Chapter II

THE ARGILLACEOUS AND ARENACEOUS METAMORPHITES.

The group of metamorphites, varying in composition from argillaceous to arenaceous, with frequent calcareous and amphibolite bands, are the oldest rocks visible in the area. The argillites constitute the major proportion among the sedimentary metamorphites, though they are very intimately intercalated with bands of quartzites of various dimensions, especially at the base and towards the top.

Quartzites, pure or with more or less argillaceous impurities, predominate towards the base where magnetite quartzites and schistose mica-sillimanite-quartzites are very common. Though the magnetite quartzites generally occur as lenticular bands merging on into pure quartzites, they extend along a fairly good distance, in interrupted bands, almost throughout the length of the area mapped. Towards the top again quartzites with a comparatively greater proportion of argillaceous impurities occur associated with argillites and calc-silicates.

Quartzites derived from quartz veins are not rare. These are most often conformable and though deformed together with the schistose formations, they are distinguishable by their more or less massive character, and they show the most imperfect development of joints even when intimately associated with well-jointed sillimanite gneisses and schists. These are pure white quartzites, composed of comparatively massive crystalline quartz, sometimes with quite a discernible schistosity. The sedimentary quartzites are finely schistose and contain a little muscovite and/or sillimanite, even if exiguous and

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sometimes also a little magnetite. Pegmatites similarly deformed with the schistose rocks are also noticed, though they are rather rare.

There are extensive occurrences of quartz veins and pegmatites of ages later than the period of the major diastrophism. These are seen to cut across the schistose country rocks in different directions and also to follow the schistose planes (Fig 3). Sometimes big lenticular bands of pegmatites, connected presumably with the porphyritic granite, are seen to have penetrated along the schistose planes. These pegmatites, not very far off from the main mass of the porphyritic granite, are occasionally associated with thin interrupted bands of the granite (See also Chapter VII).

Big lenses of these pegmatites, in pushing apart the schistose planes, have caused intense puckering in the rocks close to the veins (Fig 4). In these rocks, in contact with the pegmatites, flakes of muscovite have been developed, sometimes quite big and of considerable proportion to impart to the rock the typical cleaved appearance, and it is then composed essentially of muscovite-sillimanite and quartz.

At least three periods of hydrothermal action are recognizable in the field, one pre-granitic and pre-diastrophic, a second associated with or contemporaneous with the granite gneiss, showing intimate and profuse venation in contiguous zones or in the granite gneiss itself, and a third with a greater proportion of pegmatites, connected with the porphyritic granite, occurring inside it or in the wall rocks.

Some schistose quartzites and the pre-diastrophic quartz veins are sometimes associated with various proportions of disseminated flakes of graphite (eg near Beti (QM 468106, 73 $\frac{1}{14}$), Brindabanpur (QM 399102, 73 $\frac{7}{14}$) etc). Graphite is also present in some calc-silicate granulites and schists (Chapter III) and in sillimanite quartz schists (eg from Ramchandrapur hill 73 $\frac{1}{14}$).
Figs 3 (a and b): Pegmatite in sillimanite - almandine schist country rock, following, for the greater length, the schistose planes of the rocks, but showing locally, in places discordant relation, cutting across the planes.
On Bisram Jhor, near Railroad cutting. (see text).

Fig. 4: Lens shaped pegmatite in sillimanite schist pushing apart the schistose planes (Loc. same as in Fig 3). (see text).
Among the argillites typical cleaved mica schists have not been met with in the area, and sillimanite is universally present in proportions large or small. The dominant variety could best be described as a sillimanite gneiss with varying proportions of quartz. Quartz-sillimanite-mica schists are not rare, and there are all sorts of gradation from pure argillites to pure quartzites.

These rocks together with the associated rock types dip in a general northerly direction. The direction changes within a small range, except in case of folding which is rare, and the amount also varies from 30° to nearly 90°. Towards the northern extremity of the mapped area, the dip of the argillites changes to about 45°S along a zone close to and northeast of Laggadanga (N35°50′99; 73°10′) while further north they again dip north at a moderate angle. This fold occurs along a thin zone. Further north (beyond the area under consideration) the intensity of the folds diminishes forming broad moderately dipping pitching anticlines and synclines. In the southernmost of these synclines the argillites dip below the calc schists, calc-granulites and amphibolites, which latter, by repetition due to comparatively low angle folds, continues in the north as an exposure of considerable extent. The succession seems to be definitely established in this region.

Local instances of 'secondary' folding, generally not of any considerable magnitude, are quite common. There are good examples of minute folds with axes at right angles to the regional trend of the formation. Near Laggadanga for about 400 yards along the strike, beds of schistose micaceous quartzites are seen to be folded into successive anticlines and synclines which gradually die out in the east through minute puckerings. The axes of the folds dip roughly 78°S while the formation has at that region, an average dip of 45°S (See Chapter VIII). Small scale pitching fold are also noticed.

* The area is being mapped and studied by A.K. Banerjee, for his M.Sc thesis, under the guidance of the author.
with axes pitching in the same direction as the dip, and also parallel to the strike (e.g. in the rock outcrop 86° 27' E : 23° 25' N in between GoEunra and Maithol).  

Joints are well developed in the rocks close to the porphyritic granite. They have been described in a later section giving the structural features of the wall rocks (Chapter VIII). These metamorphites, chiefly the argillites, show also joints which are not genetically connected with the emplacement of the granite. These are comparatively sparse in frequency and are most often associated with small scale folds showing distinct relationship with them. The joints occur in the crestal region of anticlinal folds, as a typical set of tension joint fan produced due to the tension at the apex caused by the folding.

In a minor folding in the schistose rocks near Bheti (See page 8), with one of the main limbs dipping 59° towards 348°, joints have been developed in the crest of the little anticlinal fold, with dips varying from 35° to 65° towards 168° (Fig 5) forming a typical tension joint fan.

Joints, somewhat better developed, are also found associated with the regional folds. These belong to two sets mainly. One set trends at right angles to the regional fold axis with steep dips, and the second a conjugate plane with either one or both developed, trend diagonally with respect to the fold axis which coincides with their acute bisectrix (Figs 6 a & b). The first set is an AC tension set. The second is probably a set of diagonal shear joints, the angular relations determined by an effective elongation parallel to E, which is proved by the presence of AC tension joints.

Some minor faults are also noticed (as east of the rise S.S.W of Ialgar, QM 428114, 73 1/14) which are, however, of little significance.
Fig. 5.
Tension Joint fan
in a minor fold near Bheti (see text).
Fig. 6a. Intersecting shear joints in the metamorphites, with strike of foliation indicated.

Fig. 6b. Stereogram of the above to locate the strike of the plane of acute bisectrix, strike of foliation indicated.
Some non-tectonic gravity slip structures are worthy of note. The incompetence of the argillites makes them especially susceptible to such disturbances. North of the railway crossing on the Bisram Jhor (QM 420128, 73\(^\circ\) 14') a slip is noticed, the northerly dipping steep folded sillimanite-mica schists have slipped, along a plane that dips approximately 35\(^\circ\) S, through some few yards (Fig 7).

The metamorphites are found included in the porphyritic granite, and they also occur as lenticular or thin streaks in the granite gneiss. In the field there are innumerable occurrences where all possible gradations are seen from the argillites, through ultra-metamorphites into granite gneiss. The field relations suggest a gradual passage of the argillites to a pure granite gneiss.

Petrography.

Argillites.

The rocks are typically gneissose having varying proportions of the chief constituents sillimanite and quartz. They are almost always garnetiferous, the garnet sometimes attaining considerable size. Occasionally garnets may exceed the other minerals taken together. Graphite, though not universal in its presence, is also commonly associated, generally disseminated throughout. Magnetite present in varying amounts may be, at times, of considerable proportion. Microcline is rarely absent. It is present in varying proportions increasing in proximity to the granites. Biotite is sometimes present. In a few slides (5611: Lalgarih; 13156: Ramchandrapur etc) it is found to be equal to sillimanite or quartz and in a few others it exceeds sillimanite in proportion (275\(\AA\)). A little sphene is sometimes present.
Fig. 7: Closely folded part of a drag fold in the argillaceous metamorphites that has slipped down a low angle 'thrust' induced by gravity, north of the Railway cutting on Bisram Jhor. (see text).

Fig. 9: Amphibolite lens in the granite gneiss, on the Beko Nadi, south of Beko. (see text).
Sillimanite occurs as fibres or stout needles and blades, sweeping round the garnets, sometimes occurring as sheafs along fractured interspaces of the grains. Small needles are often seen embedded in quartz. The arrangement of the bundles of sillimanite needles do not always conform to the gneissosity, which, however, is quite discernible in hand specimens (Fig 8a). The bundles often simulate a fluxion structure. Very few grains of andalusite have also been noticed in a few specimen.

The garnet is almandine in composition as seen from the three analyses given below. The porphyroblasts show innumerable inclusions of quartz. The garnets often show alteration to iron oxides, sometimes the whole crystal may be thus altered. Muscovite is only rarely present in

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Other Consta N.D N.D N.D

Specific Gravity 4.19 4.20 4.19

(Analyst : S. Sen)

the sillimanite gneisses and that always in minute proportions. Close to some pegmatite veins, muscovite occurs at the expense of sillimanite, replacing the mineral and imparting to the rock a typical cleaved appearance. Sillimanite continues to be present, though only as an important accessory. This appearance of muscovite close to pegmatites points to a definite genetic connection, and it
entrance of K and (OH) which converted the sillimanite to muscovite.

In the ultrametamorphite variants, with increase in proportion in microcline (addition also of acid plagioclase) and disappearance of sillimanite, all gradations towards a composition of the granite gneiss are found. In some varieties a gradual breaking up of the sillimanite is noticed (Fig 8b) and there is a great increase in the proportion of microcline relative to the other minerals. The metamorphites (except in very rare instances) are characteristically devoid of plagioclase, and in the gradations to the granite, plagioclase is found only occasionally in some varieties of the ultrametamorphites. It appears most suddenly in the purer granite gneisses. In some cases the composition approaches or attains that of a granite (with or without biotite) in which plagioclase is absent (Fig 8c). Such granite gneiss (Kalialaskite: Johansen, 1933) are composed entirely of quartz and microcline with a few grains of sillimanite that appears in the heavy separate (c.f. granite gneiss: Chapter V).

The almost invariable absence of CaO-bearing minerals from the argillites might indicate that the gradations found in the field from these rocks to the granite gneiss do not possibly represent a gradation in the degree of granitisation. The presence of K-rich, Ca-free granite gneiss lends further support to the suggestion. The variation possibly reflects the original variation in composition (see also Chapters V and X3). Indeed, in some rare cases sillimanite gneisses contain a little plagioclase feldspar, andesine in composition (Sen 1944).
Biotite is present in some slides, and in a few it is seen to have been derived from garnet, appearing in fractured interspaces or rimming the mineral. But in others biotite is an important constituent, associated with sillimanite which is present in varying proportions, while garnet is generally absent or is only exiguous. These rocks are closely associated with sillimanite almandine gneisses of k-hondalitic assemblage described above. In summary, the assemblages met with could be grouped as follows (plagioclase when present may appear in all the groups):

I. Sillimanite-almandine-quartz-K feldspar.
IIa. Sillimanite-almandine-quartz-K feldspar (a little biotite).
II. Sillimanite-biotite-quartz-K feldspar (-almandine).
III. Biotite-quartz-K feldspar (-sillimanite).
IV. Sillimanite-almandine-quartz-K feldspar (-muscovite).
V. Sillimanite-almandine-quartz-K feldspar (-a little andalusite).

Quartz-schists, quartz granulites and quartz magnetite rocks:

Quartzites which show a marked schistosity have sillimanite (-muscovite) or muscovite (-biotite) as accessories. Sillimanite always occurs as fine needles, as inclusions in quartz, with the longest axes of the needles roughly and statistically parallel to the direction of schistosity. Muscovite occurring as inclusions in quartz may be arranged parallel to the schistosity or athwart the direction. A little of either sphene, zircon, apatite or almandine may occur as accessories.

Some rocks show a typical granulitic texture with quartz and almandine as the chief constituents. Of the two minerals again quartz is predominant. The quartz magnetite rock of Ramchandrapur shows under the microscope, besides the two minerals with a considerable proportion of almandine, some apatite and a little zircon. Quartz-granulite (Z\(\alpha\)c = 10°, X = Y = colourless, Z = light yellow) rock with apatite etc has been found in one occasion to continue strikewise, after a little interruption, into a clino-silicate granulite.
The sillimanite schists and gneisses, often containing disseminated graphite flakes, have close mineralogical similarity with the khondalites, except for the almost total absence of plagioclase in the Manbhum rocks. Plagioclase is generally present in varying proportions in the type khondalites. They resemble also somewhat similar rocks described by Dunn (1929). Chemically too these rocks, varying within a considerable range, show some similarity with the khondalites. In the following table the chemical analyses of two specimens from the present area are given in the first two columns. Analyses of khondalites from Ceylon, Kalahandi etc have been added for comparison (Column III Adams 1929, columns IV and V Krishnan 1935). It has to be mentioned that the Manbhum rocks show a very wide range, especially in the relative proportion of the constituent minerals, which would obviously give a considerable range in the chemical composition. The two following analyses are, thus, in no way representative of the different variants of the group.

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