Chapter II

Geological Setting
In the present chapter, the regional geology of the area has been outlined. In the subsequent paragraphs, the geology of the area has been dealt with in detail.

Regional Geology:

In the accompanying geological map (Fig. 2.1), the regional geology of the area has been shown, which indicates that there are exposed the rock formations, belonging to the Precambrians and to Upper Cretaceous-Oligocene period. The Precambrians in the area are represented by the granitic rocks along with the schist belt and the sedimentary rocks belonging to the Bhima Group; whereas the Upper Cretaceous-Oligocene period formation is represented by the Deccan Trap basalts - a major tholeiitic province of India. The granitic rocks along with the schist belts are of particular interest to the geologists, not only because of their diversified
mode of occurrence, different grade of metamorphism they exhibit, but their structural complexities and the vast economic mineral resources. Apart from these characteristics, the whole complex of the granitic rocks and the schist belts have posed a problem regarding their interrelationships, since the Sargur Supergroup - older than the Dharwar Supergroup is being established. The stratigraphy of the Indian Peninsula has been reviewed, in the light of the newly established data, regarding the granite-greenstone complexes, which have a significant bearing in the evolution of the crust, in this part of India.

Earlier, Foote (1876) proposed Dharwar system to indicate the granite-greenstone complex in the Karnataka State. Later, it attained a status of the Supergroup in the Indian stratigraphy. It has been regarded that, the Archean formations comprise the oldest gneissic basement on which, the younger sediments were deposited. These were subsequently metamorphosed. The gneissic basement is a complex
of granites and gneisses with the lenses and pockets of earlier metabasics, included in the Dharwar Supergroup. According to Foote (op cit), the metabasics are predominantly of the schistose character. These rocks are intimately mixed up with the rocks of the granitic characters, which are either intrusive or are formed by the granitisation. This indicates the older relationship of the schistose rocks with the associated granitic rocks, which are known as the Champion Gneiss, the Peninsular Gneiss and the Closepet Granite in the Indian stratigraphy. However, Nautiyal (1966) and Radhakrishna (1968) suggested that the Peninsular Gneisses are older than the Dharwars, but this view was rejected by Rama Rao (1946) and Pitchamuthu (1970). Srinivasan and Sreenivas (1972), on the basis of the structural and petrological investigations, suggested that the Peninsular Gneisses are younger than the Dharwars. According to Srinivasan and Sreenivas (op cit), 'the Peninsular gneisses are essentially syntectonic and synmetamorphic migmatites with respect to the folding and metamorphism of Dharwars'.
Similar orogenic events have also been recorded from the various parts of the Precambrian shields of the world. Geochronological data available for the different orogenic events from the Precambrian shields of the world indicate that, there were four major orogenic events (Condie) to which the Precambrians were subjected to. Geochronological data, however, makes it difficult to distinguish between such orogenies. The Indian Peninsular shield is no exception to it. The geochronological data available for the different granitic rocks for the Precambrians of Karnataka have made it possible to distinguish the older greenstone greater than 3000 m.y. in age i.e. Sargur Supergroup and younger greenstone, which is 2600 to 2100 m.y. in age i.e. the Dharwar Supergroup (Radhakrishna and Vasudeva, 1977). The view that the amphibolite and the schist inclusions in the Peninsular gneissic complex belong to a period older than Dharwars, was put forth by Radhakrishna (1968). However, on the basis of the field evidences, Vishwanath and Ramakrishnan (1975) identified an older Group of lavas and associated sediments, deposited in small narrow linear basins, to which they gave the
The rocks of the Sargur Supergroup have the distinct characters separating them from the rocks of the Dharwar Supergroup. These rocks are highly metamorphosed, ranging from the amphibolite to the lower granulite facies. Anorthosite and anorthositic gabbro in the form of lenses are prevalent in them. As well as, rocks of this group are extensively migmatized and mobilized during post-sargur period. Structurally, they are characterised by tight folds and steep plunges with complicated fold interference patterns. The rocks of the Dharwar Supergroup, however, form prominent belts of the schistose rocks, which can be traced along the strike for nearly 500 km. These are essentially volcano-sedimentary sequences, resting unconformably over the older migmatitic gneisses. In Karnataka State, the rocks of the schistose character are exposed in more or less parallel, nearly N-S trending linear belts. These belong either to the Sargurs or to the Dharwars. In all, twenty one such belts have been identified.
in Karnataka State. One of such belt is termed as "Mangalur band", part of which lies in the central part of the area under investigation around Kembhavi.

As mentioned earlier, there are different orogenic events recorded in this part of the Indian Peninsula. The rock types of different granitic composition occur either in the form of intrusives or as metasomatised granitic bodies. These granitic rocks have been identified as the Peninsular Gneiss, the Champion Gneiss, the Closepet Granite and the Charnokites. Of these, the charnokites are not exposed in the area investigated and have, therefore, been eliminated in the further discussion. These rocks of the granitic composition have been assigned different positions in the stratigraphic succession in the Archeans of Karnataka state, mainly by Nautiyal (1966), Pichamuthu (1967) and Radnakrisna (1968). This indicated that the relationship between the schistose rocks and the granitic rocks remained uncertain. However, Crawford (1969) with the help of the radiometric data attempted to establish the relationship between the two. Later, various workers
have submitted the geochronological data for the different types of granites. (Ramamurthy and Sadashivaiah 1967, Sarkar, et.al. 1964, Venkatasubramaniam and Narayanaswami 1974 a, b, c and Sarkar 1980). According to Sarkar (1980), the Peninsular Gneisses (2600 m.y.) and the Closepet Granite (2380-2000 m.y.) are younger than the Dharwars.

The granitic rocks, viz. the Champion Gneiss, the Peninsular Gneiss and the Closepet Granite have the distinct characters of their own. The Champion Gneiss is a fine-grained micaceous rock, which is highly sheared. It bears intrusive relationship with the schist and is associated with the conglomerate, possibly of autoclastic origin. It is traversed by the granite, which is considered as a part of the Peninsular Gneiss. The Peninsular Gneiss is represented by heterogenous mixtures of many types of granitic intrusives (?) in schistose rocks after their folding and metamorphism. It forms a very complex suite of rocks, which include composite gneisses, migmatites, granitised crystallines, granites with associated aplite and pegmatitic phases. The Closepet granite is coarse grained, porphyritic/
porphyroblastic, which is slightly foliated. It occurs in the form of bands, trending NS to NWW-SSE in the Karnataka State. However, according to Radhakrishna and Vasudev (1977), the Closepet Granite consists of the multiple intrusions of the different characters. It is grey and pink porphyritic gneiss with large felspars. According to Radhakrishna (1956), it is granitised Peninsular Gneiss. The pink colouration has been regarded to be due to the large influx of potash rich solutions. In the area investigated, the granitic rocks exhibiting these characters are exposed.

These granitic rocks, in turn, have been traversed by metadolerite dykes. These dykes have been termed as 'trappean dykes' by Foote (1876). On the basis of their orientations, Foote (op.cit) has grouped them into five major divisions, as: i) westnorthwest-east southeast, ii) westsouthwest-east northeast, iii) northnorthwest-south southeast, iv) northwest-southeast, v) northeast-southwest. These dykes have been found to extend for several kilometres. In the area under investigation, the basic dykes trending in NE-SW direction have been recorded.
The granitic and the gneissic rocks have been overlain by the sedimentary rocks, belonging to either the Kaladgi Group or the Bhima Group in the Karnataka State. In the area under study, the sedimentary rocks belonging to the Bhima Group are exposed. The term "Bhima Series" to these sedimentary rocks, was first suggested by King (1872). It has been then designated as the "Bhima Group" in the Indian stratigraphy. Foote (1876) has divided the Bhima Series into upper division and lower division. Mahadevan (1947) has proposed a three-fold classification of the Bhima Group of rocks from Gulberga district, Karnataka State, as, lower, middle and upper divisions. Later, Rao et al. (1975) have proposed five-fold classification for the rocks of the Bhima Group, exposed in Gulberga district. According to them, the Bhima Group consists of five formations, three of which are composed of the mechanical sediments, alternated by two formations, comprising chemical precipitates. The classification suggested by these different workers have been presented in Table 2.1.

In the area under investigation, the rocks of the
<table>
<thead>
<tr>
<th>Table 2.1 - Classification of the Bhima Group</th>
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<tbody>
<tr>
<td>C. Mahadevan (1947)</td>
</tr>
<tr>
<td>* Flaggy limestone</td>
</tr>
<tr>
<td>* Red lithomargic shales (at contact with Deccan Trap)</td>
</tr>
<tr>
<td>Upper</td>
</tr>
<tr>
<td>* Purple shales (calcareous in part)</td>
</tr>
<tr>
<td>Bhima</td>
</tr>
<tr>
<td>* Buff, bluish black or olive shales, (locally calcareous in part)</td>
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<tr>
<td>* Sandstones (local)</td>
</tr>
<tr>
<td>Series</td>
</tr>
<tr>
<td>* Grey, bluish and cream coloured limestones</td>
</tr>
<tr>
<td>* Splintery buff coloured and laminated limestone</td>
</tr>
<tr>
<td>Middle</td>
</tr>
<tr>
<td>with chert</td>
</tr>
<tr>
<td>Bhima</td>
</tr>
<tr>
<td>* Bluish and black limestone (both massive and flaggy)</td>
</tr>
<tr>
<td>* Cream coloured and light blue limestone (flaggy</td>
</tr>
<tr>
<td>* Reddish limestone with green blotches</td>
</tr>
<tr>
<td>Series</td>
</tr>
<tr>
<td>* Purple shales (topmost beds reddish and calcareous)</td>
</tr>
<tr>
<td>Lower</td>
</tr>
<tr>
<td>* Green shales</td>
</tr>
<tr>
<td>Bhima</td>
</tr>
<tr>
<td>* Sandstones (coarse to fine grained)</td>
</tr>
<tr>
<td>Series</td>
</tr>
<tr>
<td>* Conglomerates and grits</td>
</tr>
</tbody>
</table>

Rao, et.al. (1975)

Harwal shale - Purple shales

Katamadevarhalli Limestone - well bedded and flaggy dark grey limestones

Halkal Formation - Greenish yellow to buff coloured shales with local quartzitic sandstone and conglomerate

Shahabad Limestone - Limestones of varying physical and chemical properties

Rabapalli Formation - Greenish yellow and purple shales with thin siltstone, sandstone and conglomerate/grit at the base
schistose, the gneissose and the granitic characters, along with the sedimentaries belonging to the Bhima Group are exposed. The generalised sequence is shown in the following table:

<table>
<thead>
<tr>
<th>Upper Precambrian to</th>
<th>Lower Cambrian Bhima Group</th>
<th>Bhima sediments</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Metadolerites</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Quartz veins</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pegmatites and aplites</td>
</tr>
<tr>
<td>Proterozoic Peninsular Gneiss</td>
<td>Pink granite</td>
<td>Grey granite</td>
</tr>
<tr>
<td></td>
<td>Granite gneiss</td>
<td>Migmatites</td>
</tr>
<tr>
<td></td>
<td>Pegmatites and blue-quartz veins</td>
<td>Biotite schist</td>
</tr>
<tr>
<td>Archeans Sargur</td>
<td>Amphibolite with-associated quartzite</td>
<td>Sericite schist</td>
</tr>
<tr>
<td></td>
<td>Ultramafic</td>
<td></td>
</tr>
</tbody>
</table>
Fig 2. Geologic map of the Kembhavi area, Gulbarga District, Karnataka State.
Geology of the area:

As mentioned in the preceding paragraphs, the lithological units exposed in the area around Kembhavi have been shown in the accompanying geological map (Fig. 2.2). It shows the presence of the rock formations belonging mainly to the Archeans, the Proterozoic and the Bhima Group of Upper Precambrian to Lower Cambrian period. The following paragraphs deal with the mode of occurrence, the field characters and the interrelationship of the different rock units exposed in the area investigated.

1. The Archeans:

The sequence of the rock units of the Archean period is as follows:

v. Pegmatites and blue quartz veins
iv. Biotite schist
iii. Amphibolite with associated quartzite
ii. Sericite schist
i. Ultramafic
i) Ultramafic:

As mentioned earlier, the ultramafic forms the oldest unit in the stratigraphic sequence of the Archeans. It is exposed due SE of Kembhavi at a distance of about 10 km. It occurs in the form of a small hillock, which is more or less elliptical in shape, occupying an area of about 15,000 sq m. Its longer dimension trends in N 350°. It is surrounded from all sides by the sericite schist. The ultramafic is dark in colour, consisting of predominantly olivine, pyroxene and magnetite. Olivine occurs in the form of coarse, rounded grains, which are greenish in colour, thereby suggesting its alteration to serpentine. Pyroxene is next in abundance to olivine. It occurs in the form of platy, subhedral and medium-sized grains. Olivine and pyroxene constitute the entire framework of the ultramafic. Magnetite occurs in the form of small veins or veinlets, which are about 0.5 cms in thickness. These veins trend mainly between N to N 30° direction. Generally, they are parallel with each other and sometimes at places have criss-cross relationship. The ultramafic is traversed by a shear
zone, which trends in N 30° direction. It extends throughout the exposure of the ultramafic with a width of about 3 metres. It is observed that, the emplacement of the magnetite veins has been mainly favoured along the shear zones and also along the associated fractures.

ii) Sericite Schist:

Sericite schist is exposed in the areas, east of Kembhavi at a distance of about 5 km. It occurs mostly in planes and also in stream cuttings. It is fine grained. Its foliation strikes NS with varying amounts of dip, between 45° to 70°. Dip direction is either towards east or towards west. Due to its micaceous content, it is highly eroded and fresh exposures are rare. It bears conformable relationship with the amphibolite or the migmatites as can be seen from the geological map (Fig.2.2).

iii) Amphibolite:

Amphibolite is prominently exposed between Karadkal and Godarihal, mainly in the form of a band, which runs in NS direction. Its chief constituent mineral is hornblende. The band has maximum width of
about 5 km in the north. It tapers down towards south, with a width less than a kilometer north of Mukangavi. The amphibolite is coarse-grained mainly in the central part of the band, becoming fine-grained towards the margin. However, it can be regarded as homogeneous throughout its exposure. It has developed foliation due to subparallel arrangement of the hornblende grains. The strike of foliation is N 35° and is found to be fairly constant throughout the exposure. The dip of the foliation, however, varies between 45° to 80°. The traverses across the strike of foliation have shown the frequent changes in the direction of dip which is either towards east or towards west. This indicates the formation of synforms and antiforms in the amphibolite band, thereby suggesting that this amphibolite band is tightly folded. The strike of foliation has been found to be more or less parallel to the contacts of the amphibolite with the sericite schist.

It has been observed that on the eastern flank of the amphibolite band, rock has developed spotted appearance due to the formation of the clusters of the
hornblende grains, giving rise to "hornblende-garbenschifer" (Plate 1, Photo 1). Such a formation of hornblende-garbenschifer from the same geological set up has been described by Deshpande and Parashar (1974) and Koregave (1980). The amphibolite has been traversed by four sets of joints, which strike in N 350°, N 10°, N 240° and N 270° directions. The joints are more or less vertical or dip with high angles.

With the amphibolite, associated is quartzite, which occurs in the form of the narrow elongated lenticular bands. Two such bands have been found to be enclosed in the amphibolite. The length of these bands is parallel to the strike direction of the amphibolite. The quartzite bears a conformable relation with the amphibolite. It has been found that the amphibolite becomes finer-grained at the contact with the quartzite and hornblende, occurs in the form of fine specks. In the quartzite, its proportion gradually decreases and the quartzite becomes light, green coloured massive rock. The quartzite has maximum length of about 1/2 km with a width of about 200 m in the centre. The
quartzite is medium to fine grained. It has been traversed by four sets of joints, similar to those in the amphibolite. The amphibolite and the quartzite have been traversed by the white pegmatite dykes.

iv) Pegmatites and blue quartz veins:

The pegmatites occur as intrusive bodies only in the amphibolite with associated quartzite. There are sixty one such pegmatite dykes. On the basis of mineralogy and structure they can be classified as simple and zoned. Of these, fifty one are simple pegmatites and ten are zoned pegmatites. Quartz, potash felspar, plagioclase felspar, tourmaline, garnet and muscovite are the constituent minerals. Most of the pegmatites run parallel to each other and mainly along the planes of the foliation of the amphibolite. They are either vertical or steeply inclined. Their strike length varies between 5 m and 500 m and width between 1/2 m and 50 m. On the basis of their length and width, the pegmatites have been classified as elongate and tabular (Proctor, et.al. 1964). The classification of the pegmatites on the basis of shape has been presented in Fig.2.3.
Fig. 23 Size-shape analysis of pegmatites from Kembhavi area.
Some pegmatites show bulging at the centre, while in some cases branching for a smaller length has also been observed.

Simple pegmatites comprise quartz, K-feldspar and plagioclase felspar and rarely tourmaline and mica. Quartz occurs in the form of the big grains, which are milky white in colour, with a length of about 6 cm to 8 cm. and width of about 3 cm to 4 cm. Rarely, bluish coloured quartz is also present. Quartz grains show incipient development of the fractures. Felspar is also coarser and is either grey or pink in colour. At places, it shows eutectic intergrowth with quartz. It has been observed that the coarseness of the felspar increases along with the width of the pegmatite. Like quartz, felspar also occurs in the form of fractured grains. Tourmaline occurs as shining, black, small needles and are irregularly distributed in the pegmatite. The tourmaline is subhedral with well developed prismatic faces. It is haphazardly oriented. However, at places it may form clusters. The tourmaline needles have the maximum length up to 5 cm and width up to
1 cm. Muscovite is rare and occurs either in the form of the colourless flakes or even small specks. It is also irregularly distributed in the pegmatite.

There are ten pegmatites which are zoned. They are of various shapes and sizes and generally show asymmetric zoning. Quartz, pink and grey felspar, tourmaline, garnet and muscovite are the constituent minerals. On the basis of the mineralogy and texture, maximum up to five zones can be identified from the core to the margin. These zones are as follows:

i) Quartz

ii) Quartz-Grey felspar-Tourmaline-Biotite

iii) Quartz-Pink felspar-Muscovite

iv) Quartz-Pink felspar-Tourmaline-Muscovite

v) Quartz-Grey felspar

It has been observed that these zones are gradational with each other. The grain size at the core of the pegmatite is found to be coarsest, decreasing gradually towards the marginal zones. The zoning in the pegmatites has been found to be concentric, where the zones are either circular or
elliptical. In some cases, they are found to be lamellar, where the zones run more or less parallel to each other and also parallel to the margin. The details of the zones of the representative pegmatites have been shown in Fig.2.4.

Quartz in the core is milky white with oily lustre. It shows much variation in proportion and also in size, in different zones. Felspar is either pink or grey in colour. The proportion of pink felspar is relatively more in the central zones than the grey felspar and vice-versa. It occurs in the form of subhedral grains with varying size in different zones. Tourmaline occurs in the form of the needles, which are shining black in colour. These needles are either vertical or perpendicular to the contact of the zones. In the respective zones, however, tourmaline shows the variation in its orientation. Garnet occurs in the form of small well-developed isometric crystals. Like tourmaline, it is also irregularly distributed in the zone, wherever it is present. Muscovite is prominently present in the border zones and rarely so in the intermediate zones. It is coarser in the border zones.
Fig 2.4 Representative sketches of zoned pegmatites from the Kembhavi area.
Fig. 24. Representative sketches of the zonal pegmatites from the Kemboth area.
and finer in the intermediate zones. It is present in the form of flakes.

Like the pegmatites, blue quartz veins have also been observed to be confined only to the amphibolite. These quartz veins also run more or less parallel to the foliation planes of the amphibolite. These extend for a length of about 15 m with a varying width between 1/2 m to 2 m. These veins comprise essentially blue to smoke coloured quartz. Pyrite is rare and occurs in the form of fine specks. These veins are present mainly in the southern part of the amphibolite band and to the south of the pegmatites mentioned earlier.

v) biotite schist:

A small exposure of the biotite schist is exposed at Malgatti. It occupies an area of about 2000 sq m with its longer dimension of 500 m nearly in NS direction, with a varying width of about 40 m. The biotite schist is dark in colour, coarse grained and equigranular in texture. Biotite is the predominant constituent mineral. Hornblende, quartz and felspar
occur as accessory minerals. Biotite flakes have been arranged more or less in parallel fashion, thereby imparting schistosity to the rock. The planes of foliation strike in N 350° direction and the dip of foliation is 70° towards west. It has been observed that in the central part of the exposure, there is the development of the biotite porphyroblasts. This has given a spotted appearance to the rock. The biotite schist is surrounded from all sides by the zone of migmatite.

II. The Proterozoic:

The sequence of the rock units of the Proterozoic period is as follows:

vi. Metadolerites
v. Quartz veins
v. Pegmatites and aplites
iv. Pink granite
iii. Grey granite
ii. Granite gneiss
i. Migmatites

Migmatites:

A good zone of migmatite has been found to be
developed due east of Jainapur at a distance of about 3 km. The zone extends more or less in NS direction with a varying width of about 1/2 km. Migmatite is a megascopically composite rock. It consists of petrographically different parts, one being the parent rock i.e. palaeosome, in a more or less metamorphic stage and the other i.e. neosome, being of aplitic, granitic, pegmatitic in character. On the basis of the rock portions of different size, shape and composition, Mehnert (1968) has described twelve different types of the structures of migmatite. Of these, six types of migmatitic structures have been found to be developed in the area. In these structures, palaeosome is of the hornblende schist and the neosome is of the granitic composition. The different migmatitic structures, observed in the area are:

a) Agmatite, b) Diktyonitic, c) Phlebitic, d) Stromatic, e) Ptygmatitic, f) Nebulitic. These structures are described in the following paragraphs.

a) Agmatic structure:

Exposures showing agmatic structure are exposed due north of Gaudgera (Plate I, Photo 2). It covers
an area of about 50 sq mt. Palaeosome is of the hornblende schist, which is shattered into pieces of various sizes and shapes, mainly due to the intrusion of the granitic material. The palaeosome is trigonal and polygonal in shape. The foliation of the hornblende schist in all the fragments of the palaeosome, is same as that of the major amphibolite band. Hornblende grains in the palaeosome are arranged parallel to the contacts with the neosome. The granitic material, which constitutes neosome, consists of saccharoidal quartz and white felspar.

b) Diktyonitic structure:

Due to the interlacing of the granitic material in the form of narrow veins along and across the foliation planes of the palaeosome, diktyonitic structure is developed. It is exposed around the vicinity of Buadnur. The granitic material constituting the neosome is in the form of the long slender veins 2 to 3 cm in thickness. At places, the veins show thickening and thinning (Plate I, Photo 3). The vein material consists of quartz and white felspar.
c) Phlebitic structure:

Due west of Budnur and around Aldahal, phlebitic structure is developed. In the structure, the veins of the pegmatitic material traverse the hornblende schist, thereby separating the palaeosome in the form of lenses (Plate II, Photo 1). The pegmatitic material is of varying thickness. At places, thickening and thinning of such veins can also be seen. The foliation in the palaeosome is conformable with that of the major amphibolite band.

d) Stromatic structure:

Stromatic structure can be seen in the areas between Budnur and Aldahal. This structure is developed due to the emplacement of the granitic material mainly along the foliation planes of the palaeosome, thereby giving a layered appearance to the rock. The pegmatitic neosome occurs, therefore, more or less in parallel bands (Plate II, Photo 2). These bands are of varying thickness. At places, the neosome layers have given rise to the pinch and swell structure (Plate II, Photo 3). The neosome is chiefly of quartz, pink and white felspar.
e) Ptygmatic structure:

The ptygmatic folded structure has also been developed and is found to occur to the south of Gaudgera at a distance of about 1/2 km (Plate III, Photo 1,2,3). The veins of the aplite or the pegmatitic material traverse mainly along the foliation direction of the hornblende schist - the palaeosome. The thickness of such veins varies between 2 cm and 5 cm with a varying wavelength. It has been observed that the vein has sharp contacts with the palaeosome. Hornblende grains of the palaeosome are arranged parallel to the contact of the ptygmatic veins. The ptygmatic veins however, have varying thickness.

f) Nebulitic structure:

Nebulitic structure is developed at Aldahal. In this case, it is difficult to distinguish the contacts between palaeosome and the neosome as they are diffused. However, the relative concentrations of the palaeosome and the neosome make it possible, the distinction between the two. At this locality the nebulitic structure is found to occupy an area of about 1 sq km and is developed mainly on the
eastern extremity of the major migmatite zone. To the east of this migmatite structure are exposed grey and pink granites. An exposure of the nebulitic structure is shown in a photograph, (Plate V, photo 1) in which the palaeosome of the hornblende schist more or less elliptical in shape can be seen. The development of K-felspar porphyroblasts is also evident.

Granite gneiss:

The granite gneiss is found to be developed through the zone of the migmatite. Its prominent exposure occurs mainly due west of Karadkal and NW of Kembhavi. It is exposed in the form of rounded hummocky boulders. It is found to be associated with either the grey granite or the pink granite.

The granite gneiss is coarse grained. The gneissosity is developed due to the alternating schistose and granulose bands. The schistose bands comprise medium or fine-grained hornblende and biotite, whereas quartz-felspathic material constitute the granulose part. The strike of the foliation of the granite gneiss is more or less constant i.e. NS in all
its exposures. The dip of the foliation of the granite gneiss is generally high, but varies between as low as 35° near Karadkal, gradually increasing to about 85° west of Kembhavi.

Grey granite:

The exposures of the grey granite are present throughout the area. It is prominently developed in the eastern part of the area, north of Gaudgera, south of Parasanahalli and Kembhavi. In the eastern part of the area, it is found to be associated with the granite gneiss, which has formed through the stage of the migmatization. However, at other localities the proportion of the granite gneiss is less and the grey granite is found to be associated with the pink granite. The grey granite is medium grained with granitic texture. It is composed chiefly of quartz, felspar, either white or pink, with subordinate amounts of mafics, chiefly biotite. Quartz occurs in the form of subrounded or elliptical grains with oily lustre, whereas felspar occurs in the form of subhedral grains and have dull lustre. Mafics are irregularly distributed throughout the rock and occur
in the form of small specks. The exposures of the
grey granite are in the form of round hummocky
boulders. Its prominent grey colour can be observed
in the eastern part of the area, whereas at other
localities, the intermediate stages between grey and
pink also can be observed.

Pink granite:
The pink granite is exposed mainly to the north
and northwest of Kembhavi and to the north of
Parasanhalli. However, its exposures can also be
observed, associated with those of the grey granite.
It is medium to coarse grained rock, chiefly composed
of quartz and pink felspar with subordinate amounts
of white felspar. Mafics are rare or nearly absent.
Like the grey granite, its exposures are also in the
form of rounded hummocky boulders.

The veins and dykes of the aplite and pegmatite
are also found traversing the pink granite, in an
irregular fashion. However, their contacts with the
host have been found to be gradational. In some of
the exposures, pods of quartz and pink felspar are
developed having gradational contacts with the host. It does not contain either mica or tourmaline.

**Aplites and Pegmatites:**

There are veins and dykes of the aplit and the pegmatite, which cross-cut the hornblende schist, the granite gneiss, the grey and the pink granite. They show variation in their strike direction. Majority of them are either vertical or steeply inclined. They also show great variation in their length and width. The maximum length was found to be upto 10 m. with a width varying between few cm to one metre. There is also much variation in the grain size from fine grained to coarse grained. They are mainly composed of quartz and pink felspar and are devoid of either mica or tourmaline.

**Metadolerite:**

The granitic rocks mentioned above have been found to be traversed by the doleritic dykes. There are three such dykes which trend N 50° and run almost parallel to each other. They are found to be exposed
i) at a distance of about 200 m east of Fatepur, where two dykes are exposed, and

ii) due west of Parasanhalli at a distance of about 1/2 km.

These dykes extend for a distance of about 500 m, whereas one at Parasanhalli can be traced for a distance of about 5 km. Their width varies between 2 and 20 m. The rock constituting the dykes is fine grained, compact and dark in colour. The dykes show sharp contacts with the host rock and have been found to be traversed by numerous joints.

The Bhima Group:

The field studies have shown that the granitic rocks and the gneisses described in previous paragraphs have been unconformably overlain by the sedimentary rocks belonging to the Bhima Group of the Indian stratigraphy. They are represented by the conglomerate, sandstone, shale and limestone. However, the major litho unit in the area investigated is the limestone with subordinate conglomerate, sandstone and shale. The sedimentaries are exposed mainly in the northwestern and northern parts of the area under study. The
following paragraphs deal with the field characters of the sedimentary rocks.

Conglomerate:

The exposure of the conglomerate has been recorded only at one place i.e. at a distance of about 2 km due south of Kembhavi. The conglomerate directly overlies the basement granites and is overlain by soil cover. It is composed of subrounded to rounded pebbles and gravels of quartz of different sizes with the subordinate amount of felspar which occurs in the form of altered subhedral grains (Plate IV, photo 2). These are found to be embedded in an arenaceous matrix. The conglomerate occupies an area of about 500 sq m. with an average thickness of about one metre.

Sandstone:

The field studies have revealed that there is a subordinate development of the sandstone and wherever it has developed, it is found to occur in the form of lenses of varying sizes in the shale. These exposures were observed in a canal cutting, excavations for which were still in progress. Such lenses occur more
or less on the same horizon and can be traced continually, giving rise to pinch and swell structure. These lenses have a maximum thickness of about 1/2 m with a maximum elongation of about 3 m. These bear sharp contacts with the shale in which they are enclosed. The sandstone constituting such lenses is massive, medium to fine grained and pinkish to pale greenish in colour. Quartz is the chief constituent mineral, whereas glauconite and felspar are present in the subordinate amounts. Quartz is present in the form of medium sized, rounded grains with oily lustre. Glauconite also occurs in the form of rounded to subrounded grains, pale green in colour with dull lustre, whereas felspar is generally white in colour and occurs in the form of white or yellowish specks.

Shale:

The shale has much areal extent as compared to the conglomerate and the sandstone. Due north of Kembhavi, it directly overlies the basement granitic rocks; whereas due westsouthwest of Kembhavi at a distance of about 2 km it also directly overlies the basement granitic rocks. At all these places, it is
found to grade vertically into the limestone. Good exposures of the shale can be seen at and around Fatepur and due north of Kembhavi.

Just due north of Kembhavi, the shale is found to overlie the basement granitic rocks, giving rise to a hillock. The shale is brick red in colour with well developed fissility planes. Its thickness varies between 10 to 15 m and it grades vertically into pink, buff coloured limestone. In the northwest part of the hillock, green coloured shale has been found to be exposed. It is resting on the basement granitic rocks and has given rise to undulating dips in varying amounts and direction. The shale is very much weathered. In the western part of the hillock, the shale is found to have a peculiar weathering pattern (Plate IV, Photo 3).

A major exposure of the shale has been observed in the vicinities of Fatepur. The shale is brick red in colour. However, green, grey and yellowish varieties of the shale have also been encountered. Yet, these varieties occur more or less at the lower
level of the sequence, which in turn have been found to be overlain by the brick red variety. The shale in turn grades vertically into the limestone. It is massive and at places has developed fissility planes. Compared to its exposure at Kembhavi, it is less weathered. Here the general strike of the shale is nearly NS with gentle westerly dips of about 10°.

At this place, the shale is found to exhibit varying structures, mainly fold and fault. Such structures, however, have a local extent and are found to die out within a short distance. The various types of folds, with the fold axis having different attitudes have been observed in a nala cutting (Plate V, Photo 1, 2, 3 and Plate VI, Photo 1). Such a pattern has been found to be confined mainly along the course of the nala, which runs for about 500 m. Due west of this fold pattern and also along the western part of the hillock, there is a good development of pseudo-breccia. It is developed in both, the shale and the limestone. This zone of pseudo-breccia is about 5 m in width and runs nearly NS for a distance of about 1 km. In this pseudo-breccia, there are subangular to subrounded,
elongated pebbles of the limestone, with the recrystallised calcareous matrix (Plate VI, Photo 2). The limestone pebbles show crude orientation (Plate VI, Photo 3).

In all these structures, it has been observed that the shale laminations maintain their thickness and continuity. These characters and the development of such structural features on a local scale can be ascribed to internal flowage resulted due to the downslope movement of the competent layer. It is worthwhile noting here that due to the downslope movement of the competent material, the sand material appears to have been squeezed out to give rise to the sandstone lenses, mentioned earlier (Page 40). The possibility of the development of such sandstone lenses has been suggested by Pettijohn (1969).

Limestone:

The limestone is associated everywhere with the shale having gradational contacts. The limestone has much areal extent compared to any other litho units of the Bhima Group mentioned above. The limestone is
massive and is of black, pink and fawn coloured varieties.

Just due north of Kombhavi, the limestone is massive and is pink in colour with a thickness of about 10 m. The limestone shows rolling dips, yet it maintains the general Bhima strike which is nearly NS. However, due to variations in the dip directions, it has given rise to a synclinal structure (Fig. 2.2). The development of the synclinal structure can be ascribed to the adjustment with the basement topography, while the sediments were in compaction and depositional stage.

Due west of Fatepur, the limestone is massive and is of black, pink and fawn coloured varieties. The limestone strikes in NS direction with some local variations, with an amount of dip varying between $5^\circ$ and $10^\circ$ (Fig. 2.2). The limestone at this place also exhibits similar structural features in accordance with those of the shale mentioned earlier (Page 43), (Plate VII, Photo 12).
The limestone at the localities mentioned above, exhibits various types of solution features, which are termed as Karst. Such superficial landforms on a smaller scale have been termed as karren or Lapiés by Sweeting (1972). Various such features have been identified, which include - i) solution basins or Kamenitzas, ii) stylolites, iii) rillenkarren and iv) rinnenkarren.

These are described in the following paragraphs:

i) Solution basins or Kamenitzas:

The development of solution basins has been observed in the massive, pink and fawn coloured limestone, exposed at a distance of about 1 km due north of Fatepur. Solution basins have also been termed as Kamenitzas (Sweeting, 1972). These are developed on more or less horizontal surface of the limestone and are circular or nearly elliptical in plan and are hemispherical. The diameter of such solution basins is up to a few cms with a varying depth maximum up to 1/2 cm. The solution basins occur at most places as individual basins, the spacing
between them also varies (Plate VIII, Photo 1). Sometimes, such solution basins are joined to each other giving rise to beaded appearance (Plate VIII, Photo 2 and 3).

ii) Stylolites:

The limestone from the area also exhibit the development of stylolites, which have been observed on vertical faces of the limestone exposure and are developed along the bedding planes. The stylolites have been observed in the vicinity of Fatepur. On the vertical faces of the limestone the development of two sets of stylolites have been observed. They are the crenulations forming saddles and lobes of different shapes and size. They are asymmetrical. The material which constitute the stylolites is greyish black in colour. The saddles and lobes of the crenulations are sometimes sharp or even rounded or having flat surfaces. The amplitude of the crenulations varies between 5 mm to 15 mm and the length between 10 mm to 15 mm (Plate IX, Photo 1).

iii) Rillenkarren:

Rillenkarren are found to be developed in the massive, fawn coloured limestone, exposed due north
of Fatepur at a distance of about 1.5 km. Rillenkarren are associated with Kamenzitzas and are developed prominently on the gently sloping surfaces. At this locality, rillenkarren appear to be in the stage of development (Plate IX, Photo 2). The rillenkarren extend maximum upto 25 cm in length. They are the grooves having rounded troughs and sharp crests with a maximum depth of about 1 cm. The spacing between the adjacent crest varies.

iv) Rinnenkarren:

Rinnenkarren are also developed in the massive fawn coloured limestone and are found to be exposed in the vicinities of the karren described earlier. They are developed on the vertical surfaces of the limestone. Just like rillenkarren, they also have sharp crests and rounded troughs but have larger dimensions than those of rillenkarren. These extend for about 50 to 70 cm. The troughs are rounded and vary between 10 to 25 cm in depth and are about 5 to 10 cm wide. The crests also exhibit little rounding. The spacing between adjacent crests varies between 5 to 30 cm (Plate IX, Photo 3).