CHAPTER VIII

STRUCTURES

Introduction:

Only limited information is available regarding the structure of the area, that too of a general nature. During the present investigation, certain interesting NNW-SSE striking and dipping structural features were observed. The repetition constant of these features indicates an NNW-SSE trend. The indications of L-shaped folds are consistent with this trend, indicating a possible influence of basement structures.

Palitva (1st km. 38)

Indication of the nature of some of these features is...
part of the area. A southerly pitching asymmetrical synclinal fold was identified by him, for the first time, in the south-east of Satnur and he opined that the southerly pitch of the fold is a secondary phenomena probably due to the intrusion of the Closepet granite.

The charnockites and the associated rock types of the Satnur-Halaguru area show fairly well preserved mega-fabric elements like foliation, lineation, folds and joints. These structural elements have been mapped (Map II A.) and studied after the methods of Ernst Cloos (1932 and 1946) and his collaborators.

A very distinctive structural feature of the area is the general NNW trend and the predominant easterly dip of all the major rock formations.
A. MEGAFABRIC ELEMENTS

1. Banding and foliation

This is one of the oldest and common planar structure that has been noted in all the major rock types of the area. It is essentially due to the parallel orientation of platy and prismatic biopyriboles and to the flattened grains of felspar and quartz. The foliation always parallels the mineral (or lithological) banding or bedding of the respective rocks.

(a) Foliation in metasediments:

The metamorphosed aluminous sediments consisting of variable proportions of quartz, felspar, biotite, garnet, hypersthene, cordierite and sillimanite are characterised by a prominent metamorphic foliation, parallel to the relic lithological banding and bedding. The foliation is chiefly due to the parallel arrangement of biotite plates and flattened grains of cordierite and sillimanite. The banding is due to the variation in the grain-size and proportion of minerals in alternate layers. The thickness of the bands is commonly less than 1 cm. and the individual bands cannot be traced for considerable distance. Generally, in the bands consisting of abundant biotite, for example, the bands occurring near Naikanhalli
Halaguru and Antharvalli, the schistosity becomes prominent and primary lithological banding or bedding is subordinate, while in the more quartzofelspathic bands, like the one near Kemmalu, bedding is more prominent. The foliation of these pelitic rocks strike between N and N 20° W and dips 38° to 60° east and it parallels the foliation of the adjacent charnockites and gneisses.

The quartzites, which represent metamorphosed siliceous sediments, are usually characterised by the primary lamination with which the metamorphic foliation coincides. The lamination is due to the variation in colour from white to grey and brown in alternate laminae. The thickness of the individual laminae seldom exceeds 2 to 3 millimetres and they rarely persist for considerable distance along the strike. The foliation is due to the presence of one set of fracture cleavage parallel to, and often coinciding with, the grey and brown laminations. Usually the fracture cleavages are very thin, less than a millimetre or so, traceable for only a short distance. In the axial region of the folded quartzite band occurring in the south-eastern corner of the area, the fracture cleavage is prominent, the lamination being subordinate and the rock looks more schistose.
The iron-rich metasediments, especially the fine-grained varieties, exhibit a prominent primary lamination with which the mineral schistosity coincides. The lamination is due to the occurrence of white or pale brown quartz layers alternating with the dark layers enriched in magnetite, pyroxene and garnet. Individual quartz-layers are usually less than 3 or 4 cm. in width and are generally two to three times thinner than the layers of dark minerals. The schistosity of these rocks is due to the flattening and elongation of all the constituent minerals parallel to banding, including quartz, which is parallel to the primary lamination.

Amongst the metamorphosed calcareous sediments, the diopside and hornblende-bearing types are generally characterised by mineral banding combined with schistosity parallel to it, while the hedenbergite-bearing types usually lack megascopically visible mineral banding but show thin discontinuous quartzose ribbons, which measure less than about 2 cm. in thickness and 2 to 20 cm. in length, oriented parallel to the strike of these rocks. Under the microscope, however, even the hedenbergite types show mineral banding and schistosity parallel to the quartz ribbons.
(b) Foliation in charnockites:

The typical coarse dark looking acid and intermediate charnockites are massive and lack visible banding or foliation. This type is however of restricted occurrence, rarely comprising patches of mappable sizes.

The common acid and intermediate charnockites that are well developed in the SW and SE parts of the area are well banded and show mineral schistosity and foliation parallel to banding. The banding which usually looks more prominent than the mineral schistosity and foliation is due to the variation, which may be slight or marked, in the grain-size, colour and relative proportion of the constituent minerals in alternate layers. Individual bands are never more than a few millimetres in width and are seldom traceable for a considerable distance; they may divide and rejoin or coalesce with other bands to produce a braided appearance. The light bands are generally two or three times as wide as the dark bands and contain large amounts of felspar and quartz, while the dark bands consist of abundant biopyriboles. Contacts between bands are gradational, mineral grains interlock across the boundary and there is usually not much difference in texture. The mineral schistosity and foliation is generally due to the parallel orientation of plates of biotite,
prisms of hornblende and flattened and elongated pyroxenes, felspar and quartz. Locally, as for example, in the thin acid charnockite band located about 1.0 km SW of Kemmalu, the foliation may be mainly due to the presence of a set of closely spaced fracture cleavages along the planes of which biotite has developed (Plate ...XIV. Fig.A). Likewise, in some places, for example, in the intermediate charnockite occurring within the folded quartzite band of the south-eastern comer of the area, there is the development of oriented tiny lensoid 'quartz-leaves' giving rise to what may be called quartz-leaf-foliation. This quartz-leaf foliation also bears concordant relationship with the banding and foliation of the rocks.

The banding and foliation of the acid and intermediate charnockites of the area described above generally strike between N and N 30°W and dip 35° to 55° east. This feature is shown in Fig. 42 which is a stereographic projection of the poles of 300 foliation readings plotted on the upper hemisphere in the Schmidt equal area net. At places however, westerly dips and a swing of foliation by about 90° to ENE and NW with southerly dips have been observed. These observations are described and discussed in a later section of this Chapter while describing the folds seen in the area.
(c) Foliation in the gneisses and granites:

The gneisses of the area show banding associated with the mineral schistosity and foliation which is exactly like and often times even more pronounced than that observed in the acid and intermediate charnockites of the area. It also generally strikes between N and N 40°W and dips 40° to 60° east. This similarity in the attitude of the banding and foliation of the gneisses with those of the acid and intermediate charnockites of the area also becomes evident by comparing Fig.43, a stereographic projection on the upper hemisphere of the poles of 230 foliation planes of the gneisses, with Fig.42, a similar projection of 300 readings of the charnockites. A comparison of the two diagrams shows that the maxima for the gneisses very well coincides with that of the acid and intermediate charnockites. This close similarity is due to the fact that the banding and foliation of the gneiss is only a relic feature inherited from the charnockites by the granitization of which the gneisses have resulted.

Amongst the different varieties of granite, only the porphyritic granite is foliated. It however lacks the distinctive banding so distinctive of charnockites and gneisses. The foliation in the porphyritic granite is due to the parallel arrangement of platy biotite,
prismatic hornblende and tabular felspar. It is however, better defined with reference to the tablets of the last mentioned mineral which forms abundant porphyroblasts.

The medium grained pink granite located north of Hittur, though lacking foliation of any kind, commonly show a structure similar to banding. In this, the banding is due to the occurrence of thin, comparatively dark pink, parallel veins of granitic material with a general north-westerly strike. The spacing of the successive veins ranges from less than 2 to 3 cm. to over 5 metres. Individual veins are commonly less than 2 to 3 cm. in thickness and are seldom traceable for over 2 or 3 metres.

The abundant coarse to medium grained granite occupying the NE portion of the area is more massive and only shows rude banding and foliation, that too, at the vicinity of the inclusions of the country rocks and at the marginal portions. Even the rude banding of this granite strikes, conformable to the regional NWW trend of the area, which supports the conclusion that the structures of granite are the relics of the pre-existing rocks which have been granitized.

Westerly dip of foliation and banding:

As an exception to the general easterly dip, all
along the westernmost border of the area (particularly to
the south of Naikanhalli), at several places between the
low mounds "2798" (0.8 km. NW of Kabbal) and "2182"
(aboult 2.5 km. NW of Satmir), 0.8 km. south of Kallapura
and in the low mound "2049" (2.2 km. NW of Halaguru), a
consistent westerly dip was observed for various rock
types (Fig. II.B). In the first locality (i.e. south of
Naikanhalli), there is a fairly well defined southerly
pitching synclinal folding and the westerly dip in that
region is due to the fact that it constitutes the right
limb of the syncline. In the other localities also similar
folded structures must have been responsible for the west­
erly dip but in none of them is the folding clearly defined
so as to decide the nature of those folds.

Easterly trend and southerly dip of bedding and foliation.

On the SE of Palliya (about 1.6 km. SE of Satmir)
and in the low mound "2143" (about 3.2 km. north of
Halaguru), the bedding and foliation of the rocks strikes
consistently almost E-W and dips southwards, which is
different from the general NWW strike and easterly dip. As
the first locality is removed only about 2.4 km. from the
nose of the pitching syncline of the south-eastern corner
of the area, where a conformable attitude is recorded, one
may think that the former area (i.e. Palliya region) also
forms a part of the nose region where the fold closes, but the exposures are scanty and very inadequate to offer a definite opinion. Alternatively, it is feasible to consider it due to the presence of the easterly trend of the Palliya region as representing the trend of a separate deformation. The author of the thesis favours the latter explanation.

2 km. NW of Satvar also a swing in the trend of the banding and foliation to almost the E-W position with southerly or northerly pitch has been observed, but the variation there is rather irregular and a proper reconstruction is difficult.

The third locality (i.e., the hill .12143'), where an easterly trend and a southerly dip of the foliation is recorded, is made up of weakly foliated acid charnockites and charnockitic biotite gneiss, which show imperceptible gradation with each other. The structure (Fig. 44) in this place is very much identical to that observed in the basic charnockite lying near the inner margin of the nose region of the folded quartzite band of the SE corner of the area. There is banding trending E and NE and dipping at angles less than 25° south and this is combined with streakiness and rude foliation striking N and NNW (Fig. 44). The former structure i.e., the E and NE, trending banding
is observable mostly in the N-S vertical sections while in
the latter i.e., N-S striking streakiness and rude folia-
tion, is seen only on the exposed horizontal surface and
is not noticed in any of the cross sections. This appears
to represent a relict folded structure of the present rocks
but the actual nature of that folding is not possible to
reconstruct due to the badly exposed nature of the ground.

2. Basic Schlieren

Schlieren of basic rocks with (corresponding to
basic and ultrabasic charnockites) or without (correspond-
ing to the various basic granulites described in Chapter IX
of this thesis) hypersthene are of quite common occurrence
in all the three major rock formations of the area namely,
acid and intermediate charnockites, gneisses and granites.
They are variable in shape, size and distribution but are
very commonly stretched and elongated in one direction.
There is commonly schistosity parallel to the long dimen-
sion of inclusions. In shape they are lenticular, ovoidal,
raft-, ribbon- and pod-like or irregular and in size they
are usually small, being less than 1.5 X 3 metres. The
schistosity and elongation of the basic patches are usually
oriented parallel to the gneissosity and foliation of the
enclosing acid rocks (see Figs. 1, 3 in Chapter IX of this
thesis). Even where the basic schlieren occur in poorly foliated or nonfoliated portions they are nevertheless in parallel orientation (see Plate XVI. Fig.1 in Chapter II of this thesis). The schistosity of the basic patches becomes more and more conspicuous with the increase in the amount of hornblende but is usually indistinct in vertical sections due to the more elongated nature of the components responsible for schistosity. Though mineral banding is commonly observed in thin sections, in the field the basic rocks are not generally characterised by any prominent banding and when present it is also found to bear parallel relationship to the foliation of the rocks. Contacts of basic patches are always characterised by the interlocking of their mineral components with the surrounding acid rock, otherwise the contacts are sharp or consist of only a narrow transition zone. Often the banding and foliation of the surrounding acid rocks look more pronounced in the vicinity of the basic patches.

The elongated nature of basic patches and the orientation of their long axes parallel to one another and to the banding and foliation of the enclosing acid rocks are very much suggestive of a metasomatic and metamorphic origin of these rocks. There are no good evidences to infer that strong penetrative movements existed which might
have sheared them into perfectly oriented tabular masses.

3. Pegmatites and Aplites

Pegmatites and aplites are found to occur all over the area and in all the rock types with the exception of the metamorphosed ferruginous and siliceous sediments. They are often profuse in gneisses and charnockites, especially in places where the basic inclusions occur. Where the thin concordant pegmatites and aplites appear more frequent, the banding and foliation of the rocks look more pronounced.

The pegmatites and aplites vary considerably in colour, grain-size, composition, shape and size. In colour they generally vary from white to light grey and pink but may also be greenish black or dark greyish green (as in the basic hornblende- and diopside-rich pegmatites occurring in the basic rocks) or greasy bluish grey (as in the charnockite pegmatites). In grain-size they vary from a coarse pegmatite with a grain-size, more than about a centimeter to those below 0.5 mm., but those with a grain-size between 2 and 5 mm. are more common. Composition (mineral and chemical) appears to vary with the variation in the composition of the rock in which these bodies are found. Thus the pegmatites and aplites occurring in metamorphosed aluminous sediments contain often garnet, cordierite and
Aulianite, those occurring in the basic rocks are commonly rich in plagioclase and the basic pegmatites rich in diopside and hornblends are restricted only to basic rocks, and those in the acidic charnockites, gneisses and granites are more quartzofelspathic and only occasionally contain the dark components of the rocks in which they occur. The pink microcline-bearing pegmatites and aplites are usually confined to the gneisses and granites and are never observed in the basic rocks. In their shapes, the pegmatites and aplites are generally tabular and vein-like but they may also be lensoid, ovoid, ribbon-raft- and pod-like, wedge-shaped, labarynthic, ptygmatie and not uncommonly irregular and ameboid. Some pegmatites are merely clusters of quartz-felspar porphyroblasts in the rocks and in a number of cases every gradation can be established between single porphyroblast and somewhat larger pegmatite bodies. Small pegmatites and aplites measuring less than 3 or 4 cm x 3 or 4 metres are overwhelmingly more common than the larger ones. The contacts of the pegmatites with the host rocks may be macroscopically sharp or gradational or intimately inter-grown or combination of the three indicating that the growth of pegmatites in these regionally metamorphosed rocks is just a phase of granitization.

The attitude of the pegmatites and aplites is
generally concordant with the banding and foliation of the rock in which they occur (Figs. 45a and 45b), but discordant ones are also present. The latter type is not rare especially in the granite occurring in the north-eastern part of the area and in the vicinity of the basic inclusions. Sometimes the pegmatites and aplites are of two generations, an older bearing a concordant relationship and the younger making an angle of 30 to 60° with the banding and foliation of the rocks. Both concordant and discordant types are often folded and contorted. In the concordant types the folding pattern generally parallels the folding pattern of the banding and foliation. The discordant type may also show folding with the axis coinciding with the trend of banding and foliation.

Several pegmatites possess foliation, with reference to the orientation of felspar tablets and biotite mica, that does not extend through the entire body and remains parallel to the wall rock. Such foliation within pegmatites may represent a relict structure.

4. Lineation

Lineation is represented in the Satmur-Halaguru area by: (i) parallel elongate minerals such as sillimanite, hornblende, pyroxene and felspar, (ii) elongate inclusions and (iii) fold axis.
All the above types of lineations are essentially parallel to the trend of the enclosing rocks and to the regional trend of the fold and hence they are all B-lineations.

(i) **Elongated minerals**

Sillimanite:

Lineation due to prismatic and elongated sillimanite is best developed in the band of metamorphosed aluminous sediments located south of Halsalli. There, the sillimanite forms coarse elongate prismatic porphyroblasts, which are at times as much as 4 cm. thick and 5 to 6 cm. long, long axes of which are arranged parallel to the bedding and foliation of the rock.

Hornblende:

Linear parallelism of hornblende, markedly elongated parallel to c-crystal axis, is noticeable in all the hornblende-bearing basic and acid charnockites and gneisses. Due to the linear parallelism of hornblende the basic rocks containing this mineral look distinctly schistose.

Pyroxene:

Both ortho- and clino.pyroxenes of the charnockites and pyroxene-quartz-magnetite rocks are generally elongated.
parallel to the c-crystal axis and show at places linear parallelism. Pyroxenes showing linear orientation generally segregate into thin discontinuous layers giving rise to banding and streakiness of the rocks.

The sillimanite, hornblende and pyroxene lineations are horizontal or dip at very low angles to the north or south and lie essentially in the plane of foliation of the enclosing rocks.

Felspars:

Felspars of porphyritic granite and less commonly of gneisses and charnockites are flattened and elongated parallel to (010) and show linear parallelism which coincides with the foliation. This lineation is best seen in the porphyritic granite outcrops situated south of Kabbal and north of Attihalli. It consists of parallel rows of elongated porphyroblasts of felspars. It is either horizontal or pitches only at very low angles, less than 10° to 12°, to the north or south. This lineation is marked in the structural map of the area (Map II.B.)

(ii) Linear inclusions.

Small lensoidal and elliptical basic inclusions occurring in the acid charnockites and gneisses sometimes show linear structure. This has been observed in the acid
charnockite exposure in the hill .2143' and in the gneisses and acid charnockite occurring along the course of Shimsha river. The pitch of this lineation is also low, being less than 12° to the north or south.

(iii) Folds:

(a) Minor folds: Minor folds less than 1/3 to 2/3 metre in width are noticed in many outcrops of charnockites and gneisses of the area. The best developments are however found in the quarries about 0.6 km. S and SSW of Kabbal, 1.0 km. south of Duntur, in the hill '2049' (Plate IIIV. Fig.B) and along the Shimsha river course, especially to the south of Dodaumall. The folds are due to the contortion of banding and are almost always present in places where the quartzofelspatitic veins appear in large number. At times it so happens that only the quartzofelspatitic veins are folded, while the host rock lacks concordant folding of the banding and foliation. This is particularly true of quartzofelspatitic veins traversing the rigid basic inclusions. But normally, the quartzofelspatitic veins show fold patterns similar to the banding of the host rock. In fact it is the distinct colour and texture of the quartzofelspatitic veins involved in such a folding make the folded structure to appear prominent. Although locally the folds appear irregular, they are generally regular and
systematic in their development. The axial planes of these minor folds bear a variable relation with the strike of the banding and foliation. Some are parallel, while others are perpendicular and still others make an angle of 10° to 30° to the banding and foliation. The folds are mostly of the plunging type and the plunge is both to the north and south. Due to the lack of suitable cross sections, the exact plunge of the folds could not be always measured and the two or three readings recorded in ideal cross sections show that the plunge varies from 20° to 60°. The pattern exhibited by these flowing folds reflect the structure of the earlier rocks. Whether these structures are prehnitic or synmigmatitic has to be decided by a further detailed study.

(b) Major folds: The only well defined large scale fold lies in the SE corner of the area. This was first identified by Suryanarayana (1937). This fold is made up of a variety of rock types like charnockites (acid to ultrabasic), gneisses, quartzites, pelitic gneiss, calc-silicate granulites, pyroxene-quartz-magnetite rock and granite, but the folded structure is well displayed by the quartzite band and to a lesser extent by the charnockites and gneisses which lie by its side. It is an asymmetrical
syncline with the axis striking N 40°W and plunging southwards at 20°-25°. The axis is located about 1.2 km. NE of Naikanhalli. The quartzite constituting the western limb of the hill is more or less uniform in thickness and is well exposed continuously from a point 1.6 km. 60°E of Duntur in the SE direction. It strikes NW and dips east at angles varying from 30° to 50°. The eastern limb strikes almost parallel to the western limb but dips west, generally at greater angles (between 40° to 90°). It is well exposed on the western slopes of the hill, where it is considerably enlarged. The axial region of the fold peculiarly enough lacks the sharp angular termination of typical pitching folds. The quartzite band in particular, as shown in the geological map, is flat and shows only a

* As the southern ends of the folded quartzite band showed a tendency to meet together so as to form a doubly plunging folded structure, out of curiosity, an attempt was made to trace the two limbs of that band beyond the area shown in the appended geological map (Map II.B). The two limbs of the fold showed a tendency to come nearer and close up in Dodmundibetta. Whether the two limbs, which come so close to each other, actually close up or not could not be known as that part of the terrain is thickly covered with thorny shrubs and is inaccessible. But it looks very probable that the two limbs join and close up, in which case the structure might become a doubly plunging syncline.
very broad curvature in the axial region. It strikes between E and ENL and plunges at angles varying from 20° to 35°.

Besides the above described major fold there are a few other poorly defined folds of which only two are worth mentioning. One is located in the gneiss 1.6 km. N 40°E of Saslapura (see Map II.B.). It is also a pitching syncline. The trace of the fold axis strikes almost N-3 and is located about 1.8 km. WNW of Saslapura. The left limb is better defined than the right one. Due to the badly exposed nature of the ground where the fold closes, the exact plunge could not be determined. The second one is located about 3.2 km. WNW of Halaguru, where the main rock types are charnockites (acid to basic) and pyroxene-quartz magnetite rocks. This is also a syncline with a trace of the axial plane located about 1.6 km. of NW of Chillapura, trending parallel to the limbs. Both the limbs strike NNW; while the right limb dips west at angles varying from 55° to 83°, the left limb dips east at angles varying from 45° to 55°. In this case again the termination of the fold is not exposed.

5. **Shear belts**

The long discontinuous band of pyroxene-quartz-magnetite rock occurring immediately west of Halaguru and
a small band of the same rock exposed 2.3 km. east of Banasamudra, on the western bank of the Shimsha river, afford evidences of shearing all through their length and width. The shear planes are essentially parallel to the bedding seen in the rock. The effects of shearing are however difficult to recognize in the field. All that could be seen is the very fine grained nature, occurrence of very thin discontinuous but parallel fractures (fracture cleavages) and garnet porphyroclasts. In thin section, however, there are sufficient evidences of intense crushing associated with shearing. The main components of the rock namely, pyroxene, magnetite and quartz are all thoroughly pulverized and the rock becomes schistose. There is also the abundant development of garnet porphyroclasts, which are frequently ovoidal, with their long dimensions arranged parallel to the plane of schistosity.

**Occurrence of Mylonite:**

(a) In basic charnockite: 0.8 km. W 15°N of Chikka-yalachigere there is a small patch (with a radius of about 1 metre) of medium grained basic hornblende-rich charnockite ramified by the black, glassy looking stringers, veins, irregular knots and patches of mylonite ranging in size from a thin film to patches 8 or 10 cm in width (Fig. 46) showing sharp contacts. Under the microscope
the dark mylonite consists of black dusty material in which relics of angular fragments of quartz and rarely those of much altered felspar are disseminated (Plate XXIV. Fig.D). The porphyroclasts are highly crushed and fractured and show effects of strain. The contacts of these mylonite veins are generally irregular and at the immediate contacts with these, the rock is very much crushed and often shows thin fractures, oriented essentially parallel to mylonite veins. All along these fractures, the minerals are crushed into pulverized paste and sometimes there is the development of fine grained black dusty material similar to that noted in the mylonite. The twin lamellae of highly saussuritised plagioclase are bent and fractured, the pyroxenes (both diopside and hypersthene) and hornblende are also fractured and altered into chlorite and calcite. All the minerals show undulose extinction.

(b) in granites and gneisses: In the porphyritic granite 0.8 km. west of Arekattedoddi, and in the biotite gneiss located 0.7 km. N 25°E of Jasalapura and 2.6 km. SE of Buhalli occur thin parallel veins of mylonite. In all the three localities, two black or dark grey essentially parallel mylonite veins, 3 to 5 cm. thick and 30 to 50 metre long (Plate XXXIV. Fig.C), are seen. The interval between the two veins is only about 3 to 5 cm. At the
immediate vicinity of these veins thin discontinuous frac-ture planes oriented parallel to them are often noted.

It may be noted here that except for the presence of thin parallel fractures and cataclasis at the immediate vicinity of mylonite veins, the rocks do not show any appreciable brecciation or cataclasis. A similar observation has been made by Mahabaleshwar and Sadashivaiah (1966) and Sadashivaiah and Subbarayudu (1967) in the charnockite areas of Valvalli and Kondavidu, respectively.

In thin sections the mylonite looks exactly like the one occurring in the basic charnockite described earlier. It is composed of compact, extremely fine grained black to dark brown matter (but not glass or microlites) in which are disseminated small relic angular fragments of quartz and rarely much altered felspar both of which show peripheral granulation, fracturing and undulose extinction. The borders of the mylonite veins are irregular and at the vicinity of these veins the rocks are much crushed and show abundant strain effect.

Occurrence of mylonite has been reported from many charnockite localities including the type area. Very recently the problem of the occurrence of mylonite in the charnockites and associated rocks in specific areas has been described and discussed in detail by Mahabaleshwar...
and Sadashivaiah (op.cit) and Sadashivaiah and Subbarayudu (op.cit), wherein a brief review of the problem is also given. Divergent views have been expressed on the origin of mylonite but most investigators agree that it is a product of intense frictional fusion and shearing movement. Based on his own observations, the author of the thesis also agrees that the mylonite of the Satnur-Halaguru area is a product of brecciation and intense shearing movement leading to the fusion of the enclosed rocks. The frictional fusion to which these rocks have been subjected was not so intense as to show the development of spherulites, microlites or vesicles, the characters of pseudotachylite. It is likely that in this terrain some faults were there and these faults commonly contain large amounts of water and if the temperature is suddenly raised due to the frictional movement developed along the faults, explosion possibly occurs. If this were hot enough, melting would occur along the fracture planes through which vapours could pass and the veins of fused mylonite might form in relatively undeformed rocks. Fused mylonites in the fault zone would be charged with gas and become very mobile and therefore be able to intrude the smallest fractures.
Joints are the most common structural elements noted in all the rock types of the area. Their attitude has been studied in detail and shown in the structural map of the area appended here. Joints are generally well developed in the quartzites, pyroxene-quartz magnetite rocks, charnockite varieties, gneisses, medium to fine-grained nonporphyritic granites and dykes but are poor in the metamorphosed aluminous and calcareous sediments, and in coarse porphyritic granites.

As it is often done, in the present investigation also, the joints have been analysed by considering their relation to the foliation planes of the rocks. By such an analysis it is found that a majority of the joints occurring in the various rock formations of the area constitute two major sets. One set strikes parallel or nearly parallel to the bedding or banding and foliation and the regional structure while the other set at angles of 70° to 90° to them (i.e., banding and foliation). The first set, which is usually more common than the second, is called the longitudinal or the strike joint and the second the cross or dip joint. Diagonal or oblique joints striking at an angle of nearly 45° to the bedding and
foliation are also present but these are less frequent. Likewise, sheet joints are also present at places.

In the following account, the details of the observations on the joint pattern of individual rock types of the area are described. In most cases, the field observations have been checked by analysing the joints on a Schmidt equal area projection.

(i) Joints in metasediments.

Amongst metasediments, the quartzites and the pyroxene-quartz-magnetite rocks (especially fine-grained types) are highly and often tightly jointed whereas the metamorphosed aluminous and calcareous sediments are poorly so. The joint planes in the case of quartzites and pyroxene-quartz-magnetite rocks are usually straight and smooth but those of the metamorphosed aluminous and calcareous sediments are rough and uneven.

The poles of 310 joints of the quartzite band of the pitching syncline of the SE corner of the area have been plotted without any selection in the upper hemisphere of the Schmidt's equal area net (Fig. 47). A perusal of the diagram reveals that there are three strongly defined maxima, one each in NW, SW and SE quadrants and a fourth less prominent in the NE quadrant. The two well
defined maxima located near the circumference of NW and SE quadrants are due to the steeply dipping cross or dip joints. The other two maxima located in the SW and NE quadrants are due to the longitudinal joints. The common steep dip of even the longitudinal joints is indicated by the location of the maxima nearer to the periphery. The drawn out nature of lower contours toward the centre in the NE quadrant is due to the frequent occurrence of bedding joints.

(ii) Joints in charnockites.

The basic charnockites are generally better and often closely jointed than the acid and intermediate members. This contrast in jointing between the charnockite members is very well seen in places where the basic charnockite occurs as patches in the acid and intermediate charnockites, for instance, in the hill 2143. The joints of these rocks are mostly straight and their surfaces always smooth. Apart from brownish stain they are free from any mineral deposition.

Fig. 48 is the stereographic projection, on the upper hemisphere, of the poles of 320 joints, measured in the basic charnockite constituting the inner portion of the pitching syncline of the south-eastern corner of the area. The figure reveals that there are two sets of
joints, one of longitudinal and the other of cross, both of which dip at steep angles. The longitudinal joints, which are more strongly developed than the cross joints, mostly strike between N and N 30°W and dip towards ENE and WSW while the cross joints essentially strike between E and E 30°W and dip both to the north and to south.

In general jointing is better developed in the distinctly banded and foliated acid and intermediate charnockites, as those exposed along the course of the river Shimsha, than they are in the rudely banded and foliated types, like those exposed in the hill 2143. In addition, in the former they are more regular and straight with smooth surface but in the latter they are more irregular, curved and quite often characterised by hackly surfaces.

The joint system in acid and intermediate charnockites also mainly consists mainly of two sets, longitudinal and cross joints. Of the two, the former is much more well developed than the latter. In the strongly developed longitudinal joints there is one group, both strike and dip of which essentially coincide with the banding and foliation, and another group which dips (generally at a steeper angle) in the opposite direction of the banding and foliation. Of the two kinds of longitudinal joints, the second type is much more abundant than the first. The above
mentioned observations on the nature of the joints in the acid and intermediate charnockites are well displayed in the Fig. 49, which is the projection of the poles of 240 joints on the upper hemisphere of Schmidt equal area net.

(iii) Joints in gneiss.

The attitude of joints in gneisses is shown in Fig. 50, which is a projection of poles of 380 joint planes of the rocks on the upper hemisphere of the Schmidt's equal area net. From the diagram it is clear that in the also gneisses there are two sets of joints, one longitudinal and the other cross, among which the former is more strongly developed. In the longitudinal joints, the most frequent are those, strike and dip of which coincide with the banding and foliation while those dipping away from them are less and in this respect the joint pattern in gneiss differs from that in the acid charnockites, but is otherwise similar. The spreading out of the lower contours of SE maxima towards SW is due to the occurrence of a fairly good number of steeply dipping diagonal joints which strike at an angle of about 30° to the banding and foliation.

(iv) Joints in granites.

Amongst the granite varieties, the coarser porphyritic and nonporphyritic types are poorly jointed and
even these are often irregular, curved and characterised by rough and uneven surfaces. In contrast to this the coarse to medium grained types show pronounced jointing and the joints are mostly straight and show smooth surfaces. The Fig. 51 is the upper hemisphere projection of 210 joints of the nonporphyritic granites. A glance at the projection reveals the absence of clearly separated maxima and the distribution of poles in an incomplete and discontinuous peripheral girdle. This is due to the nearly radial pattern of the jointing of the granites. Within the peripheral girdle, strongly developed maxima are located near the circumference of the NE and SW quadrants and they are due to the occurrence of one set of steeply dipping longitudinal joints with a strike coinciding with the rude foliation of these granites.

(v) Joints in dyke rocks.

Joint is the only prominent structure that is observed in the dyke rocks. There are two sets of very well developed vertical or very nearly vertical joints of which one set strikes parallel and the other perpendicular to the walls of the dykes. Diagonal joints are less frequent than the horizontal joints. It is this kind of jointing, which is mainly responsible for the characteristic bouldery nature of the outcrops of the dykes. The
spacing of the joints appears to vary with the thickness
of the dykes; it increases as the thickness of the dykes
increases
/and with the result, the size of the boulders comprising
the outcrops of the dykes increases with the increase in
the thickness of the dykes.

The jointing in dykes is the result of tensional
forces that were set up due to a decrease in volume by
cooling and is unrelated to the forces that were responsi­
ble for the jointing in the country rocks.

There is a remarkable coincidence of the major
joint directions of the country rocks and the trend of the
contacts of the dyke rocks. This leads to the conclusion
that the contacts of the dykes were controlled by an early
formed master joint system in the country rocks. Indeed
this seems to be the only explanation for the steep and
straight disposition of the contact surfaces of the dykes,
which do not display shattering, shearing or displacement
of wall rocks.

The relation of the joints to the other structural
features of the area has been discussed in the next sect­
on of this Chapter dealing with the interpretation of the
structural data.
B. PETROFABRICS

A trial series of petrofabric analysis of a few selected rock types of the area has been carried out according to the method of Sander (Fairbairn, 1949) to find out whether the deformation indicated by megafabric study is reflected in the microfabric also.

Fig. 52a is an ac fabric diagram of 200 quartz axes of acid charnockite occurring near Murlethimmanoddidi (3.0 km SW of Satmur). The specimen shows an a-surface and a very rude lineation parallel to b. The fabric diagram does not show any appreciable preferred orientation. Nearer the periphery of the north-eastern quadrant there are two closely spaced maxima; while there are three minor maxima in the SW and SE quadrants. On the whole, there is no coincidence between the quartz fabric diagram and the quartz orientation found in tectonites.

Figure 52b is an ab-fabric of the poles of 200 quartz axes of the acid charnockite specimen described above. The diagram shows a high order of preferred orientation. There are two clearly separated maxima located in the NE and SW quadrants and lying almost mid-way between a and b. The principal maxima represent an alignment of quartz-axes within the foliation plane ab but oblique to
a and b of the fabric. Similar quartz-fabric has been recorded by Hietanen (1938) in some of the deformed quartzites of Finland.

Figures 53a and 53b are the unselected quartz-axes orientation diagrams of another sample of acid charnockite occurring near Murlethimmandoddi, removed only a few metres from the place from where the first sample was collected. The specimen shows imperfect banding, with which foliation and a rude lineation coincide and looks more or less similar to the previously described rock. Figure 53a, an ac-fabric diagram of 250 quartz axes, shows a weak preferred orientation and an imperfect ac girdle. There is one maximum almost on the fabric axis c and two minor maxima one each along north, near a, and in the south-east quadrant, near the periphery. The ab-fabric diagram (Fig. 53b) looks quite different from the similar diagram (Fig. 52b) of the previously described acid charnockite. There is an imperfect ab girdle with two maxima, one along the 'b' axis, a little removed from the periphery, and the other in between the fabric axes a and b.

Figures 54a and 54b are the quartz axes (250 each) diagrams prepared from sections cut perpendicular and parallel to the visible foliation of a quartzite sample collected from the nose region of the folded quartzite band.
located in the south-eastern corner of the area. The specimen is well foliated with a lineation produced by parallel arrangement of quartz and rare sillimanite. The ac diagram (Fig. 54a), shows almost complete peripheral girdle and two maxima, one on the west, nearly coinciding with c, and the other on the SE making an angle of 25° from a. The ab quartz axes diagram (Fig. 54b) shows some amount of preferred orientation. There are clearly separated but somewhat elongated maxima and a minor maximum almost in the centre of NE quadrant and near the western end of b respectively.

From the above description of the petrofabric data it is evident that the degree of preferred orientation is generally poor and there is neither a similarity in fabric symmetry among the three analysed samples nor is there the similarity in the symmetry between the micro- and mega-fabrics. The fabric pattern however indicates that the rocks are tectonites.
C. INTERPRETATION OF STRUCTURAL DATA

1. Banding:

The lithological banding of the various metasediments is chiefly the imprint of the initial difference in composition across the stratification of the parent sediments. Its preservation suggests the lack of migration of components across the stratification during metamorphism. The banding in charnockites may also likewise constitute a relic of the layered structure of the parent rock. What the nature of that layered parent rock was, is only a matter of conjecture. In the case of charnockite there are a good number of evidences suggesting that the migmatization and metamorphic differentiation have also played an important role in causing the banding of those rocks. The banding of gneisses and granites appears to be a relict structure inherited from the charnockites, from which they have been derived. It is also very likely that the migmatization and granitization that brought about the transformation of charnockites into gneisses must have added their own quota in enhancing the banded structure.

2. (a) Foliation and other related northerly trending planar and linear structures:

It has been already noted that the foliation of the rock of Satnur-Balaguru area always bears a parallel
relation with the bedding and banding. This parallelism of foliation with bedding and banding might have resulted due to (1) isoclinal folding; (2) mimetic crystallization; and (3) flow parallel to bedding (Billings, 1961). From the available evidences, it is difficult to decide which of the above mentioned process or processes were operative mechanism in the Satnur-Halaguru area. But it looks probable to the author of the thesis, that it was a combination of all three processes rather than any one. The metamorphic segregation process might have also added its own important quota in bringing about the development of foliation parallel to banding, in which case the structure has to be designated as 'segregation banding'. The latter interpretation appears quite adequate for the banding and foliation seen in some charnockites of the area.

The predominant easterly dip, the coincidence of the foliation with bedding and banding and the repetition of beds, such as the various metasediments and charnockite varieties, though not in such a regular order and sequence, are very much suggestive of isoclinal folding to which the area might have been subjected during early deformation. The scarcity of the apices of isoclinal folds suggests that, either most of the isoclinal folds in this area were of the nonplunging type or the banding and foliation at the apices of the plunging folds were so blurred or destroyed.
by subsequent deformation that the folds remain undiscovered. Even the repetition of the formations is not regular enough to make use of that data in the reconstruction of the folding. The folding must have taken place under-deep-seated conditions and the accompanying metamorphism, recrystallization and deformation caused the folds to obliterate into an indefinite bending. The fact that individual bands can seldom be traced for any considerable distance supports the suggestion that they represent deformed relics of tight folds.

The major pitching synclinal folds and also the minor synclinal and antilinal folds, axial traces of which are parallel to the regional NNW trend of the area, also appear to be related to the earlier deformation that was responsible for isoclinal folding. However, the possibility of some of these folds being relict structures inherited from the parent rocks is not ruled out. The latter suggestion appears to be quite feasible, especially with regard to the small folding seen in the metamorphosed ferruginous sediments.

From the general NNW strike and preponderate easterly dip of banding, bedding and foliation and other planar structures like, the elongated and tabular basic schlieren, platy felspar and quartz-leaf foliation and from
the presence of lineation coinciding with the foliation, it may be inferred that the regional tectonic forces prevailing during the deformation must have operated from the eastern direction giving rise to a general northerly strike and easterly dip. This deformation appears to have taken place under deep-seated pyroxene-granulite facies, under which condition the various metasediments of the area and charnockites originally formed. The occurrence of structures similar to those in the charnockites, even in the gneisses and some granites of the area, which are definitely of later age, is due to the fact that those rocks have retained the structures of charnockites during the metasomatic transformation from which they have resulted.

(b) Easterly trending foliation and folding:

The swing of the general northerly trend of the banding and foliation by about 90° to ENE and E-W position as noted near Palliya (1.6 km SE of Satmur) and the presence of small folds with easterly trending axial traces are suggestive of a second deformation during which the forces acted from the N-S — i.e., perpendicular to the direction from which they acted during the first. This deformation, which also appears to have taken place under deep-seated conditions, seems to have operated during the
hornblende-granulite facies conditions of regional metamorphism.

3. Joints:

In a polymetamorphic area like the present one, which has a complex tectonic history, the joints are very difficult to interpret and interferences as to the nature and significance of various joint systems in such areas are hardly reliable.

It is true that joints are the youngest of all the structural elements in any one rock type of the area, but it is difficult to decide at what stage or stages of tectonic history of the rock types they developed. The variation in the frequency, pattern and character of joints from one rock type to the other shows the differing response of the rock formations of different composition, texture and structure to the forces that were responsible for the joint formation. It is on the whole believed, that the longitudinal joints, which are usually the most well developed ones in many of the rocks, are the result of tension which prevailed after the release of compressional forces that operated perpendicular to them (i.e., they constitute release fractures) and the cross joints, which are next in abundance to only the longitudinal joints, are the
result of tension caused by the horizontal stretching in the N-S direction under similar compressional forces. The diagonal joints appear to represent shear fractures which developed at angles of 30° from the direction of compression. The sheet structure that is often seen in charnockite gneisses and granites appears to be related to the cubical expansion associated with the erosion of the overlying rocks or uplift of the terrain or both.

From the coincidence of the two main trends of the dyke intrusives of the area with those of the two major joint sets, namely longitudinal and cross, it is inferred that the dyke intrusion has taken the advantage of the pre-existing joint planes.

4. Petrofabric data:

A trial series of petrofabric analyses (based on the optic axes of quartz), carried out on a few selected rock samples of the area (which included only two acid charnockite and one quartzite), has shown that the rocks are tectonites but the degree of preferred orientation is generally poor and the symmetry of the microfabric does not coincide with that of the megascopic fabric. The poor preferred orientation and the absence of coincidence between microfabric and megafabric symmetries may be the
result of a combination of post deformational crystal growth and the repeated deformation the rocks have experienced. However, the analysed samples are very few and inadequate and a further discussion of this may be reserved till a more detailed study is made.

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