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INTRODUCTION:

The Sivasamudram area has attracted the attention of many geologists as well as tourists because of the occurrence of several interesting rock types especially charnockites, and the scenic beauty of the Cauvery river falls which is a feast to the eyes. Since the beginning of this century the area has been visited by several geologists of Mysore State Geological Department, Bangalore (Jayaram, 1917, Slater, 1908, Rama Rao 1927, Sadashivaiah 1943). Earlier workers, who had a great fascination for the investigation of charnockites showed their particular interest in the study of hypersthene-bearing quartz-magnetite rocks occurring intimate association with the charnockites. Because of their intimate association and the occurrence in them of orthopyroxene (hypersthene), an essential mineral of charnockites, the earlier workers considered the hypersthene bearing quartz magnetite rocks also as members of the charnockite series.

During the early period, geologists were, mainly concerned with the regional mapping of different rock
types and paid very little attention to the detailed study of the individual rock units. As a result, information regarding their field relationship, structure, petrography, mineralogy and petrochemistry, worked out on modern lines, which is essential for giving a complete and unified picture of the geology of the area, was very much wanting. In order to fulfil this need the author of this thesis undertook the present investigation.

LOCALITY AND ACCESSIBILITY:

The area around Sivasamudram, described in this investigation, occupies about 238 kmas, lies in Mysore State and is located 115 kmas SW of Bangalore city. It is bounded by latitudes 12°28' N and 12°15' N and longitudes 77°0' and 77°10' E and mainly falls within the NW portions of the Survey of India toposheet 57.H/3.

The area has well laid out roads. There are two highways, Bangalore-Mysore and Mysuru-T.Narsipur, passing almost through the centre of the area. There are several other motorable roads which connect the area (Sivasamudram) with its taluk headquarters Malavalli. Besides, a number of cart and foot tracks connect almost all the villages in the area.
Explanation of Plate I

Fig. A. Kundur hill (3131') located 1.61 kms west of Dasanadoddi.

Fig. B. Head works hill (2793') located 2.62 kms south east of Rottikatte.

Fig. C. Nettakallu hill (2295') located 1.61 kms due south of Ohandamahalli.

Fig. D. Rottikatte hill (2215') located 1 km due north of Rottikatte.

Fig. E. Anthravalli hill (2329') located 1.61 kms due north of Hullagala.
CLIMATE:

The area experiences a moderately hot climate for most part of the year. The temperature ranges from 20°C to 30°C. It is hottest from the middle of April to the end of May (30°C - 36°C) and coolest in October (20°C - 26°C). The annual average rainfall is about 69.75 cms. It rains heavily in May-June and August-November (about 56.4 cms.), the maximum being in September-October (27 cms.). The rainfall is mainly due to the north-east monsoon. Dry season lasts from December till almost the end of April.

PHYSICAL FEATURES AND SCENERY:

A glance at the topographic map will give an idea about the physiography of the area. The central portion is a lowland, while the southern and north-eastern regions have Kundur hill 3131', Headworks hill 2793', Nettakallu hill 2295', Rottikatte hill 2259' and Anthravalli hill 2329' respectively. (Plate I, figs. 1, 3, 4, 7, E).

The plains, which are mostly under cultivation, consist of charnockites and gneisses. They are generally over 2050' above sea-level and are interspersed at a few places by broad open mounds that rise to a height
of 200' above the ground level. These are commonly met within south and southwestern portions of the area. These are scantily vegetated with rocky and bouldery surfaces.

The hill ranges on the southern portion of the area, constituting Kundur hill and Headworks hill, are made up essentially of chamoekites and granites. The two hill ranges stretch in an almost N-S direction. These have conical top and reach heights ranging from .2793' to .3131' and are steep. The Kundur hill slopes are covered with a jumbled array of fresh granite boulders and tors of variable sizes and are so steep as to allow little vegetation growth.

In the north-eastern region, the Anthravalli Hills, which are essentially made up of gneisses, form precipitous peaks and escarp. Vegetation is scanty and accessible from certain points only. The height of the hill range is .2329'. On the top of the hill lies the shrine of Lord Hanuman which is a pilgrim centre.

DRAINAGE:

There are two prominent rivers in the area. One is Shimsha which drains the northern portion and has a characteristic meandering course, normally possessed by
rivers which have reached the mature stage. The river flows to the SW. The other is the Cauvery which has a very wide course and it flows almost in an E-W direction. It drains the southern portion, and at Sivasamudram it drops as the Gaganchukki (drop 330') and Bharchukki (drop 230') waterfalls. The Shimsha river is its main tributary, which in turn has many tributaries like Nandi halla and Mullhalla that pass through the area in all directions and join the river, thereby giving rise to a distinct dendritic pattern of drainage.

Except for the two big rivers, namely Cauvery and Shimsha, all others are active only in the rainy season. The water level is usually low but considerably rises in the rainy season.

The waters of the Cauvery and the Shimsha have been harnessed for power generation and agriculture by building bund across them near Sivasamudram and Hebbal respectively and most of the cultivated lands in the area are irrigated by their waters.

VEGETATION AND CROPS:

The forests around Sivasamudram comprise mostly of thorny shrubs. These shrubs are thickly grown in valleys and on some soil covered slopes which make those portions inaccessible.
The main food-crop of the Sivasamudram region is ragi. Only a single crop is grown in the rainy season lasting from June to October. In the lands on the north and south of the Shimsha and the Cauvery, which have irrigation facilities, paddy is grown. There are also paddy fields of considerable extent irrigated by the waters of Malavalli and Yamadur tanks which are located some 1 and 6 kms north and south of Malavalli respectively.

The main cash crops in this area are the Mulberry gardens. The leaves of mulberry form the chief food for silkworms. The mulberry gardens are mostly developed around irrigation wells or other perennial water sites. Because of the simplicity of work and good returns this crop has attracted the farmers in this region.

Coconut plantation is restricted to low lying and valley portions.

WEATHERING AND SOIL:

The area has so long been subjected to weathering and denudation, that the rocks now exposed have retained only the remnants of its former highland and subdued hills, among which occur open broad plains. As now observed weathering is essentially restricted to superficial layers of rocks.
The nature of the soil is mostly red and gravelly. Alkaline and bloom type of soil are rare. The character of the soil is controlled by bedrock. Thus the soil covering acid rocks is brown to dark brown in colour and is well suited for agricultural purposes; while those covering basic rocks and iron rich sediments is reddish brown and dark bluish grey.

WATERFALLS:

The river Cauvery which flows almost in an east-west direction, suddenly plunges down to a depth of 330' from one spot and 230' from another which are named Gaganachukki and Bharachukki respectively. This waterfall has given the name 'Sivasamudram' to the area. The water-fall is in full swing only during the rainy seasons and during summer months the flow of the water is so scanty that it is less perceptible. This waterfall adds to the natural beauty of Sivasamudram area (Frontespice).

NATURE AND FREQUENCY OF THE EXPOSURES:

In the hilly region, the exposures are generally good but considerably disintegrated and dissected. The plains and lowlands are mostly cultivated exposing only good exposures of rocks among the low open scrubs of the
area. Owing to the poorly exposed nature, the author has strived not to miss a single outcrop however small it may be.

HISTORY OF PREVIOUS RESEARCH ON THE SIVASAMUDRAM AREA:

A scrutiny of the geological literature of Mysore reveals that the Sivasamudram area has received not much attention of the state geological survey officers like other areas in Mysore. The interest of the earlier workers in this area appears to be due to:

1. The occurrence of charmockites, in the study of which the older state geological survey officers were interested.

2. The occurrence of ortho-pyroxene bearing quartz-magnetite rocks in intimate association with the charmockites.

3. Association of charmockites with Clospet granites.

The research work describing and discussing various geological features of Sivasamudram area have been briefly reviewed below.

1894. Evans (1894) was probably the first geologist to visit the area in connection with the study of iron-ore bearing rocks of Maddur-Malavalli region.
1908. During the field season of 1906-1907, Slater surveyed 483 sq. km. of Mysore district for locating iron ores. In this survey he found that the area between Malavalli and Kankanahalli road and the Cauvery river, was mainly composed of acid and intermediate charnockites. He recognised the close similarity between the intermediate phase and hornblende schists and remarked 'that one can never be sure of its identification without a thin section for microscopic observations.' He noted in the area the acid phase of the charnockite is by far the most largely developed, the intermediate variety occurring only in thin alternating bands or fragmented inclusions in the acid types" considered the magnetite 'veins', occurring in the acid charnockite, as representing an ultrabasic phase of the series.

1927. In July and August of 1924, Ramachandra undertook a revision survey of the Madur-Malavalli region (the present area forms a part of this region) and published detailed field and petrographic notes with special reference to rocks of charnockitic affinities. He gave a brief description of the interesting exposure of charnockites constituting the hill '2793' of the present area. He noted that the contact between the acid charnockite and biotite granite and between basic charnockite and hornblende rocks were gradational and adduced evidences to show the formation of intermediate
charnockite by the incorporation and assimilation of noritic rocks in the intrusive clospet granite. Nowhere in the region he got definite evidences of the intrusive nature of the hypersthene bearing rocks into granitic gneisses.

It was considered likely that quartz-magnetite-pyroxene granulites, intimately associated with charnockites, were formed by the alteration and contact metamorphism of basic granulites.

1943 Sadashivaiah in his M.Sc. thesis on the charnockites of Kailasgarh, Vellore, Madras Presidency and of Malagur, Malavalli, Mysore State, gave a fairly detailed description of some of the rocks occurring in the neighbourhood of Sivasamudram. He grouped the rock types of the area into 1) granulites, 2) gneisses, 3) pigeonite bearing metadolerite, 4) hypersthonites, 5) garnet rich varieties, 6) diopside granulite, 7) magnetite rich rocks and 8) quartzites. Their petrography was given along with a detailed study of perthites, inclined extinction in hypersthene, modal analyses and specific gravity determinations. The inclined extinction of hypersthene which was statistically analyzed making use of the formulae given by Rosenbach-Wulfing and Michel Levy, Ferro and DeSousa-Brando, was found to be limited to domal and pyramidal faces. It was opined that the
various charnockite varieties of the area were formed by comingling of the minerals of the basic patches with those of the perthite gneiss.

1945 Rama Rao compiled in a bulletin (No. 18) of the Mysore Geological Department the results of his 25 years of study of Mysore charnockites. In this the charnockites and associated rocks of Sivasamudram area have again been described based on his observations during the survey and mapping of the area in 1924. "The charnockites of the area are dominantly acidic and are in close association at various places with hypersthene bearing quartz-magnetite granulites and gneisses. Basic charnockites occur as inclusions of diverse shapes and sizes in foliated or massive acid charnockites and in the younger granitic gneisses (Closepet). The inclusions are in the various stages of digestion and a careful study of several exposures clearly shows that from progressive stages of granitization they have been transformed into types corresponding to the intermediate charnockites; the acidic injections, which granitized them, enclosing in some instances xenocrysts of hypersthene, which were set free from the breaking down of such inclusions and deriving that mineral in other cases as an effect of reaction with the constituents of the basic intrusions have formed into charnockite granite".
In the beginning of 1964 the author of this thesis started his detailed investigation of the Sivasamudram area in collaboration with his guide Prof. M.S. Sadashivaiah. From 1965 to 1967 he has published the following research papers:

1965 In 1965 the authors described numerous veins of mylonite occurring within the charnockites on the west of Halagur. Field characters, petrography, mineralogy and petrochemistry have been described and discussed. It is suggested that the mylonite formation along the fault zone from the host rock has resulted in considerable change in chemical composition. The occurrence of mylonite as veins in charnockites is attributed to their formation by fusion along the fault zones charged with gas. The fusion provided the necessary mobility to be able to intrude the smallest fractures.

1968 In 1968 the authors, for the first time, described the occurrence of fibrolite in the pyroxene-quartz-magnetite rocks of the area. Its occurrence is attributed to alumina metasomatism, as fibrolite is seen replacing all the ferromagnesian minerals of the pyroxene-quartz-magnetite rocks.

PRESENT STUDY:

The present investigation deals with field characters, structure, petrography, mineralogy,
petrochemistry, petrogenesis and age of the charnockites, gneisses, granites and the associated rock types of Sivasamudram area.

The interpretations of various geological features are based on detailed field study and mapping of the 239 sq. km. of the area for about six months during the summers of 1964, 1965, and 1966, when the geological and structural maps (Map I and Map II enclosed in the back cover of the thesis) of the area were prepared on enlarged scale 10.2 centimetres to 1.609 kilometres (four inches to a mile) and subsequently reduced photographically to the present size. The country apart from certain localised areas, is not well exposed and the construction of a solid map is consequently a matter of some difficulty. Generally the contacts between the rock types are gradational and the mapping of such contacts is inferential. There are however, a number of quarries and exposures which furnish a splendid display of many varieties of rock types found in the area and reveal a number of complex features.

Representative rock specimens numbering 450, collected at suitable intervals and covering all varieties of rocks of the area and thin-sections cut from the representative rock types were subjected to petrographic and mineralogical study. In the following
chapters the writer of this thesis has presented field, structural, petrographic and mineralogical descriptions together with the petrochemistry of the charnockites, granites and gneisses and other associated rock types of the area and has tried to discuss their origin based on the data obtained by careful examination of the different aspects as detailed above. The conclusions put forth are mainly based on actual observations supported by laboratory studies of 500 thin sections, 450 specimens, volumetric analyses of 57 thin sections, chemical analyses of 34 rock samples, supplemented by the trial series of petrofabric analyses of a few rock samples and available isotopic age data of some selected rock types.

The detailed account of the field relationship, petrography, mineralogy, petrochemistry and structure of various rock types of the area, described and discussed on modern lines in the thesis, is all new and had not been done by the earlier investigators. Occurrence and description of several rock types described in this thesis have not even been recorded by the earlier workers. Thus this investigation forms a first detailed contribution to the knowledge of the geology of the Sivasamudram area.
METHODS OF STUDY:

(a) **Structural study:** The megafabric elements have been mapped and interpreted according to the methods outlined by Ernst Cloos (193? & 1946) and his collaborators. The quartz fabric of some selected samples has been investigated on a 4-axes universal stage employing the techniques outlined by Fairbairn (1954).

(b) **Mineralogical study:**

**Refractive Index:** Refractive indices of the minerals were determined by the immersion method using calibrated liquids. The determinations have been made in sodium light. In the biaxial mineral only $n_p$ was determined directly by scooping out suitable optic axis sections from thin sections.

$2V$, Extinction angle, Orientation, Birefringence and Pleochroism

All these optical properties were determined on a 4-axes universal stage, manufactured by Leitz company, according to the methods outlined by Naidu (1958). The $2V$ values mentioned here are direct measurements corrected for the mean refractive index of the mineral concerned. The extinction angles $c \wedge z$ and $c \wedge x$ of pyroxenes and amphiboles have been determined according
to Burri's method and wherever suitable (100) twin grains were available Nemato and Turner's (Naidu op. cit.) method was employed. Birefringence values were determined employing a Leitz Berek compensator for retardation determination and using, either quartz or plagioclase for calculating the thickness.

**Anorthite content and Twin laws of plagioclase:**

The anorthite content and twin laws of plagioclase were also determined on the 4-axes universal stage according to the methods of Reinhard, Duparc, Berek and Nikitin (Naidu, op. cit.).

**K-felspars:** The K-felspars have been distinguished by the 2V values. The orientation of perthitic bodies was determined according to the procedure given by Naidu (op. cit.).

(c) **Modal analyses:** All the modes given in this thesis have been determined on a Leitz six-spindle integrating stage.

(d) **Chemical analyses:** In all the chemical analyses of rocks only the main elements, viz., SiO$_2$, Al$_2$O$_3$, Fe$_2$O$_3$, FeO, TiO$_2$, CaO, MgO, MnO, K$_2$O, Na$_2$O and H$_2$O have been reported. All these have been determined according to the procedures given by Groves (1951) and Vogel (1962).
GEOLOGICAL SETTING:

The Sivasamudram area lies within the charnockitic region in Mysore State. It represents a deeply eroded archaean terrain, where rocks formed at great depths under pyroxene-granulite facies conditions are exposed. It consists of a variety of rock types which differ from each other in their petrography, degree of metamorphism, age and origin. By detailed field and structural mapping, the author of this thesis was able to establish the stratigraphic sequence of the area shown in table 1.

In the following pages the observations on the nature and relationship of the various Archaean formations met within the Sivasamudram area are briefly given.

The Sivasamudram area consists largely of charnockites, gneisses and granites which possess thin intercalations of meta-sediments namely, calc-silicates, pyroxene-quartz-magnetite rocks and quartzites and a suite of intrusions of doleritic, spessartitic and dioritic composition.

Most of the rocks in the area have undergone deformation. A distinct feature is the general NWW trend and easterly dip of all the major rock formations.
## Table I

### Stratigraphic Succession of the Rocks of Sivasamudram Area

<table>
<thead>
<tr>
<th>Stratigraphic Position</th>
<th>Rock Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post granitic dykes</td>
<td>Diorite porphyry</td>
</tr>
<tr>
<td></td>
<td>Spessartite</td>
</tr>
<tr>
<td></td>
<td>Porphyrites</td>
</tr>
<tr>
<td>Post granitic metabasic dykes</td>
<td>Orthopyroxene-bearing</td>
</tr>
<tr>
<td></td>
<td>granulitised basic dykes</td>
</tr>
<tr>
<td></td>
<td>Alkali granite</td>
</tr>
<tr>
<td>Closepet granite</td>
<td>Pegmatites and aplites.</td>
</tr>
<tr>
<td></td>
<td>non-porphyritic</td>
</tr>
<tr>
<td></td>
<td>medium to coarse</td>
</tr>
<tr>
<td></td>
<td>grained pink granite</td>
</tr>
<tr>
<td>Peninsular gneiss</td>
<td>Biotite and hornblende gneiss</td>
</tr>
<tr>
<td>Charmockites</td>
<td>Charnockite series.</td>
</tr>
<tr>
<td></td>
<td>Acid, intermediate, basic and ultrabasic</td>
</tr>
<tr>
<td></td>
<td>varieties and their contemporary</td>
</tr>
<tr>
<td></td>
<td>pegmatite phase.</td>
</tr>
<tr>
<td>Dharwars</td>
<td>Metasediments</td>
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<tr>
<td></td>
<td>Quartzites.</td>
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<tr>
<td></td>
<td>Calc-silicate-granulite.</td>
</tr>
<tr>
<td></td>
<td>Pyroxene-quartz-magnetite rocks</td>
</tr>
<tr>
<td></td>
<td>Rocks of granulite facies.</td>
</tr>
</tbody>
</table>
The charnockites are extensively developed and restricted to the southern portion while the northern portion consists mainly of gneisses and granites. None of the above rocks shows evidences of intrusion or large scale magmatic emplacement.

The charnockites of the area include acid, intermediate, basic and ultrabasic members all of which are of the same age and all are much older than the associated gneisses and granites.

From the evidences gathered it can be said that the charnockites as seen in their present state are metamorphic rocks, forced by metamorphism and migmatization of a more uniform rock under pyroxene-granulite facies conditions. The different members are not products of magmatic differentiation of a common parent magma but are products of metamorphic differentiation and migmatization.

The metasedimentary intercalations that are found in the major rocks bear a concordant relationship. They do not show in the field any evidences of interaction and assimilation. Textural, structural, field and mineralogical evidences strongly support the assumption that these were formed by metamorphism (under pyroxene-granulite facies) of a series of sedimentary rocks that
were laid down contemporaneously with the rocks that gave rise to charnockites and have had much of the same metamorphic history.

The gneisses of the area are of two types namely, biotite and hornblende gneiss. They show gradational features with the acid charnockites. The gneisses often carry inclusions of charnockites, which are in various stages of breakdown into the gneisses. From the evidences, it appears that the gneisses were formed by the complete breakdown of charnockites by granitization and migmatization under middle or low almandine amphibolite facies conditions, where, apart from low temperature and pressure, water was widely prevalent. This took place late after the formation of charnockites.

The formation of granites of the area, which was simultaneous with the formation of gneisses, represents the final episode of the plutonic history of the area.

The available evidences do not support the idea of large scale magmatic intrusion of granite but uphold the theory of formation of granites by granitization of pre-existing rocks. The granites being much younger than charnockites have not played any role in the formation of charnockites as proposed by Vredenberg (1918) and Rama Rao (1945).
Long after the formation of gneisses and granites there was a widespread igneous activity which brought about the intrusions of dolerite, spessartite and diorite dykes. The field and petrographic, mineralogical and chemical evidences suggest a genetic relationship of all these dykes derived from the differentiation of a common parent basic magma of calc-alkaline composition.

On the basis of available age data, field and laboratory investigations, the author of the thesis suggests the stratigraphic succession of the rocks of Sivasamudram area as given in table (I).