B. SUMMARY

The area around Koppal, described in the present investigation, occupies about 300,000 Sq.Kms. and lies in the Raichur district of Mysore State. It is bounded by latitudes 15° 15' N and 15° 30' N and longitudes 76° 5' E and 76° 15' E and falls within the eastern portion of the Survey of India toposheet No. 57 A/3.

This area has not attracted the attention of earlier workers in geology, perhaps mainly because it is devoid of metalliferous deposits and partly also because it was a part of the old Hyderabad State until it merged with Mysore, consequent to the reorganization of States in 1956. As a result of the present investigation by the author the area has revealed many interesting geological features for the first time.

This area lies within the Precambrian terrain of Peninsular India and represents a deeply eroded part of the earth's crust where rocks formed under the granulite and epidote amphibolite facies conditions have been exposed. It consists of a variety of rock types which differ from one another in their petrography, degree of metamorphism, age and origin. They have been broadly classified in this thesis into metasediments, amphibolites, granites, gneisses, pyroxene syenite and dolerite dykes.
Metasedimentary rocks are very limited in areal extent, amounting to only about 2.0 Sq.Kms. occurring as small intercalated bands only in granites and gneisses of the eastern and northeastern parts of the area, which represent the oldest rock formations. They bear a concordant relationship with the associated granitic rocks and show sharp contacts.

On the basis of their chemical individuality and lithological characters, they are grouped under three heads, namely (i) metamorphosed ferruginous sediments (ii) metamorphosed pelites rich in lime and (iii) metamorphosed siliceous sediments. They show minute banding and lamination in hand specimen and granulitic to schistose textures in thin section with considerably variation in grain size and mineral assemblage. The mineralogical components of the various metasedimentary rocks of the area are quartz, magnetite, grunerite, garnet, pyroxene, cordierite and fibrolite. Mineral assemblages are usually simple. In most of the cases quartz and magnetite together constitute more than 80.0% of the mode. In pyroxene-garnet granulite the effect of diaphthoresis, where garnet forms from the breaking down of the pyroxene under dry conditions, is noticed. The distribution coefficient of Fe and Mg in a coexisting
mineral pair of pyroxene and garnet suggests that the pyroxene-garnet mineral assemblage has been formed under pressure and temperature conditions which are intermediate to those of the glaucophane schist and granulite facies conditions.

The chemical composition of the metasedimentary rocks is simple. Silica and iron oxides amongst themselves constitute more than 85.0% of the bulk chemical composition in most of the metasedimentary rocks. This simple chemical composition, with moderate to minor amounts of CaO, MgO and Al₂O₃ suggests that the parent materials from which different metasedimentary rocks are derived were iron rich siliceous sediments containing little lime, magnesia and alumina.

Field, petrographic, mineralogical and petrochemical evidences indicate that the different metasedimentary rocks of the area have been derived from the parent sediments of appropriate composition, after being subjected to more than one episode of metamorphism. They are probably equivalent to the lower Dharwars of Mysore.

Amphibolites occur as small dyke like bands, large patches and lenses, with or without sharp contacts, in granites and gneisses but with sharp contacts in pyroxene
syenite. They are drawn parallel to the regional NNW trend of the area and are well foliated. They are greenish black in colour and medium to coarse grained. They invariably show granulitic to schistose textures and occasionally exhibit relic ophitic and subophitic ones. They consist chiefly of hornblende, plagioclase and relic pyroxene. The chemical characters of amphibolites closely resemble those of dolerites and basalts. Their trace element concentration is similar to the Connemara amphibolites of Ireland, which have been described by Leake (1960) as ortho type. On the basis of field and laboratory evidences and supplemented by the information available on the neighboring Munirabad area of the terrain, it is believed that the small dyke like bands, elongated patches and lenses of amphibolites, present in the various stages of granitization in granites and gneisses, represent relics of once extensively developed amphibolites which were derived from basic igneous rocks of an early Dharwar age and subsequently subjected to episodes of regional metamorphism and finally to injection metamorphism and granitization to form the granites and gneisses of the area.

Granites and gneisses of the area are wide-spread and occupy more than 80.0% of the area investigated. They
are represented by both pink and grey varieties. They bear gradational contacts with each other and show no intrusive and transgressive relationships. The phenomenon of double inclusions, i.e. presence of small patch like inclusion of granite in gneisses and gneiss in granites, is commonly observed. They contain numerous relic inclusions of amphibolites in various stages of granitization and traversed by quartzofelspathic veins of various dimensions and shapes. On the basis of colour, grain size and disposition of the exposures, they are broadly grouped into the following six types namely i) Irakalgada granite ii) Lachanakeri granite iii) Tenkanakallu granite iv) Halavarthi gneissic granite v) Basapur gneiss and vi) Gneisses from other localities.

The granitic rocks of the Koppal area chiefly consist of microcline, oligoclase, quartz together with accessory and secondary minerals like biotite, hornblende, epidote, apatite, iron ore, sphene and zircon. They predominantly exhibit granitic texture. Most of their constituent minerals are subjected to granulation and crushing. Myrmekite, developed due to replacement of microcline by oligoclase and also due to silica metasomatism, is commonly present. Microcline is the predominant constituent mineral and occurs in two generations. It shows tartan twinning which
is occasionally discontinuous and patchy. It also exhibits perthitic texture of replacement origin. It has $2V_\text{q} = 80$ to $84^\circ$, triclinicity 0.99 and 90.0% $\text{Cr}$ molecules. Oligoclase is the next abundant mineral with an anorthite content ranging from 18 to 28%, and occurs in two generations which can be distinguished by their difference in shape, size and freshness. It is both twinned and untwinned. Twinning is mainly after the albite and albite-ala laws. Twin lamellae are occasionally fractured and bent. It has got low temperature optics. Quartz also occurs in two generations. The one of the earlier generation occurs as large grains invariably showing undulose extinction and Böhm lamellae, whereas that of the later generation occurs as blebs in other minerals. The minerals show considerable amount of replacement with each other due to potash, soda and silica metasomatism.

Biotite is the common ferromagnesian mineral and occurs as an accessory. It is deep brown in colour and pleochroic. Its chemical characters suggest that it has formed under metamorphic conditions. Epidote is the common secondary mineral in almost all the types of granitic rocks and is derived both from hornblende and oligoclase.
The petrographic characters of the granitic rocks of the Koppal area amply testify to the role of metasomatism during their evolution. It is seen that an earlier potash metasomatism has been followed by later soda and silica metasomatisms. The optics and twin laws of oligoclase and the nature of microcline of the granitic rocks not only support a metamorphic and metasomatic origin for the granitic rocks but also indicate the low temperature condition under which these rocks originated.

All the types of granitic rocks of the Koppal area are of granitic composition except for one (Hornblende gneiss A/125) which is dioritic in composition.

Their petrochemical study indicates that the geochemical changes involved during the transformation of basic igneous rocks of early Dharwar age to those of granitic characters is one of basification of desilication, followed by felspathization or granitization.

The concordant structural relationship of the granitic rocks and associated amphibolites support the conclusion that the transformation of the latter into rocks of granitic character is due to injection metamorphism and granitization which was guided and controlled by the regional structure of the pre-existing amphibolites. As a
result, the granitic rocks are seen everywhere to fit themselves into the regional structural pattern of the area.

These granitic rocks are seen to resemble the synkinematic granitic rocks of Eskola (1932), which supports the conclusion that synkinematic granitic rocks formed during the Archaean Orogenic Cycles of Peninsular India occur in the Koppal area. On the basis of field and laboratory investigations it is concluded that they were formed from the amphibolites of an early Dharwar age by injection metamorphism and granitization taking place under the epidote amphibolite facies conditions.

The pyroxene syenite is a new find and an interesting rock type which occurs in an area of about 60.0 Sq. Kms., forming an oval shaped pluton-like mass with its longer axis bearing a discordant relationship to the associated granitic rocks. At some places it shows sharp contacts with the associated granitic rocks and exhibits intrusive characters by sending tongue-like projections into them. It is pink to greyish pink in colour, medium to coarse grained with or without gneissic foliation though the foliated type is more common.

In thin section it exhibits porphyritic, holocrystalline and granulitic textures containing tablets and
anhedral plates of microcline and oligoclase, and prisms and plates of sodianaugite and hornblende together with accessory and secondary minerals like apatite, iron ore, sphene, rutile, zircon, biotite and epidote.

Microcline perthite is the most abundant mineral. Meso and vein perthites are common. The X-ray reflection on 131\(\overline{1}31\) gave the obliquity of 0.965 and 90.0% of Or molecules. The temperature of the formation of the microclines is about 400° C, based on its 2V value and triclinicity (Barth 1956). Oligoclase is fairly abundant with 20.0 to 28.0% anorthite content. Pale green sodianaugite is the characteristic mafic constituent having 2V\(\tau\) = 59 to 62°, Z\(\wedge\)c = 41 to 47°, (\(\Upsilon\) - \(\infty\)) = 0.024 to 0.028 and \(N_{\beta}\) = 1.699. In chemical composition and optical properties it is found that it is related to diopside with an affinity to aegirine. X-ray diffraction of the mineral gave (d) A° values closer to augite and diopside than to aegirine. The cell parameters are a 9.75, b 8.93 and c 5.25 A°, and \(\beta = 74°\ 10'\). Optical, chemical and X-ray characters identify the pyroxene as sodianaugite. Pale green to bluish green, pleochroic hornblende is always secondary after sodianaugite and has 2V\(\alpha\) = 76°, Z\(\wedge\)c = 14 to 21°, (\(\Upsilon\) - \(\infty\)) = 0.018 and \(N_{\beta}\) = 1.678.
Granulation and crushing of the constituent minerals, development of a good amount of epidote and uralitization of the pyroxene indicate the possibility of the effect of metamorphism witnessed by the pyroxene syenite after its genesis.

The petrochemical study of the pyroxene syenite suggests that the central portion of the syenite mass represents the original igneous rock consolidated from the residual magmatic melt which retained its original composition unchanged without assimilating the surrounding rocks, whereas along the margins the possibility of assimilation of the granitic rocks is indicated. The chemical characters closely resemble those of the calcalkaline syenite of Nockolds (1954), C.I.P.W. norm classifies the pyroxene syenite into class 2 (dosalic), order 5 (perfelic), rang 1 (peralkalic) and subrang 3 (sodiopotassic) which according to Washington (1917) resembles Umptekite described by Quensel from Sweden.

A remarkable high concentration of six critical trace elements in the pyroxene syenite, as compared to the surrounding granitic rocks, suggests a different mode of origin of the pyroxene syenite to that of the associated granitic rocks as explained earlier.
A high concentration of strontium, barium and zirconium in contrast to the low concentration of chromium, vanadium and rubidium indicates the derivation of the pyroxene syenite from a silicate melt of a late stage differentiate.

Though the observed field, petrographic, mineralogical and petrochemical evidences amply testify that the pyroxene syenite has been formed from the crystallization of a residual magma of calcalkaline composition and has intruded into the surrounded rocks, it is difficult to ascertain the time of its emplacement. However, it is believed that it has been emplaced either after or during the end phase of the injection metamorphism.

There is an occurrence of a large variety of dolerite dykes, represented by quartz dolerite, basaltic dyke, olivine dolerite, olivine bronzite dolerite, poikilitic dolerite and meladiabase. They are believed to be genetically related to one another and derived from the crystallization and differentiation of a common parent magma of a calcalkaline composition. It appears that the difference in the cooling conditions during the evolution of the dolerite dykes has been responsible for the observed textural variation in them.
From the observation of the occurrence of a large number of basic igneous rocks in the form of dykes in the preCambrian terrain of Mysore, as it is also commonly observed in other preCambrian terrains of the world, the author of the thesis believes that widespread igneous activity was operative in the deeper parts of the earth crust during Archaean times, which in turn suggests the possibility of a more extensive occurrence of basic igneous rocks in the lower part of the upper mantle.

The granites, gneisses, pyroxene syenite, metasediments and amphibolites of the Koppal area have structural features indicating deformation and they show well preserved megafabric structural features like foliation, lineation, banding, minor folds and joints. The persistent NNW trend and easterly dip preserved in the granitic rocks, metasediments and amphibolites, which almost coincides with the Dharwarian trend are remarkable structural features. Though the NE foliation is present in some of the granitic rocks, it is less prominent when compared with the NNW foliation. On the basis of detailed structural analysis, the author of the thesis opines that the structures found in various rock types of the Koppal area are related to each other and at least reflect three episodes of metamorphism. The prominent foliation, which is referred to
as the Dharwarian trend, is believed to have formed during the first episode of metamorphism and the less prominent NE foliation, commonly known as the Eastern Ghat foliation, has resulted from the third episode of metamorphism. There occurs a second episode of metamorphism (separating these two episodes of metamorphism), represented by injection metamorphism and granitization which took place under lower or middle epidote amphibolite facies conditions when the granitic rocks of the area formed. A trail series of petrofabric analysis, carried out on the selected samples of granitic rocks, has indicated that they are tectonites and support the conclusion that have been already drawn, namely that they have witnessed more than one episode of metamorphism and deformation.

The area of the present investigation is unique in many respects. In it rock types showing polymetamorphism are exposed; there a later metamorphism of migmatization has been superimposed on an earlier high grade regional metamorphism. This has resulted in the occurrence of rocks of two metamorphic grades, exposed side by side with sharp contacts. Thus amphibolites are seen associated with modified amphibolites of migmatized rocks.

It is thus evident that the present nature of the amphibolites and the extent and the degree to which they
have been modified are the result of a 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 Koppal area shows that they are largely lithological units which have undergone metamorphism showing chronological events rather than stratigraphic or structural characters.

In conclusion, it is emphasized that the detailed information regarding field characters, petrography, mineralogy, petrochemistry and structures of various rock types of the Koppal area, described and discussed at length in this thesis to give a complete and unified geological picture of the area, is all new and forms an original contribution to our knowledge of the geology of the Crystalline Complex of Mysore in general and that of the Koppal area in particular.