present as fine grained subhedral to euhedral grains elongated parallel to the schistosity. Frequently quartz form segregated bands of 100 to 500 mμ thickness. Muscovite is present as colourless flakes in segregated bands, 0.5 to 1 mm thick and oriented parallel to the schistosity in association with biotite. Minor amount of muscovite of probably a second generation is characterized by its large size and bright interference colours and its nature of cross-cutting the foliation (Fig. 3). Biotite is in fine-grained, prismatic flakes, pleochroic from olive grey to pale brown and generally in the form of aggregates associated with muscovite.

Epidote is present as colourless short columnar aggregates, occasionally as porphyroblasts of clinozoisite variety. It is preferentially associated with biotite. Schorlite is irregularly disseminated in the rock. Apatite is rarely present as a constituent of biotite schist.

Almandine Schists

The almandine schists consist of quartz, biotite, muscovite and chlorite with minor amounts of almandine, tourmaline and opaque minerals. Albite is also found. Epidote is occasionally present in the Mauji area. Minor amount of apatite is concentrated in a band (Fig. 5). Association of minor carbonaceous material is also

Fig. 5. Almandine schist containing quartz (light grey), biotite (grey), muscovite and chlorite (light grey flakes) almandine and tourmaline (grey). Apatite (A) is present in a band. Miscovite (M_2) of second generation is seen in the middle. X80. Polarized light.

TABLE 6. MODAL COMPOSITION OF BIOTITE SCHISTS BASED ON VISUAL ESTIMATES

Sample No.	Quartz %	Muscovite %	Biotite %	Clinozoisite %	Prochlorite %	Schorlite %	Apatite %	Magnetite %	Limonite %
27	30	23	18	14	7	5	—	3	—
28	25	38	14	15	—	5	—	1	2
37	50	23	15	—	9	—	1	2	—
39	55	17	12	5	7	—	1	3	—

indicated. Modal composition of the almandine schists is given in Table 7. Biotite as brown to reddish brown flakes occurs in association with pale green to green short prismatic prochlorite flakes forming parallel foliation in the rock. Occasionally biotite contains minute inclusion of magnetite. Muscovite is preset as scaly flakes in aggregates and fine segregated layers. Minor amount of a second generation of muscovite is developed at an angle to the foliation.

Almandine garnet is present as light brown irregularly subhedral shaped porphyroblasts generally deformed, fractured and somewhat displaced at fractures. The grains contain magnetite, quartz, biotite and sometime tourmaline as inclusions oriented in an arc shape (Fig. 6). Schorlite is irregularly disseminated as minute triangular shaped cross-sections and prismatic grains.

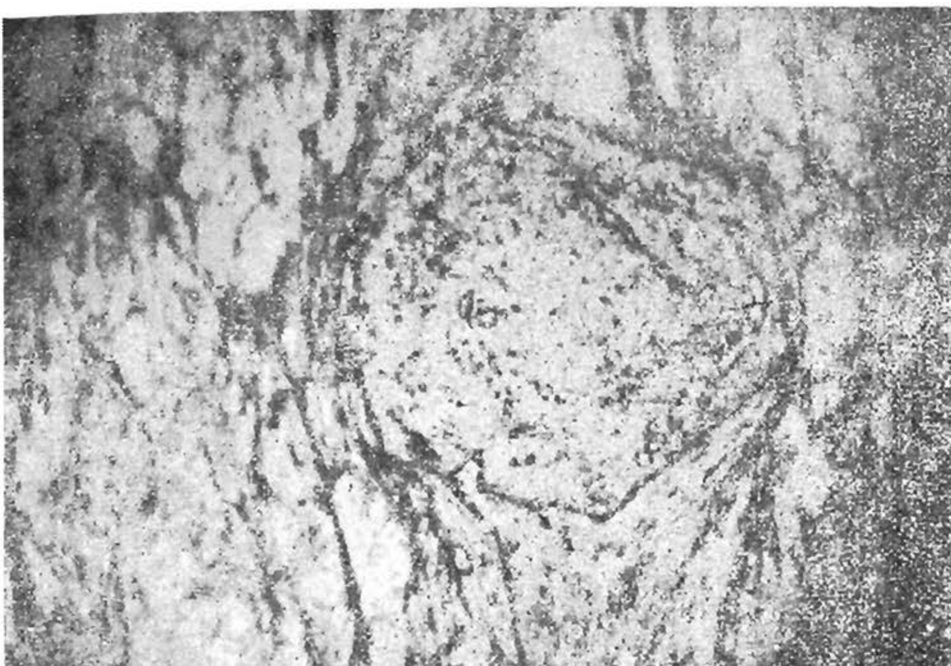

Fig. 6. Almandine porphyroblast (middle) showing inclusions oriented in an arc shape in the almandine schist. X120. Polarized light.

Zoisite is characterized by pale coloured prismatic grains often showing zonal structure. Apatite is present as anhedral grains with abundant development in band of about 1 mm, containing quartz 50%, apatite 30%, chlorite 15% and biotite 5% (Fig. 5). Subhedral grains of magnetite are irregularly distributed in the almandine schists.

Biotite Granite Gneiss

The rock consists of albite, quartz, biotite, muscovite, perthite, microcline and epidote in variable proportion with minor amounts of rutile, apatite, sphene and limonite. Modal composition of this rock is given in Table 8. On the basis of the quartz content and predominent plagioclase together with the abundance of biotite, the rock is called biotite granite (Williams, Turner and Gilbert, 1954).

Albite is present as subhedral to euhedral porphyroblasts generally elongated along the plane of schistosity. They are altered to sericite and zoisite, showing portions of unaltered albite characterized by albite twinning. Albite is also present as a minor fine-grained constituent of the rock. In Reshian gneiss, it was noted that sometime two or more albite crystals in contact with microcline crystals form composite grains of porphyroblasts. Furthermore, in Reshian, albite and microcline porphyroblasts contain dust like opaque inclusions and show myrmekitic growth near the grain boundary. Porphyroblasts of microcline are also present in Mauji but in Reshian, they are absent. In Mauji, these porphyroblasts contain biotite and sericite together with zoisite as inclusions. Minor perthitic and myrmekitic growth and fine-grained quartz around microcline porphyrolasts are also present. Perthitic growths are occasionally developed at the margin of the older albite phase.

Quartz is present as fine to medium, subhedral to anhedral grains often as aggregates. Biotite is present as thin flakes, generally curved and bent around feldspar porphyroblasts, vaguely following the schistosity. Some biotite porphyroblasts contain rutile grains oriented in two directions at about 45° and epidote as inclusions. Such porphyroblastic biotite sometime shows kinkling. A minor second phase of brown biotite is developed at an angle with the major foliation characterized by a lighter colour and higher interference colours.

Muscovite is present as prismatic and tabular flakes. Occasionally, it contains minor inclusions of biotite and anhedral quartz and is generally developed at the margin of microcline porphyroblasts. A second phase of muscovite, characterized by its larger size, is also developed at angle with the foliation.

Epidote, as subhedral to euhedral grains is present in two forms: (1) as aggregates associated with biotite and (2) present within albite as an alteration product.

In Mauji gneiss, epidote occurs as colourless grains varying in composition from zoisite to clinozoisite. Rutile grains are irregularly distributed. Sometimes these are enclosed by irregularly shaped schorlite. Fine-grained sphene is also disseminated. Apatite is also present. Limonite is present in minor amount.

TABLE 7. MODAL COMPOSITION OF THE ALMANDINE SCHISTS BASED ON VISUAL ESTIMATES

Sample No.	Quartz %	Muscovite %	Biotite %	Proclorite %	Almandine %	Zoisite %	Schorlite %	Apatite %	Magnetite %	Carbonaceous material %
2	40	25	10	8	5	5	3	3	1	—
22*	50	13	6	10	5	3	1	—	6	—
24	50	15	8	10	7	2	2	—	1	5
41	50	—	30	7	7	—	2	1	3	—

* In addition to the listed constituents, it contains albite 6%.

TABLE 8. MODAL COMPOSITION OF BIOTITE GRANITE GNEISS BASED ON VISUAL ESTIMATES

Sample No.	Albite P+* %	Quartz %	Microcline Perthite %	Biotite %	Muscovite %	Epidote %	Hornblende %	Chlorite %	Apatite %	Rutile %	Sphene %	Opaque %	Goethite %	Schorlote %
3	27	22	23	15	3	6	—	—	—	2	Trace	—	1	1
4	15	20	20	16	10	7	3	—	1	3	1	—	1	3
40	30	18	20	9	10	7	—	—	2	3	—	1	—	—
42	43	24	5	10	7	7	—	2	—	—	1	—	1	—

* P – Porphyroblasts G – groundmass
Biotite and muscovite estimates include both 1st and 2nd generation.

The foregoing petrographic description of rocks in the Mauji-Reshian region indicates the presence of metamorphic zones. These zoes are characterized by the progressive rise in metamorphic grade demonstrated by the presence of the index minerals chlorite and biotite. Following the classification of metamorphic rocks by Turner and Verhoogen (1960) and Winkler (1965), the rocks in the Mauji-Reshian area are classified into varius metamorphic assemblages.

The rocks in the chlorite zone contain predominantly quartz, prochlorite, albite (An_8–An_{14}), muscovite and sericite. They contain characteristic mineral albite ± epidote but the presence of high anorthite content (> An_7) suggests that the temperatures attained during metamorphism might have surpassed the range of the greenschist facies (Winkler, 1965). The quartz-graphite-sericite schist and quartz-graphite-albite-sericite schist represent assemblages of greenschist facies probably equivalent to the chlorite zone. This however, indicates a low grade metamorphism of black shales. As they contained significant amount of organic matter, it was reduced to graphite (Harker, 1939).

The quartz-muscovite-biotite-epidote assemblage represents the biotite zone of relatively higher temperature under the greenschist facies. Furthermore, the quartz-muscovite-biotite-prochlorite-almandine schist is characterized by the presence of all gradations of micas which enable it to be distinguished from the quartz-albite-epidote-almandine subfacies of the Barrovian Type (Winkler, op. cit). The almandine zone subfacies is developed at the contact of the biotite granite gneiss as an aureole which suggests a contact metamorphic origin. Almandine is probably formed at the expense of chlorite in the rock (Harker, op. cit). The growth of almandine porphyroblasts is demonstrated by the presence of inclusions of magnetite, quartz, biotite and tourmaline (Fig. 6). These inclusions are oriented in an arc shape and is indicative of rotation features (Spry, 1969) probably due to local stresses.

The mineral assemblages in the schist together with the presence of gypsum and calcareous bands in the area is indicative of flysh type deposits as a result of sedimentation under shallow water marine conditions. The graphite schist is characterized by extremely fine grained quartz averaging 50 μm in size and abundant carbonaceous material averaging 30% of the rock which indicates a black shale origin (Rahman, 1979). The abundance of carbonaceous material can be explained by the presence of marine algal life in the Precambrian period (Gardezi, 1970).

The gneissic rocks are granite. A concordant relationship of the granitic gneiss with the metasediments together with the evidence of chilled contact and the development of the almandine schist along its contact indicate the granitic gneiss to be of instrusive origin.

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