CHAPTER LIV.
I. GEOCHRONOLOGY

In this section it is intended to discuss in detail the stratigraphic sequence of the different rock formations of the Jatnur-Halaguru area. This discussion is based on absolute age data and on the detailed study of the field relationships, structural characters and petrology of the different rock types of the area. As the area of the present investigation constitutes an integral part of the Archaean formation of the Mysore plateau, a review of the views that have been expressed on the stratigraphic sequence of the rock formations of the Mysore plateau as a whole may serve as a good background in appreciating the deductions of the present investigation.

Smeth for the first time in the year 1915 gave a classification (table 68) of the rock types comprising the Mysore plateau, based on the field relationship of the rock types established by the officers of the Mysore Geological Department. He grouped all the rocks of the plateau under Archaean and divided them into two main groups; the schistose group termed the Dharwars and the gneissose group constituting the gneissic complex. Dharwars, which he divided into lower and upper divisions, were considered by him as "the oldest known rocks of the
Archaean complex. The gneissic complex, which according to him consisted of four major epochs of igneous intrusions namely, Champion gneiss, Peninsular gneiss, Charnockites and Closepet granite, in the order of succession, are younger and intrusive into the Dharwars. For many years this classification and stratigraphic succession of epochs was accepted without any controversy.

Rama Rao (1940) investigated various rock formations of the Archaean complex of Mysore over a number of years and felt the need for a revision of Smeeth’s classification. The revised classification of Rama Rao is shown in table 69. From a comparison of Rama Rao’s (table 69) classification with that of Smeeth (table 68), the following modifications are seen.

1. The classification of Dharwars into three divisions instead of two.
2. Peninsular gneiss and Closepet granite are considered to represent two epochs of post-Dharwar granitic intrusions instead of four.
3. Champion gneiss has been found to occupy a position between middle and upper Dharwar divisions, representing a part of the middle division, instead of considering it as the earliest epoch of igneous
intrusion into Dharwara and older than the Peninsular gneiss.

(4) Charnockites do not represent one of the four major post-Dharwar igneous intrusions but are metamorphic rocks resulting from reconstruction of earlier rocks of diverse composition and age. The period of charnockite formation is placed by him between the formation of Peninsular gneiss and Closepet granite.

The stratigraphic sequences of Smeeth and Rama Rao described above were mainly based on the field study and were not supported by any isotopic age data.

Rama Rao (1964) in one of his recent articles entitled "The Archaean Provinces of India and their comparison with those of other continental shields", has briefly reviewed the available information on the composition, classification and correlation of the Archaean formations of the several Pre-Cambrian shields of the world and given a broad and generalised correlation based on the absolute ages, making a particular reference to the Archaean formations of Mysore. By correlating the Archaean formations of Mysore with those of identical rock formations occurring in other parts of India and in other shield areas of the world, which have been isotopically dated, and
### Probable ages of Archaean rocks of Mysore according to Rama Rao (1964)

<table>
<thead>
<tr>
<th>Age (m.y)</th>
<th>Rock formations</th>
</tr>
</thead>
<tbody>
<tr>
<td>900-1050 (?)</td>
<td>Closepet granite</td>
</tr>
<tr>
<td>1570-1750 (?)</td>
<td>Peninsular gneiss</td>
</tr>
<tr>
<td>1600-2000 (?)</td>
<td>Upper Dharwar</td>
</tr>
<tr>
<td>2300-2450</td>
<td>Champion gneiss</td>
</tr>
<tr>
<td>2500 (?)</td>
<td>Lower Dharwar</td>
</tr>
</tbody>
</table>
taking into account Ashwatthnarayan's (1956) absolute age data, Rama Rao gives the approximate range in age of different rock types of the Archaean complex of Mysore, the details of which are shown in table 70. From a perusal of the table, it is evident that Rama Rao has tried to use such age data which will fit into his earlier classification and stratigraphic sequence.

The present investigation of the Satnur-Halaguru area, where the gneiss (Peninsular) charnockites and granite (Closepet) of the Post-Dharwar crystalline complex occupy the major part of the area was started in the beginning of 1962. A detailed field study of the rock formations of the area brought to light the following features: (1) The three dominant rock types namely, gneiss, charnockite and granite do not bear an intrusive relationship with one another nor do they provide evidences of large scale intrusion so as to consider them as constituting epochs of igneous intrusions. (2) The charnockites are older than the gneisses and granites — there are evidences of the formation of the gneisses from the granitization and break-down of charnockites. (3) The granites and gneisses are metamorphic and metasomatic in origin and they are formed from the granitization of the Charnockites of the
**TABLE - 71**

K-Ar ages of pre-cambrian crystalline complex of Mysore
(Sadashivaiah and Naganna, 1964)

<table>
<thead>
<tr>
<th><em>K</em> Ar (m.y)</th>
<th>Rock types</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920</td>
<td>Biotite from Closepet granite (Molakalmuru)</td>
</tr>
<tr>
<td>1990</td>
<td>Biotite from Peninsular gneiss (Bangalore)</td>
</tr>
<tr>
<td>2020</td>
<td>Biotite from Champion gneiss (Kolar)</td>
</tr>
<tr>
<td>2130</td>
<td>Biotite from acid charnockite (Diaphthoretic) (Satnur)</td>
</tr>
</tbody>
</table>

* K-Ar dated from the central Geological Institute
  (U.U.G) Prague, Czechoslovakia (λ = 0.557 x 10^-10 yr^-1
  λβ = 4.72 x 10^-10 yr^-1)
Gneisses represent an intermediate phase in the evolution of the granites.

The above mentioned findings of the author of the thesis needed corroboration by absolute age data. This was provided by the work of Sadashivaiah and Maganna (1964) and Murthy and Sadashivaiah (1966).

Sadashivaiah and Maganna (1964) gave the $^{40}K/^{40}Ar$ isotopic age data (table 71) on the biotites drawn from the champion gneiss from Kolar, Peninsular gneiss from Bangalore, acid charnockite from Satnur and granite from Kolakalur (which is considered to represent the northern extension of Closepet granite). The above investigation showed the isochron did indicate a higher age than Peninsular and Champion gneisses for charnockite but the difference in age between the different rocks was not appreciable, as the four determinations approached an age very nearly 2000 my.

Murthy and Sadashivaiah (1966) published subsequently a more detailed and important isotopic age data. They have given $Rb^{87}/Sr^{86}$ and $Sr^{87}/Sr^{86}$ isotopic age data on the whole rock and minerals of the Champion gneiss, Peninsular gneiss, charnockite and Closepet granite and on the biotites for which Sadashivaiah and Maganna (op.cit) had given $K^{40}/Ar^{40}$ data. The complete data of those...
authors is given in table 72. On the basis of this isotope data, the authors (op.cit) have drawn the following conclusions:

1. The acid and the basic charnockites are essentially of the same age. Both of them yield a nice isochron of about 2950 my. (Fig. 55).

2. The charnockites are distinctly older than the granites and the gneisses.

3. There are no significant age differences between the gneiss (Peninsular) and granite (Closepet). The Rb-Sr data gives a very nice isochron (Fig. 56) indicating that the two rocks are about 2500 my.

4. The low $^{40}\text{K}/^{40}\text{Ar}$ ages when compared with $^{87}\text{Rb}/^{87}\text{Sr}$ ages for the corresponding samples (see table 73) and almost the same $^{40}\text{K}/^{40}\text{Ar}$ ages of all the four rocks namely, Champion gneiss, Peninsular gneiss, charnockites and Closepet granite, has been explained by these authors to represent either an episodic loss of $^{40}\text{Ar}$, as for example, a metamorphic event at that time, or due to continuous diffusive loss.

Taking into account the above age relationships that have been established on the basis of isotope data for the gneisses (Peninsular and Champion) charnockites
and granite (Closepet) by Murthy and Sadashivaiah (op.cit) and on the basis of his own detailed field observations, the author of this thesis has attempted to give the stratigraphic succession of the various rock types of Satnur-Halaguru area as shown in table 74.

The assignment of the same age as that of charnockites for clinopyroxene-bearing granulites devoid of hypersthene and metasediments (including the hypersthene-bearing rocks constituting an integral part of the metasediments — described in the Chapter VII of this thesis, and assigning the age of gneisses and granites for amphibolites (see table 74) is based on field relationships and on the similarity in petrographic characters and metamorphic history of these rocks. Therefore, the ages assigned to these rocks are tentative and subject to modification, as and when more work is done on their age determination.

There is another point which is necessary to be considered in this connection, that is, the basic and acid charnockites of the Satnur-Halaguru area, for which Murthy and Sadashivaiah have given isotopic age data, are hornblende-and biotite-bearing types corresponding to hornblende-hypersthene granulite sub-facies of regional metamorphism. But there are also charnockite varieties which contain only pyroxenes and are devoid of hornblende or biotite, the
field and petrological characters of which are suggestive of an older age than hornblende or biotite-bearing varieties. They might represent products of an earlier metamorphic event of the area which took place under pyroxene-granulite sub-facies. However, whether they really represent a separate earlier metamorphic event under pyroxene-granulite sub-facies or only metamorphic differentiates under hornblende-granulite sub-facies needs to be confirmed by radiometric dating.

No estimation of the ages of dyke rocks on the basis of isotopic data are yet available. From field study all that could be said is that they are post-granitic. But, whether they are of post-Cudapah or of Deccan Trap age or of different ages, as has been suggested by various authors, is not possible to decide from the field data alone. It can be decided only by isotopic age data. This isotopic dating of the various dykes of the area has now been taken up by Murthy and Sadashivaiah (in a personal communication to the author of this thesis). Therefore, it is necessary to wait and see the results of their further investigation.
II. EVOLUTION OF THE SATNUR-HALAGURU CHARNOCKITES 
AND THE ASSOCIATED ROCK TYPES

The Satnur-Halaguru area represents a deeply eroded part of the Archaean terrain, where rocks formed at deeper levels are exposed. The area is composed of a variety of rock types of diverse petrographic characters, degree of metamorphism, age and origin. In a polymeta-
morphic terrain like the Satnur-Halaguru area, where the effect of each metamorphic event is not completely discernible for thorough observation, a correct reconstruction of events is difficult. However, taking into account the available data on the field relationship, structural and petrological characters and the isotopic ages of the different rock types of the area, the author has attempted to give in the following account a co-ordinated picture of the evolutionary history of the rock types of the area.

The earliest metamorphic episode that is exhibited by the terrain is the formation of the charnockites from their parent rocks and the transformation of the associated calcareous, ferruginous, argillaceous and siliceous sediments into their metamorphic derivatives under pyroxene granulite facies conditions of regional metamorphism. Though it is not certain whether the parent rocks of charnockites were only igneous or only sedimentary or partly...
sedimentary and partly igneous in origin, it is believed that at least a part of the charnockite is igneous in origin. During metamorphism there was thorough recrystallization of the original rocks resulting in the formation of various types of metasediments and a more or less uniform variety of charnockite from the parent rocks having the mineral assemblages and texture characteristic of the pyroxene granulite subfacies of regional metamorphism. There is no evidence at present to infer that there was appreciable transfer of the material across the contacts of the rocks during metamorphism. Accompanied by the thorough recrystallization, both metasediments and charnockites underwent metamorphic differentiation which favoured the formation of varieties within the individual rock units. The more uniform charnockite differentiated into acid, intermediate, basic and ultrabasic types.

The migmatitic varieties of charnockites owe their formation to "charnockitic migmatisation" (Cooray, 1962), which has affected the charnockites only and not the surrounding country rocks. The charnockitic migmatisation is believed to have taken place when the rocks were still under pyroxene granulite facies conditions and it was associated with the introduction of silica, potash and soda under metasomatic conditions. Certain amount of
deformation was associated with this metamorphic event resulting in the formation of prominent N-S and NW-SE banding and locally developed minor folding whose fold axes also run along NW-SE direction.

Subsequent to the formation of the charnockites and the metasediments under the pyroxene granulite sub-facies of regional metamorphism, the rocks have undergone modification due to diphthoresis, probably due to the up-lift of the metamorphic terrain, when pressure temperature conditions were lower than in the pyroxene-granulite sub-facies and the influence of water was fairly prevalent, corresponding to hornblende granulite sub-facies conditions. During this second metamorphic episode, there was widespread partial breakdown of the pyroxenes of the charnockites into hornblende and biotite with the formation of common hornblende- and biotite-bearing charnockites of the area. Where the water was not prevalent and where directed pressure was active, pyroxene changed to garnet with the development of garnetiferous varieties of charnockites.

Metasediments have also responded to similar modification. Pyroxenes, cordierite and sillimanite were partially changed into hornblende and biotite. Hornblende- and biotite-bearing charnockites and metasediments, showing the impress of this second metamorphic episode, are well seen.
in the southern part of the area where bands and patches of least modified rocks of the earlier pyroxene-granulite subfacies metamorphic event also occur. The NE-SW minor folding occasionally seen in the modified charnockites is probably related to this metamorphic event. This episode has been dated at about 2950 m.y. based on the Rb-Sr isotopic data.

The third metamorphic episode brought about the complete destruction of the hornblende and biotite-bearing charnockites into hornblende- and biotite-gneisses (Peninsular gneiss) and granites (Closepet) which are so commonly seen in the northern part of the area. This has been brought about by the process of granitization and migmatization taking place under middle or low amphibolite facies conditions, where apart from lower temperatures and pressures, water was widely prevalent. These hornblendes and biotite gneisses often contain patches of hornblende and biotite-bearing charnockites of the second metamorphic episode as relics. Minor and local folds seen in the charnockites are present and preserved in the gneisses. The formation of the gneisses and granites appears to represent a chain of events that took place during this metamorphic event which was one of granitization. The granitic rocks of this metamorphic event have been dated to be about
2500 m.y. The formation of the granites and gneisses marked the end of the major metamorphic episode witnessed by this metamorphic terrain during Archaean times.

Long after the formation of the crystallines, the area witnessed the intrusion of dykes in succession. The earlier is the intrusion of orthopyroxene-bearing basic dykes intruding in depths, followed by a suite of genetically related dykes of dolerites, spessartites, diorite porphyries and alkali syenites probably intruding at upper levels. None of these dykes have been dated to decipher their exact stratigraphic position.

In the Satnur-Halaguru area diverse rocks of many ages are seen. Some of the rock types have undergone more than one kind of metamorphism. The charnockites associated with the younger polymetamorphic rocks show a series of retrogressive changes resulting in the formation of hornblende- and biotite-bearing charnockites and non charnockitic rocks. It is thus seen that, in this part of the metamorphic terrain of Peninsular India, charnockites must have extended over a greater area in Archaean times than to-day. Due to subsequent metamorphism, the charnockites not only changed to non charnockitic rocks but also occur as patches within them.

The area of the present investigation is unique in
many respects. In this area, rock types showing polymetamorphism are exposed, where a later metamorphism or migmatization has been superimposed on earlier high grade regional metamorphism. This has resulted in the occurrence of rocks of two metamorphic grades exposed side-by-side with a sharp contact. Thus charnockites are seen associated with modified charnockites or non-charnockitic rocks.

It is thus evident that the present nature of the charnockites and the extent and degree to which they have been modified are the result of complex metamorphic history and reflect the metamorphic conditions under which the surrounding rocks were formed during the Archaean times. The ultimate analysis of these rock formations in the Satnur-Malaguru area shows that they are largely lithological units which have undergone metamorphism showing chronological events rather than stratigraphic or structural characters.
III ECONOMIC GEOLOGY

A survey of the literature on the geology of the Satnur-Halaguru area shows that the earlier investigations of Evans (1894), Slater (1908) and Jayaram (1917) were done mainly with an object of utilizing the iron-ore deposits occurring near Halaguru. But when it was found that the iron ores were not of suitable grade, the investigators diverted their attention to the study of the occurrence of orthopyroxene in those iron ores and in establishing the relationship of those rocks with the intimately associated charnockites. They also believed, as has been stated already, that the iron-ores to be local gravitative differentiates of the charnockite magma.

Subsequent to the above cited investigations, during recent years also, some prospecting work has been carried out by the State Geological Survey. The prospecting pits and trenches that were dug during the prospecting work are still found all through the thick long band of iron ore located to the west of Halaguru. However, no investigation to exploit the iron ores on a commercial scale has yet been started.

Slag heaps are scattered all over the area indicating the smelting of the iron ores during early days.
There is in fact a story which goes to say that in this part of the country at one time there were as many as 700 families of blacksmiths engaged in smelting of iron and in the manufacture of implements and armaments.

The author of this thesis has not carried out any detailed work on the possibility of utilizing the 'iron-ore' of the area. But from field and petrological study it is clear that it is a poor quality ore usually containing a larger proportion of quartz, pyroxenes and relatively smaller proportion of iron oxide. It needs considerable beneficitation before it could be utilized for the extraction of iron. As good grade ore is extensively available in the other parts of the state, there is no such immediate necessity of utilizing a poor quality ore. So the iron ore of Satnaur-Malaguru could only be looked upon as a potential reserve.

Excepting iron ore, there is no other mineral deposit of economic value. But there are ample supplies of rocks available for the construction of roads, buildings, dam sites and other engineering structures. There are indeed a number of quarries of smaller and bigger sizes scattered all through the area. There is one particular community called 'Vaddaru' whose main profession is quarrying. At times the entire family is seen engaged in this work.
Both charnockites and gneisses, due to their common foliated and banded nature and due to the presence of longitudinal- and cross-joints and a close system of rift and grain, permit easy quarrying more than the granites in which all these qualities are only poorly developed. The acid charnockite occurring around the hills .2049', .2143', on the northern slopes of Basavanabetta and in a number of other places in the southeastern and south-western portions of the area; and the outcrops of gneiss located between Halasahalli and Kallapura, between Kallapura and Kunthru, in various parts on the western slopes of Bhiman-kandi betta and in the south-eastern foothills of Abbaldurga, are actively quarried for building stones and road metal. The charnockites and gneisses are also capable of yielding beams, pillars and slabs and quarrying for this purpose may be seen in the quarries located in the hills .2049', .2143' in Kabbaldurga (.3500') and near Kallapura.

Granite is also quarried in a number of places; for instance, near Hongindoddi, Achalu, Bommanhalli, Chikka-chalu, Suranhalli, Kabbal, for building stones and road metal. The coarse porphyritic variety of granite does not appear to be quite suitable for building stones as that of the pink non-porphyritic variety and so it is seen quarried only as road metal.
Besides the major rock types, charnockites, gneisses and granites, the dyke rocks namely, dolerites and porphyries are also quarried locally as building stones and road metal.