CHAPTER IX

PENINSULAR GNEISS
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INTRODUCTION:

The earlier workers of the Mysore Geological Department considered the rocks of the thesis area as belonging to closepet granites and showed them as such in their maps. Radhakrishna (1956) has re-drawn the boundaries of the closepet granites on the basis of his field survey undertaken during his detailed studies on the closepet granites of Mysore State. Fig.57 shows the new boundary of closepet granites as re-drawn by Radhakrishna. It will be clear from his map that the southern extremity of the closepet granite is not so broad as shown by the earlier workers.

The various granitic rocks of the area fall in that portion of the map shown in Fig.57, shown in dotted line, which has been separated from the area constituting closepet granites. The work by the present writer has confirmed the legitimacy of identifying the rocks of this area as distinct and different from the closepet granites to which the former do not show any resemblances whatsoever. Since the granitic rocks of this area are gneissose and banded in character, bearing similarities to the Peninsular gneiss, they have been grouped under the head "Peninsular gneiss", which have extensive distribution in and beyond the area of investigation.
REVISED WESTERN MARGIN OF THE CLOSEPET GRANITES.

FIG. 57
The suite of Peninsular gneisses has received more attention in Mysore State than elsewhere, and much of the information we have on them is mainly from the works of Smeeth (1916), Sampat Iyengar (1920), and Rama Rao (1940). The report given by these workers is an account of the field features of various rock types included under the Peninsular gneiss. Much attention has not been paid to their petrographical, mineralogical, and petrochemical aspects. In the present chapter all the important aspects of the Peninsular gneisses of the thesis area have been described and discussed.

THE TERM "PENINSULAR GNEISS":

The granites and gneisses of Mysore State, including those of the thesis area, were originally described under the name "Fundamental Gneiss", on the belief that it formed the old floor upon which there were out-pourings of lavas. Smeeth (1916) gave the term "Peninsular gneiss" to this gneissic complex, as it was found by him and his co-workers to be intrusive into the folded and highly disturbed Dharwarian rocks. He thus considered the Peninsular gneiss to be younger than the Dharwars and the Champion gneiss, but older than charnockites and closepet granites. The composite nature of these rocks has been recognised by the early workers also. The various granitic rocks of the thesis area are also included under the Peninsular gneissic group of rocks, as they are very similar to them in many aspects.
PART PLAYED BY PENINSULAR GNEISS IN PRODUCING THE TOPOGRAPHY OF THE AREA:

The Peninsular gneiss determines the essential topographic features of the area. They constitute hillocks of various heights, whose slopes are generally gentle, but for a few precipitous ones near Singarajpur. The gneissic granites and the banded gneisses form the heights of the hill ranges, whereas the slopes and the low grounds are constituted mostly of gritty granites. The different varieties of the Peninsular gneiss have contributed to the undulatory topography of the area, because of the differential weathering to which they are subjected.

COMPONENT TYPES OF PENINSULAR GNEISS:

The investigation made by the earlier workers has established the fact that the area covered by the Peninsular gneiss consists of a heterogeneous mixture of several types of granitic rocks. For the purpose of description Rama Rao (1962) has grouped the various granitic rocks under the following four heads:

a. Banded gneisses.
b. Granitic gneisses.
c. Gneissic granites;
d. Granites, granodiorites, diorites, interaction dikes, and other variants.

The above classification also holds good for the
granitic rocks of the thesis area. But a number of variants are found in the above rock types in respect of texture and colour. When these variants are considered, the following types can be recognised:

a. Banded gneisses.
b. Gneissic granites.
c. Granitic gneisses.
d. Gritty granites.
e. Leucogranites.
f. Garnetiferous granites.
g. Medium- to coarse- grained pink and grey granites.
h. Fine- grained pink granites.

The above varieties, though recognisable, cannot be demarcated in the map, as any one exposure constitutes a heterogeneous mixture of several types. The difficulties experienced in demarcating one type from the other on the geological map are due to, 1) the frequent variation in texture and mineralogy within short distances, 2) the intermixture of various types, 3) the gradual transition of one type to the other, and 4) the weathering of the rocks which obscures the true textural and mineralogical features of the rock exposures.

If a wider picture of the area is taken into consideration, a more or less restricted occurrence of certain types can be made out and delineated on the map. The rock types that are shown on the map are:

1. Banded gneisses, gneissic granites, and gritty granites shown as a single unit.
2. Leucogranite.
3. Garnetiferous granite.
4. Fine-grained pink granite.
5. Medium-to coarse-grained pink granite.

FIELD FEATURES OF VARIOUS TYPES:

Banded gneiss

Among the several types of Peninsular gneiss, the banded gneiss shows a wide variation in colour, texture, and in the nature of its banding. The banded appearance is due to the arrangement of different lithological units in alternate bands (Fig.59 to 62). The bands show generally marked parallelism trending N.N.W. dipping mostly eastwards (Fig.58. A & B), at angles varying from as low as 20° to as steep as about 80°. But the common dip angle is 25° to 45°.

The banding is due to the alternation of lithological units of pink, grey, and dark colour. The individual bands may vary in width from a fraction of a centimeter to about 15 centimeters or in some cases even more. In some granitic exposures, the bands may not be straight or continuous, but may be lenticular and ribbon-like.

The dark bands are usually amphibolitic, or biotitic, or charnockitic, whereas the lighter bands, both pink and grey, are granitic in character. The dark grey bands may be dioritic in nature. The banded gneisses themselves may be distinguished as grey banded gneisses and pink banded gneisses. The grey banded gneisses have an over all
grey colour, the lighter colour bands of granitic character alternating with the dark or dark-grey bands. The bands are usually straight without much contortions (Fig. 59. A, B & C). The pink banded gneisses have an overall pink colour, the pink-coloured light bands of granitic character alternating with the dark-coloured bands. As contrasted with the grey ones, the individual bands of pink banded gneisses are folded and contorted (Fig. 60 and 61). These pink banded gneisses are sometimes migmatitic in nature (Fig. 62). The other distinctive features of the pink bands are that they are much coarser and are often pegmatitic in character.

Taken as a unit, the pink banded gneisses may be considered to be younger than the grey ones, formed at the last stages in the evolution of Peninsular gneiss. The general contorted folding of the pink banded gneisses and the coarse pegmatitic nature of the pink bands are proofs for their late stage formation. If the history of the evolution is traced, the course would be, first, the formation of grey banded gneisses by the injection of granitic material along the planes of schistosity of the pre-existing rocks, attended, later on, by the injection of more mobile granitic solutions which, by intimate penetration into the pre-existing rocks and grey gneisses, rendered the latter more plastic. This plastic mass has been further rendered gneissose, and become folded due to the deformational forces, to give them the appearance of migmatites. The mobility of these late stage granitic solution is probably due to the concentration of volatiles.
The pink colour of the pink banded gneisses is due to pink feldspar present in it; and elsewhere Suryanarayar in connection with the study of porphyritic granites of closepet, and other workers in other parts of the world, alluded to these pink feldspars as growing as porphyrobl at the late stages of the evolution of these rocks. There is always a close relationship between the contorted gneissic bands and the pink feldspars present in them. The two are closely associated, their formation at a later stage is conveniently deciphered. Further, the pink colour may be attributed to the impregnation of the feldspar by some pigment carried by the late stage volatiles which abode in the feldspars. It can, therefore, be inferred that contorted folding, formation of pink feldspars, and the activity of the volatiles are closely associated, that at late stages.

Considering the dark and light bands proper, the light bands are seen cutting across the dark ones by taking a sudden deviation in their trend. The dark bands are therefore considered to be older.

The dark patches and bands of amphibolitic character are seen in all stages of transformation. At one extreme, we find lenticles of uncontaminated amphibolite enveloped within a granitic mass of homogeneous texture. Next, the amphibolites are seen cut-up into shreds, streaks and patches, drawn out in the granitic envelope. Where the amphibolites are schistose, the granitic material has
insinuated along the schistose planes to form gneisses where the banding is rather crude, irregular and contorted. A more thorough injection and intimate penetration, at the other extreme, has given rise to gneissic granites and granites. Thus all gradations can be seen from homogeneous granites through gneissic granites, granitic gneisses, banded gneisses, to amphibolites.

The detailed field and textural study by Raja (1959) on Hyderabad granites has led him to consider the grey granites to have formed by granitisation of older Dharwars now represented by hornblende schists. The pink granites, according to him, are supposed to have formed from grey granites by a later potash metasomatism. But Janardhan Rao (1963) in his studies on the Hyderabad granites argues that there may not be any age difference between the grey and pink granites, that the colour of the feldspar should not be taken as a criterion in determining their relative ages, that the difference in colour of the two granites could be due to difference in the parent material which were subjected to the process of granitisation, and that the grey granites could have resulted from one type of sediment and the pink granite from the other.

It is difficult to lend credence to Janardhan Rao's views that grey and pink granites have formed by metasomatic alteration of different parent materials. The process here visualised (for the rocks of the thesis area) is a continuous one, starting with the parent material, which is amphibolitic,
or any other metamorphosed rock, and its conversion at various stages into grey and pink gneisses. Since the pink granites are next to grey granites in their formation, they are younger in their age. This view is in agreement with Raja's view, though the present author does not subscribe to the potassic metasomatism of grey granites.

**Gneissic granite and granitic gneiss**

Since the gneissic granite is more abundant than the granitic gneiss, the latter is included under the former and described as such. These two types are generally biotite and/or hornblende-bearing rocks, granitic in character. The gneissosity is discontinuous, because of the streaky, curly, whorled, and contorted character of the individual mineral layers. The rocks are generally medium-grained, and at some places potash feldspar, which is microcline perthite, is seen as porphyroblasts within these rocks. They are traversed by aplitic- and pegmatitic-veins. These veins may sometimes follow the direction of gneissosity. Quartz veins, though, noticed are not common. Demarcation between these two rock types and the banded gneiss in the field is not possible as these varieties are seen intermingled with each other, one often grading into the other.

**Gritty granites**

Gritty granites usually occur at the lower levels of the area (Fig.63.A). They are seen mostly in the nalla-courses. They may contain very little amounts of mafic
minerals, which, where present, is mostly biotite. Texturally they are medium- to coarse-grained rocks, composed essentially of quartz and feldspar. Feldspar sometimes occurs as porphyroblasts, attaining a size of about 6 inches (Fig. 63.B).

**Leucogranite**

This is a medium- to coarse-grained rock, white in colour, composed essentially of feldspar (microcline and/ or plagioclase), quartz, and devoid of mafic minerals. The rock occurs in the field as isolated patches, bouldery in nature, and gritty in their character. At some places, these rocks carry few grains of garnet sprinkled in the rock here and there.

**Garnetiferous granite**

This is a medium-grained rock, varying occasionally to coarser one. The colour of the rock varies from pink to pinkish-white. The rock is seen studded with pink garnets as a result of which it presents a spotted appearance. Biotite is seen occasionally in smaller quantities. This rock is seen associated with leucogranite, garnetiferous-sillimanite quartzite, and kodamite.

**Structural Features:**

The structure of the area is simple, which is rather unexpected of the rocks of the archaean terrain. A general glance at the geological map herein produced reveals that the rock types of the area do not show much variation in
their strike direction. The various types of Peninsular gneiss show a general strike direction varying between N.N.W and N.N.E. The dip is generally eastwards, the angle of the dip varying from 25° to 80°. The folded structure of the area is referred to in page No.13, under chapter II on geological setting of the area. It should be emphasised that the folded structure of the area is essentially dependent upon the attitude shown by the Peninsular gneiss in its strike and dip trend, and from this the anticlinal and synclinal structure has been inferred. The other high grade metamorphic rocks like, quartz-magnetite rocks, cordierite-bearing rocks, charnockitic rocks, and garnetiferous-sillimanite quartzite occupy the right limb of the anticline or the left limb of the syncline and so they dip eastwards. The dip and strike of these rock formations is concordant with that of the general strike direction of the Peninsular gneiss. From this fact, it will be clear that the Peninsular gneissic rocks were formed by the injection of granitic liquids along the bedding planes or the planes of schistosity of the pre-existing rocks.

**Foliation**

The gneissic bands have a planar disposition and hence exhibit a foliated structure. The foliation planes have the same strike and dip as the rock itself. The foliation planes, here and there, are contorted and show
wide variation in strike and dip directions, discordant with their main trend. Fig.64 is the stereographic projection of the poles of about 200 foliation planes plotted on the lower hemisphere. There is one strongly developed maximum to the west indicating that the majority of the foliation planes dip towards east.

Lineation was not observed anywhere in the Peninsular gneiss. This is probably because of the absence of any linear elements in the rocks. Caught-up patches of hornblende schists do have hornblende rods; but because of paucity of exposures parallel to the foliation planes, the trend and plunge of lineation could not be determined.

**Joints**

Joints of any particular type are not prominently developed anywhere in the area. They are few and sparse, and their relationship with the other structural elements lies in obscurity, though some of them are parallel to the foliation planes, and others perpendicular to it, as is often to be expected.

Sparse as they are, the following grouping can nevertheless be made:

1. Joints parallel to the foliation planes,
2. Joints perpendicular to the foliation planes,
3. Diagonal joints lying in between the above two sets.

The joints parallel to the foliation planes may be considered as the longitudinal joints, and those perpendicular to it as cross joints. The geologists are familiar
with this classification of joints and the interpretation of them is too well known to everyone. The present writer, however, has not made any attempt at a detailed study and interpretation of these joints, firstly, because of their sparse development and, secondly, because of the absence of the linear fabric with which they bear a better genetic relationship. The paucity of joints may be ascribed to other reasons also. The dominant rock type which is the Peninsular gneiss, with a general N-S trend, and with little structural discordance, indicates a situation of quiet development formed by the injection of the granitic liquid along the planes of schistosity and the bedding-planes of the country rocks. The process here is one of injection and alteration of country rocks by metasomatic-metamorphism on a regional scale, resulting in the formation of Peninsular gneiss. No forcible intrusion of rocks of enormous dimensions is evident here. No analysis of granite tectonics as enunciated by Cloos (Cloos' works are summarised by Robert Balk, 1948), therefore, can be made here, as his analysis is done only in respect of those bodies of rocks where there is always a dependable relation between the movement of the individual blocks in the earth's crust and their internal structure. The structural features of igneous rocks, according to Cloos differ from those of non-igneous rocks in that the rupture phenomena is closely associated with flow structure in igneous rocks.
In the rocks under discussion, ruptures and flow structures are inconspicuous because of their non-igneous character. This is the reason for the scarcity of joints in the area; and hence they are of little value either in the structural framework or in their interpretation.

Joints are often filled-up by pegmatitic, quartzose, feldspathic, and plutonic veins. They occur filling up longitudinal, cross, and diagonal joints.

Shear planes

The shear planes are common in the banded and granitic-gneisses (Fig. 65). They traverse the planes of foliation of the gneiss. They trend in such a way that they often make an angle of 30° to 40° with the strike of foliation of the gneisses wherever they occur (Fig. 65). Usually these shear planes occur in groups, each not more than 1 to 5 feet in length. The gneissic bands are sheared along the shear planes along which they are slightly shifted with a drag effect. The convex side of these drag folds, near the shear planes, points towards the direction of relative motion.

Conclusion

The general northerly strike and the easterly dip of the foliation indicates that the regional tectonic forces must have operated from the eastern direction towards west during the injection of granitic liquids giving a northerly strike to the flow layers with an easterly dip.
It is significant to note that the Peninsular gneiss has its structure concordant with that of the shear-wrks suggesting that the Peninsular gneiss imparted the structures that were prevalent in the shear-wrks. Some of the joints have been filled-up by pegmatites, quartz veins, feldspathic- and mafitic-veins during the late stages of the evolution of Peninsular gneiss. Shear fractures were developed in the late or even in the post-crystalline stages due to the deformational forces that continued even after the crystallization. The shear zones are the loci along which the frictional movements have taken place during the evolution of Peninsular gneiss.

PETROGRAPHY:

For the purpose of petrographic description, the various types of Peninsular gneiss have been grouped under the following three heads;

1. Gneisses
2. Granites
3. Dioritic rocks.

Gneisses include banded gneisses, granite gneisses, gneissic granites; granites include gritty granites, leucogranites, garnetiferous granite and medium- to fine grained pink granites.

Since the former two groups, viz, gneisses and granites, vary widely in their potash feldspar and plagioclase feldspar content, they have been classified into various types based
on the ratio of potash feldspar to total feldspar in them.

This type of compositional classification is similar to the several published systems (126). Boundaries between the fields of different granitic rocks are in terms of the ratio of potash feldspar (including perthite) to total feldspar as follows: quartz-diorite, 0 to 10%; granodiorite, 10% to 35%; quartz-monzonites, 35% to 65%; and granite, more than 65% (Jentzen, 1961). According to this classification, the granitic rocks contain at least 10% of quartz.

**Gneisses**

These are fine- to medium-grained rocks, the colour of which varies from pink to grey. The pink colour of the rock is mainly dependent upon the pink feldspar present in it. It has already been pointed out that the gneissosity is due to the different lithological units arranged in parallel bands.

The typical texture shown is hypidiomorphic granular to allotriomorphic granular. The gneissic habit is due to the presence of biotite and/or hornblende which show parallel to sub-parallel arrangement of their longer axes. Kyrmekitic and perthitic textures are common.

According to the compositional (modal) classification stated already, the gneisses can be resolved into the following petrographic types based on the ratio of potash feldspar to total feldspar in them.

1. Biotite-granite gneiss.
FIG. 66
System of classification of granite rocks
(Bateman, 1961)
2. Biotite-rhomaphillite granite.
5. Biotite-hornblende-granite granite.

Table 10.28 gives the modes for the above rock types.

Quartz occurs scartely. Indolose extinction is characteristic of all grains. The cleatic effect in quartz are marked at its margins.

Potash feldspar is either microcline or microcline perthite. The mineral occurs in equant grains found in association with plagioclase and quartz. The grains commonly exhibit grating. The mineral grains show alteration, which is sometimes intense, to sericite or kaolin.

Plagioclase occurs as sub-hedral or sub-rounded grains. A few plagioclase grains show alteration along their twin lamellae. Many of the plagioclase grains are untwinned.

Biotite is the usually dominant ferromagnesian mineral. It occurs in clusters and clots in association with hornblende (when it is present) and magnetite. The mineral occurs as elongated flakes and streaks with frayed margins. It often occurs wrapping the plagioclase grains. It is pleochroic with $N_x$=yellow; and $N_y=N_z$=dark brown.

Hornblende occurs elongated, prismatic grains with their longer axes generally paralleling the gneissosity.
of the rock. They are associated with biotite. Alteration of hornblende to biotite is clear here, as hornblende is seen to pass gradually along its borders to biotite. It is pleochroic with $X=$light yellow; $Y=$yellowish green; and $Z=$dark yellowish green.

Accessories include apatite, magnetite, epidote and rarely sphene.

Granites

Except for the fine-grained pink granite, all the other varieties (viz, gritty granite, leucogranite, garnetiferous granite and medium-grained pink granite) are medium- to coarse-grained rocks. Gritty granites and leucogranites are normally coarse-grained rocks.

The rocks are essentially composed of quartz and feldspars. On the basis of the compositional classification, already referred to in page Nos. 104 and 105, the granites can be classified into the following three types:

1. Granite
2. Adamellite
3. Tonalite.

Quartz occurs generally as bigger grains, showing sutured borders and characterised by undulose extinction. The potash feldspar is microcline or microcline perthite. Plagioclase feldspar, which is subordinate in granites and abundant in adamellites and tonelites, occurs mostly
as irregular grains. A few of the grains are anhedral in outline. Twinning in plagioclase is not prominent and many of the grains are untwinned. Antiperthites are noticed. Few grains show alteration to sericite. Table No.28 gives the modes for the three types of granites.

**Dioritic rocks**

These rocks occur as caught-up patches, or as dark lenticular clots, or as irregular bands in the Peninsular gneiss. They are similar in shape to basic clots of amphibolites, or basic charnockitic rocks. The banded gneisses may also contain these dioritic rocks as their individual bands. These dioritic dark grey bands may alternate with lighter material of granitic character to give rise to banded appearance. Similar occurrence of dioritic patches in closepet granite was also recorded by Suryanarayana (1959). By digestion and alteration (biotitisation and feldspathisation), the basic clots have passed into more acidic dioritic and quartz-dioritic rocks, retaining their original shape.

Apart from the above type of occurrence of dioritic rocks, a mappable unit is seen near Vanderguppe. Here, the dioritic rock contains garnet as an additional mineral.

In the field, gradation between an ordinary granite to diorite, and diorite to amphibolite can be traced out. The study of thin sections of dark dioritic patches reveals the
paucity of potash feldspar and quartz and the concomitant abundance of plagioclase, hornblende and biotite, with augite and garnet as additional minerals. Table No. 28 gives the mode of the dioritic rock.

In thin sections, the rock is medium-grained exhibiting gneissose, equigranular texture. Banding can be also seen where biotite and hornblende tend to occur in parallel to sub-parallel layers. The constituent minerals are plagioclase, biotite, hornblende, augite, and sometimes garnet. Apatite and magnetite occur as accessories. Minor amounts of quartz and K-feldspar may be present in certain cases.

Plagioclase occurs as irregular but sub-rounded grains. Majority of the grains are untwinned. It is twinned mostly after albite–ala law and albite law. In some cases the twin lamellae are seen bent. The margins of plagioclase are surrounded by biotite and magnetite. Plagioclase shows slight alteration to sericite and epidote. There are apatite inclusions in plagioclase, the apatite being colourless, fresh and rectilinear. The anorthite content of plagioclase is 28% to 35%.

Biotite is yellowish to reddish brown in colour. It wraps round the feldspar grains tightly. Biotite occurs with hornblende in varying proportions, but usually both are present more or less in equal amounts. At a few places, hornblende appears to give rise to biotite by alteration, as gradual passage from hornblende to biotite is seen.
Hornblender shows pleochroism from yellowish green to green.

The pyroxene present is augite, which occurs as colourless, irregular plates, showing one set of \((110)\) cleavages. \(2V=56^\circ\) to \(58^\circ(+ve)\). In some places it has given rise to hornblende, and hornblende thus formed by alteration is pale green in colour.

**MINERALOGY:**

**Quartz**

Quartz, an essential and important constituent of the granitic rocks of the Peninsular gneiss, generally occupies the interspaces between the minerals, and hence occurs as irregular grains. Occasionally the grains in some gneissic rocks are elongated, the direction of elongation being parallel to the mineralogical banding observed in them. The boundaries of quartz may be smooth or sutured, as is observed in coarse-grained rocks.

The quartz grains show evidences of crushing between crossed nicols. A big grain of quartz is seen often passing gradually at its borders to small crushed granules, each having a highly irregular and intricate margin.

The mineral is characterised by undulose extinction, which is mainly a strain effect. The undulose extinction may be wavy, in that, the extinction may appear as a dark band brushing from one side to the other in the grain as the stage of the microscope is rotated. In the other case,
the undulose extinction is irregular, in that, the
different parts of the same grain shows unequal illumina-
tion and extinction. These are the characteristic features
of the quartz subjected to strain. Prasad (1967) has divided
the different patterns of undulose extinction into two
categories, viz, continuous and discontinuous. He is of
the opinion that this feature of undulose extinction is a
strain effect and a mechanical feature that depends upon
the microfabric of a rock as a whole.

Quartz is usually clear and devoid of any inclusions.
It usually occurs in the rocks as discrete grains associated
with feldspar, and occasionally it is found as rounded grains
included in either plagioclase or microcline (Fig.67.A & B).
From the given two modes of occurrence of quartz, it will
be clear that quartz in Peninsular gneiss belongs to two
generations, the older occurring as rounded grains within
feldspar and the later as separate discrete grains in
contact with feldspars.

**Plagioclase feldspar**

There is often some difficulty encountered in
distinguishing the untwinned plagioclase from the potash
feldspar which is also sometimes untwinned. The following
are the important features by which an untwinned plagioclase
can be distinguished from the untwinned potash feldspar:
1) Potash feldspar, twinned or untwinned, shows distinct
cleavage lines parallel to (001) plane. Such grains can be
essily identified as microclines when the poles of the cleavages are verified on the Nikitin's stereogram. The poles of the cleavages present in the mineral fall near $M(001)$ (Fig. 68), 2) Untwinned plagioclases are devoid of any cleavages, and they sometimes show antiperthitic blebs. These blebs are parallel to $(010)$. 3) The degree of alteration is more in potash feldspar when compared with the plagioclase. 4) The staining test applied on thin sections revealed the presence of potash feldspar which develops yellow colouration while the plagioclase remains as it is.

Anorthite content of plagioclase varies from 20% to 30% in granitic rocks and from 28% to 35% in dioritic rocks. It is clear that the plagioclase of the granitic rocks of the Peninsular gneiss is essentially an oligoclase. Fig. 69 is the cumulative diagram of the poles of the composition planes of a number of plagioclase grains in granitic rocks. The diagram shows concentration of points between 20% and 30%. The poles of these composition planes form a band as noticed by Monolescu (1934).

The 2V values vary from $82^\circ$ to $86^\circ$ with a negative sign. The 2V values determined for the plagioclase are compared with the values read from Kohler's graph (1941) for the corresponding anorthite content. The comparative values are given in Table No. 29. These values are in close agreement.
## TABLE No. 29

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<th>An. content $%$</th>
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Tertsch (1942) has made a distinction between the high and low temperature optics of the feldspars and has constructed a stereogram on (010) with the wandering of $X$, $Y$, and $Z$ ellipsoidal axes for the various anorthite content values. The curves are distinguished as high and low temperature curves. The transferred poles of the ellipsoidal axes of the feldspars when plotted on this Tertsch diagram, fall on the low temperature curves. The feldspars of the granitic rocks of the Peninsular gneiss belong to the low temperature series (Fig.70).

One of the characteristic features of the plagioclases of the Peninsular gneiss is that about 90% of them are untwinned. A closer examination of the plagioclases reveals that generally the twinned grains are bigger in size than the associated untwinned ones. In some grains the twinning is not well defined, and in this case the composition planes are not sharp even after they are made parallel to the axis of the microscope. The twin lamellae, which rarely reach the other end of the grain, may either be straight, broken or curved. Some of the important patterns of twinning in plagioclase of Peninsular gneiss are illustrated in Fig.71.

Donnay (1943) regards the discontinuous and curved lamellae as characteristic of metamorphic and hybrid rocks. Kohler (1948) regards such a poor development of lamellae as characteristic of feldspars formed at low temperature.
As in most of the cases the twin loreles of the plagioclase are indistinct, thin in width, and closely spaced, some difficulty was experienced in the determination of twin laws. From about 30 thin sections, twin laws for 87 grains were determined. The frequency of each twin law is shown in the Table No.30. It is rather difficult to distinguish between albite-ala B and albite law in plagioclase of 23\% to 30\% of anorthite content, but the conflict was resolved by Coulson's (1931) check, and Nikitin's construction.

From the Table No.30 it is evident that albite-ala B is predominant(47), while the albite law(25) comes next in abundance. The other laws such as ala, carlsbad, albite-carlsbad, manebech-ecline, and manebech-ala laws are subordinate.

There has been some difference of opinion regarding the incidence of albite-ala B in plagioclases of different composition. Coulson (1931) from his study concluded that albite-ala B law frequently occurs in plagioclase of composition 33\% An. content. But in the plagioclase of the Peninsular gneiss of the thesis area, albite-ala B law is observed more commonly in plagioclase of composition 23\% to 29\% An.content. Naidu (1950), Raghavan (1954), Ramanathan (1954), and Suryanarayana (1959) have recorded the frequency of albite-ala B in plagioclase of composition 22\% to 29\% An. content.

The Tertsch (1942) values, which are the angles
measured between the line poles of the optical ellipsoids of the two individuals of the twin were determined for the plagioclase under discussion. For the albite 1 w the values \( a' \) and \( a'' \) are shown in Table 8.3. There is a close agreement between the values determined for the various twin laws for the plagioclase feldspars of Peninsular gneiss and the Tertsch values. It is evident from this that the feldspars of the rocks of Peninsular gneiss belong to the low temperature optics of Tertsch, suggestive of their metamorphic origin.

Similarly, Kohler (quoted by Reynolds, 1952) by measuring the angles between \( \gamma \), \( \beta', \alpha, \) and \( AA' \) and \( AB' \) demonstrated the difference in the optical orientation between the volcanic plagioclases, on the one hand, and the plutonic and metamorphic plagioclases, on the other. Kohler attributes the difference in optics to a difference in the crystallization temperatures, contrasting the known high temperature of crystallization of plagioclase of volcanic rocks with the inferred low temperature crystallization of plagioclase in plutonic and metamorphic rocks.

Gorei (1951) and Turner (1951) have made a statistical study of the twin laws of plagioclases of both igneous and metamorphic rocks. They pointed out that the untwinned crystals of plagioclases are more common than the twinned crystals in metamorphic rocks. Suwa (1956), in the light of his own work, critically examined the findings of Turner (1951),
<table>
<thead>
<tr>
<th>Twin law</th>
<th>An.%</th>
<th>Values measured</th>
<th>Tertsch values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$a a'$</td>
<td>$r r'$</td>
</tr>
<tr>
<td>Albite law</td>
<td>21</td>
<td>177</td>
<td>178</td>
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<td>22</td>
<td>178 2</td>
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<td>178 15</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>179 15</td>
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</tr>
<tr>
<td></td>
<td>27</td>
<td>178 19</td>
<td>178 19</td>
</tr>
</tbody>
</table>
Gorsi (1951) and others regarding the mode of the origin and frequencies of twin laws in plagioclase. He prepared a trilinear diagram delineating the fields of igneous and metamorphic plagioclases. For this purpose, Suwa clubbed the different twin laws under the following three groups, the three occupying the three corners of the triangular diagram:

1. Albite + pericline laws.
3. Carlsbad + ala + albite carlsbad.

The frequency of incidence of the laws of the three groups is expressed in percentage and the values for the same are 28.74, 63.22 and 8.04 respectively.

When the above values are plotted in the Suwa diagram (Fig.72) the plot falls within the metamorphic field.

The preponderance of untwinned plagioclases over the twinned ones and the abundance of A-twins of Gorsi (1951) indicate the metamorphic origin of the rocks. This is also quite clear from the Suwa diagram. The rarity of twins, such as, carlsbad and albite-carlsbad (characteristic of igneous rocks) in the plagioclases under discussion is in favour of ascribing a metamorphic origin to the Peninsular gneiss. Tertsch values, calculated for the albite law, suggest that the feldspars belong to the low temperature optics of Tertsch. Reynolds (1952) concludes, "The fact that the metamorphic plagioclase is of the low type..."
FIG. 72
© Plot of the values of twin laws of Plagioclases of peninsular gneiss.
suggests that the fundamental difference between high and low plagioclase is that whereas the high variety crystallises from a melt low plagioclase grows by replacement in solid rocks, even in schists. The complex albite-als B, which Goral (1951) has not observed in the plagioclases of metamorphic rocks, and which has been observed in the plagioclases of Peninsular gneiss, appears to be as characteristic of metamorphic granites and gneisses as albite and pericline laws.

Potash feldspars

In the study and discussion of granites, greater emphasis is now being placed on the nature of the potash feldspars. Of the two types of feldspars, orthoclase and microcline, which are the chief constituents of granites, potash feldspars of orthoclase type are found to be absent in the Peninsular gneiss, but potash feldspars of the microcline type are present, and these microclines are usually perthitic.

On the basis of experimental proof, orthoclase, microcline, and perthite are now regarded as different modifications of potash feldspars, containing a small amount of soda dissolved in it. The different forms assumed by these minerals are only functions of temperature, orthoclase being stable at high temperature, perthite at low temperature, and the intermediate form, microcline, occupying a position in between orthoclase and perthite in
regard to its temperature of formation. The occurrence of potash feldspars in any of those three modifications in granites gives an indication as to the temperature of formation of these granites and, to a certain extent, their genetic history.

Most of the microcline and microcline perthite grains show typical cross-hatched twinning. They usually show distinct cleavages parallel to (001), and the identification of the mineral as microcline in all these cases is established on the Universal Stage, making use of the Nikitin's stereogram (Fig. 68).

2V varies from 82° to 86°, with a negative optic sign. Alteration seems to be common for microcline and microcline perthite, the alteration product being either sericite or kaolin. Some microcline perthite have inclusions of plagioclase grains which are unoriented (Fig. 73.A). Microcline blebs also occur as islands within the plagioclase (antiperthite). Myrmekites are also noticed at the borders between plagioclase and microcline.

Grating or cross-hatched twinning in microcline: Though a few grains of microcline are untwinned, most of the grains are twinned showing the typical cross-hatching (Fig. 73.B). The grating differs in coarseness in the same grain at different portions. A combination of both fine and coarse grating in a single grain is common. The whole area of microcline may be characterised by grating or a portion of it may lack the characteristic grating (Fig. 73.C).
Higazy (1949) has also observed the difference in coarseness of microcline grating in the perthites of pegmatites in the Black Hills, South Dakota.

The grating in the microcline is due to the development of albite and pericline twin lamellae, closely interwoven; and when they are viewed between crossed nicols in a direction approximately parallel to both the composition planes, the typical cross-hatched pattern is seen.

Regarding the origin of the microcline structure, most writers emphasise the importance of the influence of stress or the dynamic force in its development. Harker (1909) points out that "the conversion of orthoclase to microcline, or the setting up of the microcline structure in orthoclase, has been attributed to dynamic causes".

Kohler (1949) found that the change to microcline form is aided by tectonic forces which, with increased intensity, increases the coarseness of the exsolution albite and produces microcline grating.

Prasad (1967) has referred to the cross-hatched twinning in microcline and he concluded that twinning in microcline is mostly a mechanical feature and a reflection on the crystals environmental history. He presumed the microcline twinning to be one of the different imperfections which have been referred to as thermodynamically unstable imperfection. It is suggested by him that the continued deformational forces,
which in initial stages induce twinning, are also responsible for the subsequent untwinned microcline.

Gratia, structure in the microcline of the Peninsular gneiss can also be attributed to the dynamic pressure to which the Peninsular gneisses were subjected during their formation. The pressure effects are quite evident from the occurrence of undulant and granular quartz, the curved nature of the albite twin lamellae in the associated plagioclases, and the bent and broken nature of the biotite flakes. In the field, the role of pressure during the evolution of the granitic rocks of the area is indicated by the folding and contortion of the gneissic banding, and by the shear planes.

**Microcline perthite:** The perthitic lamellae in microclines reveal themselves on the Universal Stage, when rotated on one of the horizontal axes. The (010) sections show fine longitudinal lamellae and sharp (001) cleavages. The poles of the lamellae, plotted on the Nikitin's stereogram, fall near M(15.0.2) indicating that the perthitic lamellae are parallel to (15.0.2), or murchisonite cleavage. Some points also fall near M(100) showing that they are parallel to (100) also (Fig.74). The angle between the cleavages and the perthitic lamellae are measured and this varies from 70° to 78°, the most common angles being 74°.

Perthites have been classified in various ways.
A nomenclature to describe the habit and the appearance of microperthites and perthites was proposed by Alling (1938). A classification according to the modes of formation, unit shapes, and other morphological features has been proposed by Rudenko (1954). Uttle (1952) put forward a genetic classification of perthites, based on the size of the exsolved phase in which various types are correlated with decreasing temperature of formation and increasing time, subsequent to the homogeneous feldspars.

In the classification of perthites from the granitic rocks of the thesis area, Alling's classification is followed. According to this classification, the perthites under discussion fall under the rod, stringlet, string, bead, vein, and patch perthites (Fig.75).

The disposition and the distribution of the different perthites is very interesting. The strings, or stringlets, may either occupy the central portion of the grain or the whole of the grain, leaving the margin clear. The rods, strings, or stringlets may be few in number or may be numerous in the grain. In some cases, a single grain of microcline may show gradation in the perthites, from stringlets to patch perthites (Fig.75.A). Sometimes two sets of perthitic lamellae, interpenetrating each other, are also seen in a single microcline grain. The rods, veins and patch perthites are observed cutting across the boundaries of the grain.
The rence in the size of the different types of perthites is given in Table 0.32, together with the values as given by Alling (1938) for the corresponding type of perthite, for comparison.

The origin of perthites has been discussed by workers such as Anderson (1928); Alling (1938); Higazy (1949); Evans (1953); Gates (1953); Heir (1956); Suryanarayana (1959); Gates and Scheerer (1963); Smithson (1965); and Hibbard (1965).

Three processes—unmixing, simultaneous crystallization, and replacement—are now generally accepted for the formation of perthites. The perthites are considered to have formed by one or the other of the three processes.

Petrographic features of perthites observed, such as, 1) the uniform orientation of some blebs concentrated at the centre of the grains, 2) the occurrence of vein and patch perthites, and 3) the cross-cutting relationship exhibited by some of the rods and strings, suggest that no one process is solely responsible for the formation of perthites in Peninsular gneiss. The two processes, viz, unmixing and replacement are found to be responsible for the formation of perthites within the Peninsular gneiss. These two processes are now considered.

There are microcline perthites presenting characters of those formed by exsolution. These perthites are seen
<table>
<thead>
<tr>
<th>Term</th>
<th>Length in mm.</th>
<th>Width in mm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stringlet</td>
<td>0.011 - 0.017</td>
<td>0.007 - 0.009</td>
</tr>
<tr>
<td>String</td>
<td>0.035 - 0.150</td>
<td>0.01 - 0.02</td>
</tr>
<tr>
<td>Rods</td>
<td>0.105 - 0.350</td>
<td>0.017 - 0.04</td>
</tr>
<tr>
<td>Vein</td>
<td>0.20 - 0.80</td>
<td>0.08 - 0.10</td>
</tr>
<tr>
<td>Flakes</td>
<td>0.10 - 0.30</td>
<td>0.08 - 0.20</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Term</th>
<th>Length in mm.</th>
<th>Width in mm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stringlet</td>
<td>0.01</td>
<td>0.00075</td>
</tr>
<tr>
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<td>0.0075 - 0.0225</td>
<td>0.00025 - 0.0012</td>
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<tr>
<td>String</td>
<td>0.06</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>0.02 - 0.09</td>
<td>0.0075 - 0.0175</td>
</tr>
<tr>
<td>Rods and bead</td>
<td>0.08</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>0.02 - 0.30</td>
<td>0.01 - 0.05</td>
</tr>
</tbody>
</table>
concentrated in the outer portion of the grain, leaving the inner clear. The perthites are either stringlets, or rods, having always definite and uniform crystallographic orientation and showing no cross-cutting relationship with the boundaries of the grain.

Thermal experiments conducted by Kozu, Endo (quoted by Yamons and others, 1953, 56-57) and Spencer (1937, 1938) suggest that orthoclase inverts to microcline when the temperature falls from 750°C to 500°C. The inversion is simultaneous, accompanied by the separation of sodic component dissolved in orthoclase (which is stable at higher temperatures) to form perthitic texture, along with the development of fine grating in microcline. Further, the exsolation of the sodic component to form perthitic plagioclase lamellae is possible under slow cooling.

The microcline and microcline perthite of the granitic rocks of Peninsular gneiss are characterised by optic axial angle 82° to 84°, which is characteristic of low temperature microclines. Further, the absence of any orthoclase grain, the presence of some untwinned microcline grains, the range in 2V of potash feldspar from 82° to 84°, and a slight dispersion of the poles of the cleavages (001) in microclines towards (001)0, suggest that the microcline and microcline perthite might have formed at temperatures above 500°C but definitely below 750°C— the exsolution temperature as fixed by Spencer. The regularity in the orientation of these
perthites and in absence of any cross-cutting relationship, suggest that the perthites are formed due to exsolution. The sod component for the formation of these perthites is derived from the sod component present in solid solution within the potassium feldspar at high temperature. The sod component thus exsolved occurs as fine lamellar growth in the host microcline.

Some of the string's, rod, and bead perthites and the frequently occurring patch and vein perthites present characteristics of those formed by replacement.

It is only with Anderson's work (1928) that the replacement process for the formation of perthites has received a serious consideration. Anderson points out "that a process involving crystallization produced by circulating solutions in contraction cracks...... has played an important part in the formation of all ordinary perthites of the granite pegmatites". The replacement origin of the perthite is given mainly based on the investigation of pegmatite perthites, myrmekite, and graphic granites.

Some of the string and rod perthites are seen cutting the border of the grain. The patch and vein perthites (Fig. 75. C and D) are irregular in shape varying widely in their sizes, and having no preferred orientation. They cut the margin of the host suggesting derivation from an outside source. In some places, the vein perthites are seen
cutsin, across the uniformly oriented blebs and thus are considered to be later than the exsolution perthites. Similar vein and patch perthites have been noticed by Higazy (1949) in the perthites of Black Hills, South Dakota. He has noticed the intricate net works of arborescent and Anastomosing veins which gradually grade into the patch type. Higazy ascribes a replacement origin for these perthites by a metasomatic process. According to him, in the early stages, albite material circulating in the rocks followed a certain preferred direction in the atomic structure of the feldspars forming the regularity in the trend of these strings and films. By further diffusion, veins were formed. The vein and patch perthites in the granitic rocks of Peninsular gneiss of the thesis area are considered to have resulted from a replacement origin.

From the foregoing discussion, it is quite clear that the microcline perthites of the granitic rocks of the area are of two types differing in their origin. Perthites of both exsolution origin and replacement origin are present. The source material for the perthites of exsolution origin is purely local and is derived from the potash feldspar in which is present the soda component as an immiscible phase. The soda component present in the potash feldspar at high temperature has exsolved due to the fall in temperature, thus resulting in the perthites. These
exsolution pertnites are contemporaneous with the formation of microcline itself and hence their formation is associated with pressure.

Gates (1953) has emphasized the role of differential pressure in the development of pertnites and he has observed an increased development of pertnites in zones of intense fracturing.

The other variety of pertnite, which is due to the replacement process, is considered to be younger than the exsolution pertnite, as the blebs cut through the margin of the host. The source material for this is from outside i.e. from the circulating soda solutions which were active during the evolution of Peninsular gneiss.

**Myrmekite:** Myrmekitic textures (Fig. 76 A & B) are commonly noticed in the granitic rocks of the thesis area, where quartz occurs either in the form of vermicules, or rods, or droplets, inside the plagioclase grains. The general features of myrmekites observed are in conformity with those observed by Becke (1908) and Sederholm (1916). The following are the important features of the myrmekites that are observed in the granitic rocks of the Peninsular gneiss:

1. Myrmekites are commonly found at the junctions of the two minerals, viz, microcline and plagioclase, or quartz and microcline. The occurrence of myrmekite at the border between microcline and quartz
is rare when compared with the other variety.

2. Myrmekites occur as wart-like portuberances with convex surface projecting into microcline or microcline perthites.

3. In some cases myrmekite is also seen as small grains included in microcline (Fig. 76 B).

4. When a small plagioclase grain is in contact with a bigger grain of microcline it is completely myrmekitic, projecting towards microcline. When plagioclase occurs as a bigger grain in contact with microcline grain, only the convex margin of it is myrmekitic, and this myrmekite is found to grow out from a central core of quartz-free plagioclase invasively into microcline. The convex margin in microcline is the locus for the concentration of vermicular quartz, while the rest of the plagioclase grain is free of myrmekite.

5. In certain places where granular quartz, plagioclase, and microcline occur, myrmekite is not found either inside microcline or projecting into it.

6. Whenever the twinned grains show the development of myrmekite, the twin planes are seen bent and disturbed. The vermicules or rods of quartz are seen irregularly cutting across the twin lamellae.

7. Quartz, which is involved in the intergrowth, occurs in three forms, viz, as vermicules, rods, and droplets.

8. Sometimes quartz occurs as droplets along the margins, perforating the plagioclase.
9. The vermicules and rods are seen arranged irregularly or radially from a point.

10. The number of the vermicules, or rods, or droplets vary widely even within the same section. The number is not dependent upon the size of the myrmekite; a bigger myrmekitic grain may show only a few vermicules or rods of quartz, while a smaller myrmekitic grain may show more number of them. In general, myrmekites associated with bigger microcline grains show more quartz vermicules or rods.

11. The myrmekite is an acidic plagioclase which is normally an oligoclase.

Several theories have been presented to account for the occurrence of myrmekitic texture in granitic and other related rocks. The views of different workers regarding the origin of the myrmekites have been briefly summarised below.

According to Secke (1908) the potash in the orthoclase was replaced by soda and lime, which are present in the late magmatic solutions, the lime setting free the silica as quartz in the process.

Sederholm (1916) supported the view of Becke with the modification that the Skeletal crystals of plagioclase may be filled with quartz.

Tilley (1925) supports the view that potash feldspar will be replaced by plagioclase in the formation of myrmekite.
Reynolus (1943) is of the view that myrmekite originates when plagioclase is replaced by potash feldspar. Spencer (1945) does not support a replacement origin for the myrmekite, but considers that the intergrowth is due to the segregation of microperthitic albite originally present in solid solution in the potash feldspar.

According to Dreschler-Braden (1948), the solutions that are responsible for the formation of orthoclase corrode the plagioclase along "smekal defects". The solutions deposit silica, while the removed cations fill the empty spaces in the lattice of the plagioclase.

Osterwald (1955) has reported the occurrence of myrmekitic intergrowth that have resulted due to the replacement of albite plagioclase by potash feldspar, the silica required for this reaction being introduced during regional metamorphism.

According Suryanarayana (1959), the plagioclase fraction that has been exsolved during the formation of microcline or microcline perthites, attains mobility under the influence of differential pressure then prevalent and behaves like a fluid. The mobilised exsolved fraction has filled up the fractures in certain microcline phenocrysts to form vein perthites, while in other cases it has replaced the potash feldspar to form myrmekite.

Sarma and Raja (1959) suggested that the break down
of anorthite content of plagioclase and expulsion of Ca and Al, leaving behind quartz in relatively acidified plagioclase, results in the formation of perthites.

Janardhan Rao and Sudarsana Raju (1963) are of the view that the development of myrmekite is due to metasomatism and the quartz is introduced from outside.

Shelly (1964) proposed a new theory for the origin of the myrmekite which is believed to have formed by the incorporation of the recrystallising quartz in growing albite.

Based upon the petrographical features of the myrmekites, from the granitic rocks of the thesis area, described already and in the light of the different views on the origin of myrmekites put forward by several workers, the origin of the myrmekite is discussed here.

The theory as suggested by Sarma and Raju (1959) cannot be accepted here on the following grounds:

1. Myrmekitic plagioclases are not more acidic than that of the associated plagioclases.

2. No epidote or apatite is noticed in the neighbourhood of myrmekite.

3. All the characteristics of the myrmekites under discussion indicate that these myrmekites have formed by the replacement of potash feldspar by plagioclase.

The convex and the invasive character of the myrmekite
into microcline is an evidence in favour of the replacement of potash feldspar by plagioclase feldspar. But in some twinned plagioclase grains it appears that solution carrying silica has penetrated into the plagioclase grains resulting in the formation of rods. These rods and vermicules are seen cutting across the lamellae of the plagioclase.

The replacement process which is upheld by a number of workers, is expressed in the following reactions:

\[2\text{KAlSi}_3\text{O}_8 + \text{Na}_2\text{O} = 2\text{NaAlSi}_3\text{O}_8 + \text{K}_2\text{O}\]

\[2\text{KAlSi}_3\text{O}_8 + \text{CaO} = \text{CaAl}_2\text{Si}_2\text{O}_8 + \text{K}_2\text{O} + 4\text{SiO}_2\]

As anorthite would require a low percentage of silica for its formation this would release the equivalent of four molecules of silica; hence the quartz of the myrmekite, the more basic the plagioclase, the greater the quantity of quartz. K\text{2O} liberated goes to form shreds of biotite. The circulating soda solutions, which are active during the evolution of Peninsular gneiss have replaced potash feldspar, resulting in myrmekite.

**Antiperthite:** Some of the big plagioclase grains noticed are antiperthitic (Fig. 77. A & B). They are normally euhedral to sub-euhedral in outline, enclosing blebs of potash feldspar. Generally smaller grains of plagioclase do not have these blebs. The host grains show an content varying from 20% to 30%. 2V varies from 82° to 86°(-ve),
as in the case of those free from blebs. The twinning is predominantly on albite law. The blebs of microcline occur either as rectangular or square patches or as long rods (Fig. 77.B). They vary in size from 0.1 mm. to 0.4 mm. When the plagioclase feldspar shows twinning, these blebs are seen along the (010) composition plane. The number of blebs in an individual plagioclase grains varies widely.

Vogt's ratio (as quoted by Warren, 1915) for the eutectic composition of two crystal phases in cryptoperthites is Or 40% to 44% to (Ab+An) 60% to 56%. The ratios of the potash feldspar blebs to host does not correspond to the above ratio and as such cannot be regarded as eutectic mixtures.

According to Deer et al. (1963), the development of antiperthite is common in oligoclase and andesine as the oligoclase analyses showed a tendency for the potash feldspar molecule to increase. They state that the antiperthite development is considerably less common in albite and almost unknown in labradorite and more calcic plagioclases (Deer et al. 1963b). This finding is supported by the present occurrence. The host plagioclase is an oligoclase.

Sen (1959) believes that the potassium content of plagioclase depends less on the anorthite content than on formation and temperature, and availability of K; the
antiperthites have resulted from exsolution during cooling under appropriate conditions, the K otherwise going for sericite.

From what has been said so far, antiperthites from the granitic rocks under discussion have been considered to be of exsolution origin. The following are the important features that support the above contention:

1. Regularity in the orientation of the blebs which are parallel to (010).
2. The blebs occupy the central portions of the grains, leaving the margins clear.
3. The blebs are uniform in shape, either rectangular or rod-like in their appearance.

The source for the K is purely local and has been derived from the feldspar itself in which it is present in solid solution. On cooling, this has separated as potash feldspar blebs to give rise to antiperthites.

**Biotite**

Biotite has been separated from biotite-hornblende ademellite and chemically analysed. The chemical analysis, number of ions calculated on the basis of 24(0,OH) atoms, and optical properties are given in Table No.33.

Berman (1937, p.385) gives the formula for biotites on structural basis as,

\[ W(X,Y)_{2-3} Z_{4}O_{10} (0,OH,F)_{2} \]

where the ratio of
### Table No. 33

**Chemical analysis of biotite**

<table>
<thead>
<tr>
<th>Compound</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>TiO₂</td>
<td>3.43</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>16.41</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>2.07</td>
</tr>
<tr>
<td>FeO</td>
<td>16.92</td>
</tr>
<tr>
<td>MnO</td>
<td>0.30</td>
</tr>
<tr>
<td>CaO</td>
<td>0.20</td>
</tr>
<tr>
<td>Na₂O</td>
<td>1.21</td>
</tr>
<tr>
<td>K₂O</td>
<td>8.80</td>
</tr>
<tr>
<td>H₂O</td>
<td>3.10</td>
</tr>
<tr>
<td>H₂O</td>
<td>10.31</td>
</tr>
</tbody>
</table>

**Number of ions on the basis of 24(0,OH,F)**

<table>
<thead>
<tr>
<th>Ion</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>5.606</td>
</tr>
<tr>
<td>Al</td>
<td>2.394</td>
</tr>
<tr>
<td>Fe⁺³</td>
<td>30.236</td>
</tr>
<tr>
<td>Fe⁺²⁺Mn</td>
<td>37.49</td>
</tr>
<tr>
<td>Al³⁺</td>
<td>0.531</td>
</tr>
<tr>
<td>Ti</td>
<td>0.400</td>
</tr>
<tr>
<td>Fe⁺²⁺Ti</td>
<td>20.15</td>
</tr>
<tr>
<td>Mn</td>
<td>0.036</td>
</tr>
<tr>
<td>MgO</td>
<td>2.453</td>
</tr>
<tr>
<td>Ca</td>
<td>0.036</td>
</tr>
<tr>
<td>Na</td>
<td>0.345</td>
</tr>
<tr>
<td>K</td>
<td>1.708</td>
</tr>
<tr>
<td>OH</td>
<td>3.12</td>
</tr>
</tbody>
</table>

N<sub>y</sub> : 1.655

**Color scheme**

- X: Golden yellow
- Y = Z: Dark brown

**Analyst**: A. Kripandhi

*Biotite from biotite-hornblende adamellite near Singarajpur.*
Si:Al in Z is 5:3 to 7:1. Cast in this form, the formula of the biotite is:

\[(\text{Ca,Na,K})_{2.09} (\mu_-, \text{Fe}^3+, \text{Ti}, \text{Al}, \text{Fe}^{+2}, \text{Mn})_{5.79} (\text{Si,Al})_{8} 0.20.87 (\text{OH}, \text{F})_{3.13}\]

Heinrich (1946) has grouped several hundred analysed biotites and phlogopites into eight classes according to their geological occurrence. Their \(\text{Fe}_2\text{O}_3+\text{TiO}_2-\text{FeO}+\text{MnO}-\text{MgO}\) ratios are plotted by groups on triangular diagrams. Each group occupies a restricted field in the diagram indicating the fixed relationship between the chemical composition and the geological occurrence. Fig. 78 is the triangular diagram after Heinrich showing the fields of biotites present in 1) granites, quartz monzonites, and granodiorites and 2) in gneissess and schists. Overlapping of the two fields is evident from the diagram. The biotite analysed falls in that portion of the diagram where the two fields overlap.

Foster (1960) has pointed out that there is considerable overlap in the various rock groups designated by Heinrich, the field of biotite from 'granites' being an extended one and enclosing the field of biotites from tonalites and diorites. She commented on the loose usage of the term 'granite' to cover, for example, monzonite, diorite, quartz-diorite etc.

She proposed another triangular diagram based on the \(\text{Mg}^{2+}, (\text{Fe}^{2+}+\text{Mn}^{2+})\), and \((\text{octahedral } \text{Al}^{3+}+\text{Fe}^{3+}+\text{Ti}^{4+})\) values of
FIG. 78
Bitite from biotite/income/lamellite.
FIG. 79
biotites. When these values for the biotite under discussion are plotted in such a diagram (Fig.79) the plot falls in the field of granite biotites.

**Hornblende**

The analysis, number of ions calculated on a basis of 24(O,OH) atoms and optical properties of hornblende from biotite-hornblende-adamellite are presented in Table No.34. Berman (after Warren) (1937, p.354) gives the general formula of hornblende as,

\[
(w, x, y)_{7-8} (z_{4,011})_2 (o, oh, f)_{2-3}
\]

where \(w=Ca, Na, K\); \(x=Mg, Fe, \text{and} Al\) in part; \(y=Al, Fe, Ti\) and \(z=Si\) and \(Al\) in part.

The formula of the present hornblende according to Berman is

\[
(w, x, y)_{7.61} Z_{8 O 22.24} (o, oh, f)_{1.76}
\]

On plotting the chemical data of the hornblendes in the chemical variation diagrams of Deer et al. (1963a), it is shown that the analysed hornblende is a common hornblende (Fig.80.A & B).

Rosenzweig and Watson (1954) have discussed the effect of granitization process on hornblende. Since almost all the hornblendes contain alkalies, which can be present in variable amounts, it is conceived by them that the amount of potassium present should increase in hornblende which have been granitized. Rosenzweig and Watson have prepared a diagram by plotting \(K\) content against \(K/Na\) in the vacant position. They obtained two distinct fields, one
<table>
<thead>
<tr>
<th>Chemical analysis of hornblende*</th>
<th>Number of ions on the basis of 24(OH,F,Cl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>Si  6.556 ( | ) 8.000</td>
</tr>
<tr>
<td>TiO₂</td>
<td>Al  1.344 ( | )</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td></td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>Al  0.402 ( | )</td>
</tr>
<tr>
<td>MnO</td>
<td>Ti  0.088 ( | )</td>
</tr>
<tr>
<td>MgO</td>
<td>Fe³⁺ 0.406 ( | ) 4.925</td>
</tr>
<tr>
<td>CaO</td>
<td>Fe²⁺ 1.261 ( | )</td>
</tr>
<tr>
<td>Na₂O</td>
<td>Mn  0.035 ( | )</td>
</tr>
<tr>
<td>K₂O</td>
<td>Mg  2.733 ( | )</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Fx</td>
<td>Ca  2.063 ( | )</td>
</tr>
<tr>
<td>Ny</td>
<td>Na  0.443 ( | ) 2.682</td>
</tr>
<tr>
<td>Nz</td>
<td>K  0.176 ( | )</td>
</tr>
<tr>
<td>2Vₓ</td>
<td>OH  1.763</td>
</tr>
</tbody>
</table>

**Fleochroic scheme**

- **X**: Light yellow
- **Y**: Yellowish-green
- **Z**: Dark yellowish-green

**Analyst**: A. Kripanidhi

*Hornblende from biotite-hornblende adamellite near Singarejpur.*
FIG. 80
Analysed hornblende from bio-horn. Adamellit.
ungranitized hornblende field and the other granitized hornblende field (Fig. 3). When the values of $K$ against $K/Na$ of the hornblende analysed are plotted in a such a diagram, the plot falls within the field of granitized hornblende.

**HEAVY MINERAL ANALYSIS:**

Six rock samples from both the groups of Peninsular gneiss, viz. gneisses and granites, were crushed and subjected to heavy mineral separation as described by Milner (1940) in order to study the nature of the heavy accessories and its relative concentration in these granitic rocks. The heavy residue obtained was weighed and the index figure of the rock was calculated according to Groves (1927). A suitable sample of each heavy fraction was mounted in order to identify the various heavy minerals that are present and to obtain their frequency of occurrence. The results thus obtained are shown in Table No. 35.

The index figure is seen varying widely from 1 to 26. In gneisses it is higher than 13, whereas in granites it is generally lower. The wide variation in the index figure indicates that several granitic rocks do not represent a uniform mass formed by igneous activity, but they have originated due to contamination of igneous fluids with the pre-existing rocks, resulting in granites and gneisses. According to Groves (1927) a high index figure (above 10)
**Table No. 35**

*Heavy minerals in the granitic rocks*  
( in % )

<table>
<thead>
<tr>
<th></th>
<th>K28</th>
<th>K90</th>
<th>K70</th>
<th>K138</th>
<th>NK242</th>
<th>AK114</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biotite</td>
<td>22.31</td>
<td>0.33</td>
<td>64.55</td>
<td>95.87</td>
<td>83.30</td>
<td>60.00</td>
</tr>
<tr>
<td>Hornblende</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6.00</td>
<td>4.00</td>
<td>25.00</td>
</tr>
<tr>
<td>Epidote</td>
<td>11.58</td>
<td>-</td>
<td>2.00</td>
<td>1.50</td>
<td>2.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Sphene</td>
<td>0.50</td>
<td>-</td>
<td>2.00</td>
<td>0.90</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Apatite</td>
<td>1.12</td>
<td>-</td>
<td>1.50</td>
<td>1.35</td>
<td>1.50</td>
<td>5.00</td>
</tr>
<tr>
<td>Chlorite</td>
<td>-</td>
<td>-</td>
<td>0.50</td>
<td>0.50</td>
<td>0.20</td>
<td>1.00</td>
</tr>
<tr>
<td>Garnet</td>
<td>3.36</td>
<td>97.53</td>
<td>12.75</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Magnetite</td>
<td>57.85</td>
<td>0.94</td>
<td>11.40</td>
<td>2.88</td>
<td>5.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Ilmenite</td>
<td>2.48</td>
<td>-</td>
<td>2.00</td>
<td>0.60</td>
<td>1.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Haematite</td>
<td>1.66</td>
<td>0.92</td>
<td>3.30</td>
<td>0.40</td>
<td>2.00</td>
<td>4.00</td>
</tr>
<tr>
<td>Rutile</td>
<td>-</td>
<td>0.18</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Index figure**  
1.00  4.00  6.50  13.00  14.00  26.00

*Key*:  

- **K28**: Leucogranite  
- **K90**: Garnetiferous-medium-grained granite  
- **K70**: Fine-grained pink granite  
- **K138**: Biotite-granodiorite gneiss  
- **NK242**: Biotite-adamellite gneiss  
- **AK114**: Hornblende-biotite-adamellite gneiss
indicates their origin by contamination. Nockolds (1931, 1932) in his studies on the contaminated granites of Dhoon, and Alderney suggested that the occurrence of biotite, sphene, hornblende, apatite, and epidote is characteristic of contaminated granites.

The present study on the heavy minerals of Peninsular gneiss brings out some important points. The high index figure of the gneisses suggests that they have formed by contamination, and these are the granitized portions of original hornblende rocks by magmatic granitic fluids. The low index figure of the granites suggests that they are less contaminated indicating thereby that they have formed due to granitization of, probably, original grits or arkoses. It is clear from this that the rocks of Peninsular gneiss have formed due to the granitization of original sediments, like grits or arkoses, and also the original igneous hornblende rocks. Because of this fact one can see a wide variation in the index figure from 1 to 26.

**PETROCHEMISTRY:**

Granites, gneisses, diorite, and amphibolite are chemically analysed and the analyses are shown in the Table No. 36 with the CIPW norm, and quartz-orthoclase-albite percentages.

It is clear that the SiO₂ content decreases from granites, through gneisses, diorite, to amphibolite. In order to
study the actual variation in the chemical elements and their behaviour with certain other elements, variation diagram is prepared and is shown in Fig.82. The different oxides are plotted against SiO₂ of the rocks (Wt.%) is considered. Even though a general tendency for the oxide K₂O to decrease with the decrease in SiO₂ and for the oxides Na₂O, CaO, MgO, FeO, Fe₂O₃, TiO₂ and Al₂O₃ to increase with the decrease in SiO₂ is traced, smooth curves to depict gradual variations are not at all obtained. The different rock types show haphazard variation in the above oxides with respect to SiO₂ content.

The pattern of variation of the major constituents, as discussed and shown in the Fig.82, is not characteristic of igneous rocks and hence the variation cannot be attributed to any magmatic differentiation.

Vistelius and Hurst (1964) have examined the phosphorous content in the granitic rocks of North America and have found phosphorous to be a very important component in them. They have drawn a correlation between the phosphorous content and the mineralogical composition; the higher the quartz, the lower the phosphorous, and the higher the percentage of mafics, the higher the phosphorous. They found that there is a negative correlation between quartz and phosphorous, while there is a positive correlation between phosphorous and biotite. But in the present study it is observed that phosphorous is either absent or poor in granites having
biotite or granites having no mafics at all. As a matter of fact a strong positive correlation is noticed between phosporous and hornblende. This is quite evident from the modes given for the granitic rocks which show the presence of biotite when hornblende is present. An increase in biotite with the increase in hornblende content is also recorded.

A BRIEF REVIEW OF THE PROBLEM:

Before actually taking up the subject of origin of Peninsular gneiss, a brief resume of granite problem is given here.

Granites and other related rocks are by far the most extensively developed rocks of pre-cambrian terrains and eroded folded mountains. These rocks have long been grouped with igneous rocks and have been considered to be the products of crystallization of molten magma. But this view has been revised thoroughly during the past two decades and a metamorphic origin (granitization) has been given for certain granitic rocks. This modern concept of metamorphic origin, or granitization, derives mainly from the work of French and Scandinavian schools of Petrology. Numerous discussions have appeared in geological literature on granite problem (Gilluly, 1948; Read, 1957; Tuttle and Bowen, 1958) Now it is generally accepted that there are "granites and granites", which means that granites can originate in
several ways. In short, there may be magmatic granites, formed by the consolidation of a primary or a secondary magma, or metamorphic granites formed by granitization. Sometimes a combination of both magmatic and metamorphic-metasomatic process may also lead to the formation of the granites (migmatization).

Several people have discussed the granitization process and have put forward very interesting theories to explain the mechanism by which solid rocks of diverse composition have undergone granitization (Perrin and Roubalt, 1937; Reynolds, 1946, 1947; Ramberg, 1952).

If granites are considered to be of metamorphic origin, the mineral assemblage in them does not normally indicate the grade of metamorphism to which they were subjected. This is because of the fact that the normal minerals in a granite are stable under a wide P and T conditions of regional metamorphism from the low green schist facies to the high almandine amphibolite facies (Ramberg, 1952, p. 136).

ORIGIN OF PENINSULAR GNEISSIC COMPLEX OF THE THESIS AREA:

In this section, the origin and the evolution of the granitic rocks, comprising the Peninsular gneiss, of the area is discussed in the light of field, petrographical, mineralogical and petrochemical features of the rocks so far described and discussed.

The Peninsular gneissic complex was regarded by
Smeeth (1916) as a huge granitic intrusion, which, after differentiation, injected as separate portions resulting in the different series of granitic and gneissic rocks. According to him the gneissic portions have resulted from magmatic flow, pressure, and intermingling of separate fractions, while consolidating. But this view was critically reviewed by Rama Rao (1962) who on the basis of his own work on this complex concludes, "one can see the replacement and granitization of the older rocks are much more in evidence than magmatic stoping and its consequent effects".

The investigation made by the present author lends support to the view of Rama Rao (1962). The present studies indicate that the different types of granitic rocks of the area have resulted due to granitization of pre-existing rocks of both sedimentary and igneous parentage. This granitization was mainly brought about by the magmatic emanations of granitic nature that soaked into the country rocks and converted them into various types of the present granitic rocks.

The following are the evidences that support the above conclusions.

**Field evidence**

*Regional attitude of the rocks of Peninsular gneiss and of its associated rocks:* The banded gneisses and gneissic granites show a regional N.N.W. to N.N.E. trend and dip
eastwards. The general strike direction of the banded gneisses and gneissic granites coincides more or less with the regional trend of central and eastern schist belts of Mysore and the general trend of Dharwar rocks. The amphibolites and some charnockitic rocks, which occur as elongated lenses or patches, also coincide, in their structural attitude, with the general trend of the banded gneisses at any particular area. They may be said to occur as porting screens. The associated rocks like quartz-magnetite rocks, kodamites, basic charnockitic rocks etc. show a concordant relationship in their attitude with the Peninsular gneiss.

All the above features suggest that the Peninsular gneiss must have originated by the injection of granitic liquids along the original stratification or schistose planes maintaining the parallelism with inclusions, such as amphibolites and charnockitic lenses, and also with the other associated metamorphosed sedimentary rocks. Similar such conclusions are drawn by Mayo (1937), Cloos (1932), Williams (1934), Noble (1952), Barrel (1921), Misch (1949), Cheng (1944), and Suryanarayana (1959).

Wide variability of Peninsular gneiss: Several components of the Peninsular gneiss have already been described. Non-uniformity of their mineralogical and textural character is a feature that is not characteristic of rocks of igneous origin. The rocks vary from banded gneisses, through
gneissic granites to granites. This kind of heterogeneity, even within shorter distances, can not be attributed to magmatic processes, but is possible only through metamorphic-metasomatism or granitization. Further, the contacts between the various components are mainly gradational and one can see gradations from a portion rich in mafic minerals (such as biotite and hornblende) to diorite. This diorite may ultimately pass onto a uniform granitic rock, through biotite- and hornblende-bearing gneissic granites. This clearly emphasises the role of granitization process in the evolution of Peninsular gneiss.

Feldspathization: The sporadic occurrence of microcline porphyroblasts is noticed at certain places within the Peninsular gneiss. This microclinization is considered to be due to the impregnation of potash-rich or feldspathic solutions into the pre-existing rocks.

Marmo (1956, p.436-487) supposes that "the formation of microcline is necessarily bound to a temperature lower than that of the high amphibolite facies and to any extremely slow accumulation of material".

Cannon (1964) in support of Marmo's views says that "a slow accumulation of potash-rich material would certainly be a favourable feature for the development of porphyroblasts".

The optical data of the microcline indicate that they have formed under low temperatures.
Heterogeneous nature of the Peninsular gneiss: The three petrographic types, such as granites, gneisses and diorites, vary widely in the mineralogical constituents, viz., feldspars and mafics. Accordingly, based on potash feldspar to total feldspar ratio, the granites and gneisses were further sub-divided into granites, adamellites, tonalites, and granodiorites. These may or may not contain biotite and/or hornblende. This kind of heterogeneity of Peninsular gneiss cannot be achieved by normal igneous processes and is characteristic of metamorphic-metasomatic process or granitization.

Textural characteristics: The rocks are not uniform in their texture even within short distances, but show variation from coarse-to fine-grained varieties and from gneissic to uniform granites. These varieties are commonly gradational. Perthitic and myrmekitic textures (of replacement origin) are common. All these features favour a replacement origin for the rocks.

Absence of euhedral mineral grains: The constituent minerals present irregular crystal boundaries. For the most part euhedral minerals are absent. Accessory minerals, like apatite and magnetite, very rarely present euhedral outlines. Absence of euhedral outlines of the mineral is against assigning an igneous origin to the rocks.
Two generations of mineral grains: Two generations of quartz and microcline are noticed. Quartz of older generation occurs mostly as rounded inclusions in plagioclase or microcline, and that of later generation occurs as large sized grains with sutured and irregular boundaries. These two modes of occurrence of quartz cannot be explained by a magmatic process. The late formed microcline generally occurs as porphyroblasts within the area.

Varying proportions of minerals: The proportions of the minerals in the different varieties of the Peninsular gneiss is highly variable. This variability indicates their mixed origin and it is characteristic of a process other than magmatic.

Evidence from the heavy accessories: The variability in the index figure, from low to high, is characteristic of the rocks of the Peninsular gneiss. The degree of contamination undergone is different in different rocks, as is clear from their index figure. The high index figure shown by gneisses (both hornblende- and biotite-bearing) is indicative of their origin by contamination. The rocks vary from the least contaminated to the most contaminated types, as is clear from their index figure which varies from one to twenty-six.
Mineralogical evidence

Plagioclase: The predominance of untwinned grains, abundance of A-twins of Gorai (1951), absence of twins characteristic of igneous rocks, and the bent and broken twin lamellae point to a metamorphic origin for the rocks. Further, when the twin data according to Suwa (1956) are plotted in his diagram (Fig. 72) the plot falls within the metamorphic field. Kohler and Tertsch values calculated from the twinned plagioclases indicate a low temperature of formation for these rocks, suggesting again a metamorphic origin, by transformation, of the pre-existing rocks, at low temperatures. The bent and broken twin lamellae of plagioclase point to the role of stress during metamorphism.

Microcline and microcline perthites: Microcline and microcline perthites indicate that they have formed at lower temperatures, as they are the only stable forms of potash feldspars at low temperatures. The perthite that is present may be either due to exsolation or replacement. Among the two types, perthites of replacement origin are more common. This indicates that the circulating soda solutions were more active during the evolution of Peninsular gneiss.

Myrmekite: Myrmekites of the granites have formed by the replacement of microcline by soda-lime feldspar carried by circulating solutions. The myrmekite observed has its convex side towards microcline, growing invasively into it.
Hornblende: When the values for K and K/Na in vacant space for the hornblende are plotted on the diagram (Fig. 81) given by Rosenzweig and Watson (1954) the plot falls within the granitized field of hornblende indicating that its host rocks have resulted due to granitization.

Retrochemical evidence

The analyses presented for different types of granitic rocks do not present any gradual variation of the various oxides with reference to silica. Absence of smooth variation is against accepting an igneous origin.

The normative minerals, quartz, orthoclase and albite, of the analyzed rocks are recalculated to hundred and are plotted in the Q-Ab-Or diagrams of Tuttle and Bowen (1958). Among the two, one (Fig. 83) illustrates the distribution of normative quartz, orthoclase, and albite in all analyzed plutonic rocks of Washington's Table that carry 80% or more of normative quartz, orthoclase and albite. When the Q-Ab-Or values of the rocks of the area are plotted in this diagram (Fig. 83), the plots fall outside the shaded area. This readily explains the fact that no magmatic history is involved in the origin of the rocks. If the Q-Ab-Or values of the rocks are plotted in the second diagram (Fig. 84), all the plots (except No. 3) fall on the feldspar side of the quartz-feldspar boundary. The plots of the rocks of Peninsular gneiss fall in between the isotherms 780° and (most probably) 840°C. As the plots
FIG. 83
granitic rocks of the area.
FIG. 84

© Granitic rocks of the area.
are away from AB, it may be concluded that the granitic gneisses have not formed as a consequence of melting of the country rocks and by the subsequent cooling of the magma so generated.

Conclusion

The granitic liquids injected into the pre-existing rocks have supplied the necessary Ca, Mg, and Si ions to bring about widespread granitization of the rocks. During the process of granitization, the hornblende rocks (including amphibolites and also basic charnockitic rocks) were cut-up into thin stringers and dark small clots. The stringers were mechanically disintegrated and during this process the hornblendes were converted into biotites. The evidence for the mechanical disintegration of the rocks is revealed in thin sections by the minute crushed granules of quartz, surrounding the bigger grains of quartz, microcline, and plagioclase. Shreds of biotite wrapped tightly around feldspar indicate the disintegration of the former during the forcible growth of the feldspars. The fractured, curved, and bent twin lamellae in plagioclase also indicate the role of stress during the formation of the rocks.

The banded gneisses and gneissic granites of the Peninsular gneiss are mainly due to the conversion of hornblendeic rocks by metasomatising granitic solutions. Similar interpretations have been drawn by Gindy (1953),
Pitcher (1955), Huyse (1951), and Burke (1957). Conversion of amphibolite to quartz diorite by acidic alkaline intrusions has been discussed by Bebu (1956). Buddington (1957) during his studies on the inter-related pre-cambric rocks, has stated that the original raw material, viz, biotite-quartz-plagioclase gneiss, was modified and converted by the granitising fluids to yield a porphyroblastic granite gneiss, a migmatite, and a sillimanite-muscovite-rich granite gneiss. The transformation of amphibolite by metasomatism to the migmatitic and feldspathic gneisses has been reported by Snook (1965).

The source for the granitising fluids can only be sought in the deeper levels of the Earth's crust, where melting of some silicate rocks results in the production of granitic magmas. According to Barth (1952, p.236) "granite magma may originate by a differential refusion, or anatexis, of any silicate rock containing the components of granite". Barth also quotes (1952, p.238) the observation of French masters who concluded that the newly developed granite magmas are "accompanying by a halo of attenuated solutions capable of penetrating into the adjacent rocks as oil soaks into a piece of cloth".

Buddington (1939) has stated that "conditions in the interior of the earth have been such that at intervals throughout the earth's history granite magma has developed by partial or complete melting of local portions of the
primordial granite".

The quartz-normelite rocks, nodules, and garnetiferous-
sillimanite quartzites are least affected during the process
of granitization and they may represent resisters.
According to Read (1957) these rocks represent extreme
chemical types, requiring a great expenditure of energy
and a great inflow and outflow of materials to convert
them into granite. Resisters are commonly encountered
in granitic terrains in different parts of the world
(Sacklund, 1943; Read, 1957; Suryanarayana, 1959; Babu, 1959
and Jagadeeswara Rao, 1965).

In summarising the origin of the Peninsular gneiss of
the area, it is pertinent here to quote Rama Rao's sentences,
"that in the complex formation of Peninsular gneiss,
granitization of the other rocks has played a much larger
part than the direct crystallization of a differentiated
granitic magma. The granitization has taken place in
pulsations—at several interrupted phases—and not as a
continuous effort. The argillites, quartzites, and grits
having been rendered to biotite granite rocks, cannot be
easily recognised and differentiated as granitised
sediments; but the hornblende schists and granulites not
so completely granitised can be easily recognised as
modified xenoliths, in many of the types of the granitic
rocks" (1962).