Zeitschrift: Schweizerische mineralogische und petrographische Mitteilungen = Bulletin suisse de minéralogie et pétrographie

Band: 28 (1948)

Heft: 1: Festschrift P. Niggli zu seinem 60. Geburtstag den 26. Juni 1948

Artikel: On charnockite rocks of Palamau, Bihar, India

Autor: Rode, K.P.

DOI: https://doi.org/10.5169/seals-23041

On charnockite rocks of Palamau, Bihar, India

by *K. P. Rode,* Ph. D., Zurich. Dalmianagar, Bihar, India

Introduction

The problem of the charnockites is one of the major petrological problems in Indian Geology still awaiting satisfactory solution. Since the first detailed study of these hypersthene-bearing granulites and gneisses of South India by Sir THOMAS HOLLAND nearly fifty years back a number of papers has been published in India and abroad dealing with the nature and origin of these complex rock types. Not only have our ideas regarding their geographical distribution changed during this long interval due to the discovery of similar rocks in other parts of the world but our conceptions regarding their nature and origin have also suffered similar changes with the accumulation of further data.

Charnockites are no longer confined within a petrographical province limited to South India. They have a much wider development and identical types have been recognised in almost all the Archaean shields of the world. They have thus become a world problem and any theory regarding the origin of these rock types must be one which is capable of explaining their world-wide distribution.

During recent years the present author had opportunities to study these rocks in South India particularly in the Eastern Ghats. The evidence obtained in the hills near Bezwada suggested to him certain new conceptions regarding the nature and mode of formation of these rocks. He came across a further occurrence of these charnockitic rocks, this time in Bihar from where no charnockites were so far reported. The evidence obtained in the field has been strongly supported by microscopic studies which inevitably lead to the view that the charnockites in their less basic phases are a product of inter-reaction of basic and ultrabasic hornblendic magmas intruding into the granites and gneisses of the basement complex along certain well-defined tectonic zones during a particular orogenesis in the Archaean period of world history. Later recrystallisation of hypersthene from hornblende in various rock types has imposed charnockitic characters on the rock-suites.

Area under investigation

The area which has yielded fresh evidence on the above problem lies in the valley of the Auranga-Koel river system a few miles south-east of Daltonganj, the headquarters of the Palamau District in Bihar.

The area forms a strip of land about 16 miles in length and about 8 miles in width. It stretches from Daltonganj in the north-west to Palamau fort and Kerh in the south-east and comprises the major portion of the northern half of the one inch Topo sheet 73 A/1.

The River Koel and its important tributary the Auranga flow through the area and form a wide valley in which the solid geology of the area is considerably covered under alluvium. This valley is flanked by rugged hills rising to more than 500 ft. above ground level and exposing the Archaean complex.

Previous Literature

The area under description has not received any detailed study as yet.

In the geological map published in 1942 (Mem. G. S. I. Vol. 78) the area has been marked as „unsurveyed" though coloured to indicate granites and gneisses. Being situated in between the three well-known coal fields of Daltonganj in the north, Auranga in the east and Hutar in the south, the area has not altogether escaped the attention of geologists but no systematic work has yet been published.

A. K. Day in the annual report for 1930 (Rec. G. S. I. Vol. LXV, 1931) in his field mapping of the area adjoining to the north mentions of the occurrence of hornblende-schists, epidiorite, crystalline limestone, graphite-schist and sillimanite-schists as inclusions in the gneisses. He further adds that coarse-grained augite plagioclase rock is associated with gneisses. He does not make mention of hypersthene as a constituent of any of the rock types indicative of their relationship with charnockites. So far as the author is aware charnockitic rocks have not yet been recorded or recognised from any part of Bihar a fact which led Fermor to regard the whole of the province as a non-charnockitic region.

Geology of the area

In the present investigation a detailed geological mapping of the area has not yet been completed but the field observations made so far go to show that granites and gneisses form an overwhelming portion of the terrain in the hilly part of the region on either side of the valley. Numerous granitic exposures occur even in the valley area peeping out through the alluvial covering.

Dispersed in a series of parallel lenticular bands occur parametamorphic rocks like graphite-schist, sillimanite-schists, garnetiferous schists, quartzites, marbles and calc-silicate rocks. Almost parallel to the foliation of these crystalline rocks occur dykes of basic and ultrabasic intrusives in the form of low elongated hillocks jutting out of the alluvium. They also appear to cut through the granite gneisses and through the schists in the hilly portion of the area.

The whole region is traversed in a criss cross manner by an intricate system of pegmatitic and aplitic dykes and veins.

In a few patches are seen outliers of Gondwana sediments.

The stratigraphical sequence of these Archaean rock formations has been a matter of controversy. The geological survey of India at present holds the views sponsored by DUNN and others according to which the sequence is as follows:

Gondwanas	
Vindhyans	
Newer Dolerite	Archaean
Kolhan Series	Archaean
Granites and related rocks	Archaean
Iron Ore Series including other sedimentary and igneous schists	Archaean

According to this view the Iron Ore Series (Dharwars) form the oldest rock types now preserved as remnants after the whole sedimentary floor had foundered and been assimilated by the batholithic intrusions of granites. The Iron Ore Series here has been made to include not only the banded hematite-quartzites and other less metamorphosed sediments but also the highly metamorphosed garnetiferous graphite- and sillimanite-schists and marbles.

The field relations as observed by the author not only in this region but also in other parts of India lead him to a different interpretation of the data. According to this the rock formations can be arranged in the following sequence:

Gondwanas
Vindhyans (not met with in this area)
Dolerite dykes
Kolhan Series (not met with in this area)

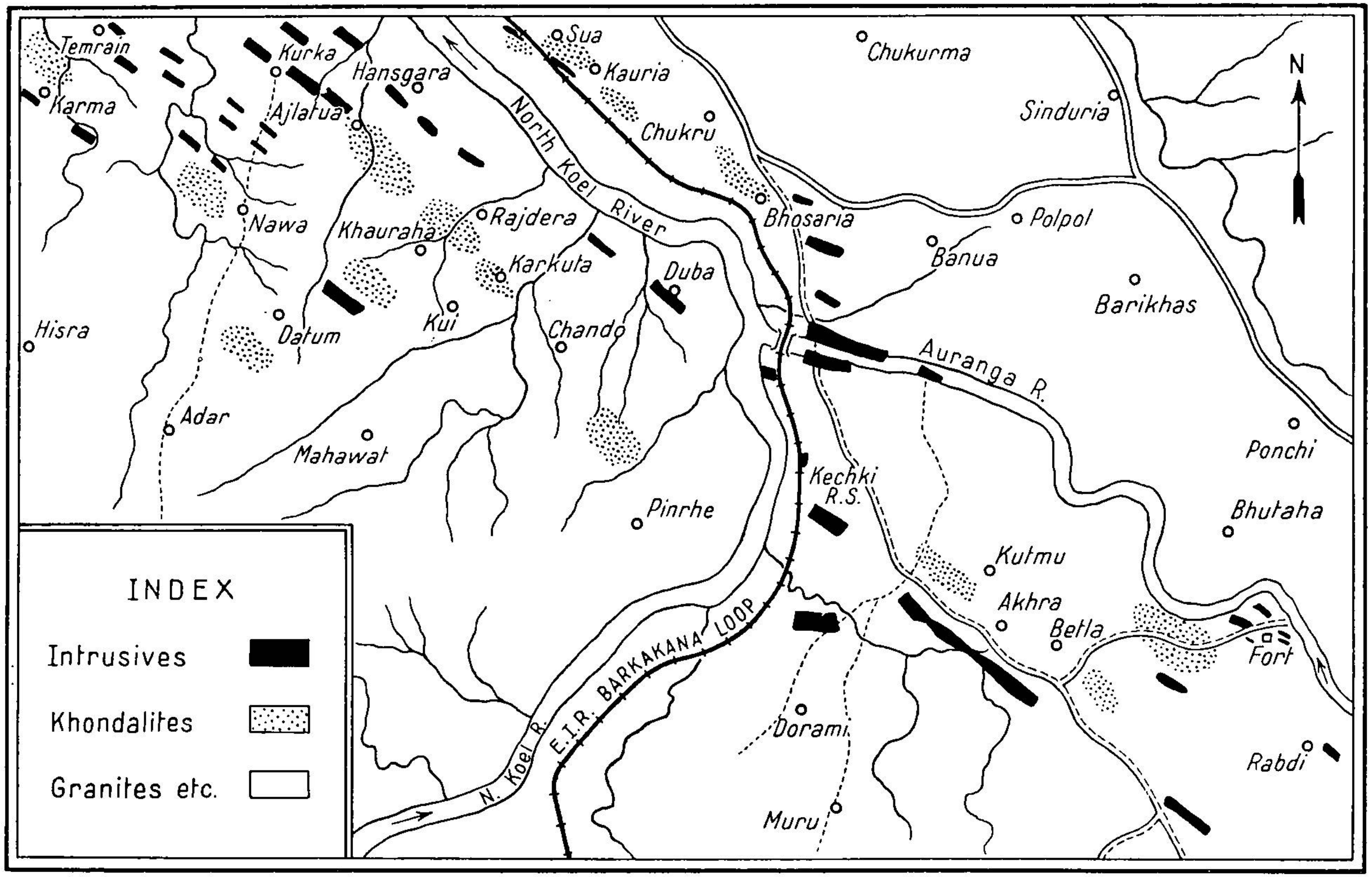

Fig. 1. Geological Sketch Map on scale 1″ = 2 miles = 3·2 km, of the Auranga-Koel Valley, Palamau district, showing the distribution of khondilites (dotted) and basic intrusives (thick lines and dashes) within granites and gneisses (without signature) forming the basement of the whole area. Pegmatites and aplites occuring in swarms in the area are not shown separately

Dharwars of banded hematite-quartzite
facies (not met with in this area)
Pegmatites and quartz veins.
Basic and ultrabasic charnockitic intrusives.

Khondalite Series {
Quartzites
Marbles and calc-silicate rocks
Quartz-magnetite-schists, graphite-sillimanite-garnet-cordierite-bearing schists, mica-schists.

Granites and gneisses (later partly transformed into acid and intermediate charnockites).

Distribution of the Rock Types

The general distribution of the rock types is shown in the sketch map Fig. 1. It will be seen that granites and gneisses form the general basement structure of the region over which are dispersed

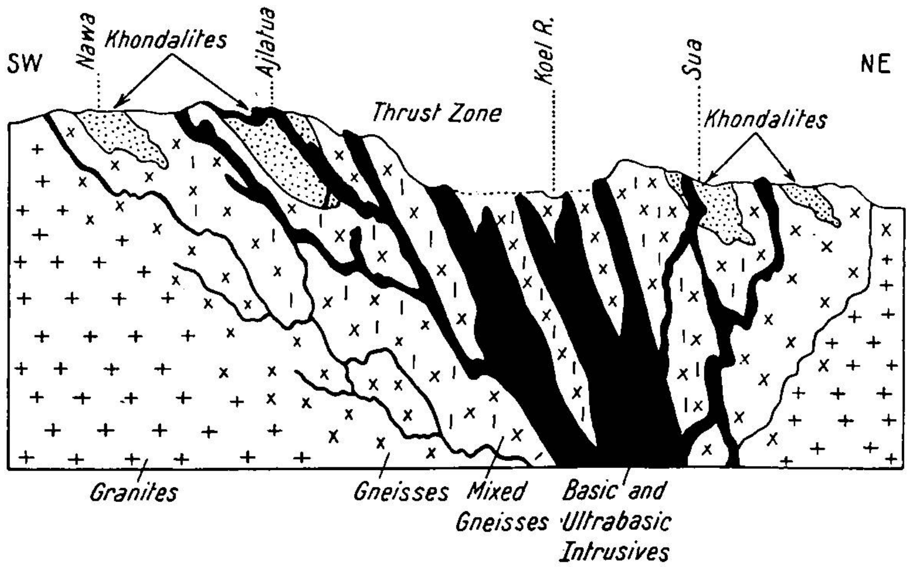

Fig. 2. Diagrammatic section across the Koel Valley showing the relations between granites, granite gneisses, mixed gneisses, basic intrusives and the khondalites

in parallel bands the various schists and marbles of the Khondalite series squeezed into narrow synclinal folds now occurring as eroded outliers all with a NW—SE strike, which is also the foliation direction of the gneisses. Jutting out through these, also in the same direction, occur parallel series of low hillocks of dark hornblendic intrusives which appear to be more numerous in the central or valley portion than in the outer granitic hills. This is particularly so in the case of ultrabasic intrusives. The whole area appears highly disturbed and brecciated and pegmatitic veins and dykes cut all the above rock formations in irregular directions.

These field observations lead one to the possibility that this region was one of the major thrust zones during the upheaval and folding of the Khondalitic sediments.

Figure 2 represents the generalised structure of the area as visualised by the author.

Petrography of the Rock Types

The following groups of rock types have been recognised in the field collections from the above area.

Group A. Granites including microcline- and biotite-granites
granite gneisses
pegmatites and aplites

Group B. Hornblende granodiorites
hornblende-diorites
injection gneisses

Group C. Basic intrusives including hornblende-gabbro, hornblende-norite
hornblende-olivine-norite
hornblendite, pyroxenite
peridotites
hornblende-dolerite

Group D. Khondalitic para-schists with graphite, garnet, sillimanite, cordierite etc.
Marbles and calc-silicate rocks, quartzites and leptynites.

The rocks of groups A, C and D are easily recognisable in the field, having distinctive megascopic characters but those of group B, are very similar to those of A and C into which they grade.

The Problem under Study

A large number of rock types in groups A, B and C have shown unmistakable presence of hypersthene, and have granular to gneissic textures which strongly suggest their affinities with the charnockites of South India. Their variety and range in composition and their intimate association with Khondalitic facies of the Eastern Ghats have invested these rocks with all the characters which justify their identification with the charnockites of the type area. The evidence therefore that these studies will yield in respect of the origin of these rock types will go a long way to solve the controversial problem of the origin of charnockites in general.

Though the area studied is comparatively small the processes invoked to explain the origin are of the world-wide application which the problem demands in view of the world-wide development of these charnockitic rocks.

In the study of the above problem all the three groups A, B and C are important as they contain types which exhibit relationship with the charnockitic suite. In the following description the more basic rocks will be dealt with first followed by the less basic ones as this will help in following the course of their development.

Description of Rock Types

Group C

Ultrabasic and Basic Types

These are thoroughly holocrystalline coarse-grained dark massive rocks with high specific gravity. They occur in the form of huge dykes often forming hill masses.

There are a number of such dykes all running more or less parallel in a NW—SE direction. They are more numerous in the central portion of the valley belt though their real development is obscured under the alluvium. They become less numerous as we go outwards in the bordering hills.

The central series of dykes exhibits a more basic phase as seen near Kurka, Hansgara, Duba, Auranga bridge near Kechki, Betla and Rabdi. Some of these are intimately associated with less basic phases also.

Ultrabasic Types

This subgroup includes the following varieties.

Hornblendites, hornblende-hypersthene rocks, pyroxenites, hornblende-hypersthene-peridotites.

These rocks are generally coarse-grained equigranular and sometimes show beautiful schiller structure on large crystal faces. The rocks do not show any development of foliation or schistosity.

Under the microscope we find that hornblende is a constant and usually the most abundant constituent in these rock types. It is generally broad, lath-shaped with terminal faces rarely developed. In most cases it is quite fresh and shows typical pleochroism in light and deep greens. Both the cleavages are quite well developed.

In a few cases it is seen altered to chlorite. But the more remarkable changes which it exhibits are the development of hypersthene and olivine. In several slides the phenomena of transformation of hornblende into these two minerals can be studied very thoroughly.

Hornblende usually forms very large crystals within which are seen smaller irregular crystals of hypersthene developed at a number of places, all having their cleavages slightly inclined to those of the enclosing hornblende. These new crystals of hypersthene have rarely any well-defined faces, their outer boundaries advancing irregularly within the body of the enclosing hornblende. The various stages can be recognised and in some of the later ones small traces of hornblende are left fringing hypersthene crystals. This stage when seen alone may lead to the reverse but erroneous inference of hornblende being secondary after hypersthene.

Hypersthene very commonly shows distinct pleochroism in pinks and sometimes in pinks and greens.

Cleavages are rectangular but frequently they are not well developed and in some a little obliquity in the two cleavages is discernible. The same variability is shown by the extinction angles. While extinction is generally straight oblique extinction is shown by those individuals not quite perpendicular to at least one symmetry plane.

In addition to hypersthene the other product of transformation seen in these hornblendic rocks is olivine. Grains of olivine are found developed in intimate association with hypersthene. Often both minerals occur enclosed within a big crystal of hornblende (fig. 3). Olivine is found developed not only at the contact of hypersthene with hornblende but also right within the hypersthene crystals. The whole picture gives the following trend of transformations:

Hornblende → Hypersthene → Olivine.

This order is just the reverse of the Reaction Series of Bowen. This reversal is probably due to the formation of ultrabasic segregations under gravitative crystallisation differentiation whereby heavier crystals sink to deeper levels of higher temperatures.

As a counterpart to the above process the felsic segregations rise to higher levels. The initiation of this process is also registered in some rocks: enclosed in a predominantly hornblende-hypersthene mass occur small specks of basic plagioclases which appear to increase in other types giving rise to basic rocks, the gabbros and norites which are described below.

Fig. 3. Hornblende-Olivine-Norite. (T23iii) from Betla Forest showing the development of hypersthene and olivine at a number of places within a single crystal of hornblende

Basic Types

The feldspar-bearing mafic rock types are in our case indistinguishable from the ultrabasic types, with which they often occur in intimate association in the field. Their occurrence however is more abundant and somewhat more wide-spread than that of the ultrabasic types.

These basic types are also dark, holocrystalline, massive, granular rocks like the previous group. Laths of feldspar, however, may be visible in hand specimens. Their texture is somewhat variable since besides coarsely granular types we also find fine-grained doleritic types. A few rocks have a clear porphyritic texture.

Under the microscope we find a wide variation in mineral composition. From highly mafic types with very low content of feldspars to highly feldspathic types with only low mafic contents we find all gradations. The following types have been recognised.

Hornblende-norite,
Hornblende-olivine-norite,

Hornblende-gabbro,
Hornblende-hypersthene-dolerite,
Augite-dolerite.

Here again hornblende is the dominant mineral in the plutonic types. In some hypabyssal types it is found replaced by augite. In the deep-seated rocks we find hornblende again associated with hypersthene and even olivine, exhibiting the same relationship as obtains in ultrabasic types. Besides these mafic constituents we find variable proportions of basic plagioclases with broad lamellae and high extinction angles. While studying the various ultrabasic and basic types under the microscope the relationship of feldspar to mafic constituents appeared one of genetic significance and one is inclined to ascribe the development of basic plagioclases to the differentiation of hornblendic magmas.

The basic and ultrabasic rocks of this group have some common characteristics which differentiate them from other rock types. They are all massive largely coarse-grained dyke rocks in which hornblende is the most common and abundant constituent. They are not foliated nor do they contain any minerals of typically parametamorphic origin. They are also free from any inclusions of older rock types. These rocks are therefore purely igneous and represent a hornblendic to gabbroidal magma which has intruded into the basement rocks.

They have acquired an abundant development of hypersthene as a transformation product from hornblende through magmatic processes and no evidence of contamination is anywhere obtained.

These basic and ultrabasic charnockitic rocks are thus primary, derived directly from hornblendic magmas.

This feature assumes importance when we study the origin of other rock types which follow.

Group B

Intermediate Types

This group includes diorites and granodiorites which are characterized by the abundance of hornblende and intermediate plagioclase. These rocks and particularly the diorites grade imperceptibly into the norites with which they are intimately associated in the field whereas granodiorites similarly grade into granite gneisses.

In the field they are observed fairly commonly in the central belt but are also abundant in the hills bordering the valley. By themselves they do not form any big dyke masses but are found developed along the margins of thick basic dykes. They also occur over wider areas as broad bands and lenticular patches peeping out through the granite gneisses parallel to their foliation.

They are found principally developed in the area near Palamau fort, Khauraha, Kurka and in the valley of the Kawaldaha.

The rocks are dark, only slightly lighter than the basic types and are largely massive. Their faint gneissic structure is disclosed by specks of felsic material arranged in roughly parallel direction.

Fig. 4. Mixed Gneiss (Pe 33) from near Kaska). Hornblende intruding into and enclosing fragments of quartz and feldspar; development of epidote at the contact

The microscopic examination of these rocks gives very interesting information about their nature. These rocks are very diverse in composition and are found to contain in variable proportions minerals which characterize both acid and basic types. Besides hornblende, hypersthene and plagioclases which form the main mass of the diorites, we find clots and patches of quartz, microcline and biotite forming islands within the basic groundmass. On the other hand, in the acid granodioritic types consisting largely of quartz-microcline and acid plagioclases we find hornblende and basic plagioclase occurring as strings and irregular lenses along the foliation planes giving gneissic appearance to the rock. In the former case the clots and patches of acid minerals are only fragments of granites, crushed and picked up as inclusions. The quartz and feldspar of these inclusions frequently show signs of strain, crushing and turbidity in contrast to the fresh look of the basic enclosing minerals and give an evidence of old age.

Within the basic portions of these rocks we again see the development of hypersthene at the expense of hornblende as was observed in basic rocks.

These basic portions have often brought about intense epidotisation in the feldspar particularly at its contact with hornblende giving rise to patches of saussurite (fig. 4).

Fig. 5. The same rock (Pe 33) showing formation of garnet at the contact; feldspar also saussuritised

Garnet is also occasionally developed probably as a result of reaction of hornblende with felsic minerals (fig. 5).

It will thus be evident that in these intermediate rocks we see invasion of hornblendic magma fluids into the older granites giving rise to a type of mixed rocks which may be termed injection gneisses. Moreover hypersthenisation of hornblende in some of these rocks has induced charnockitic characters in these types.

Group A

Acid Types

This group includes a wide variety of rock types such as granites, granite gneisses and leucogranites including pegmatites and aplites, all characterized by the presence of quartz and microcline. Among these, the granites and granite gneisses occur over the largest part of the area and constitute the basement rocks for the whole region.

Pegmatites and spilites, on the other hand, are among the youngest of the types described here intruding in various directions not only the basement granites but also the khondalites and basic intrusions.

The granites are largely bluish to light pink in appearance, generally massive passing gradually into gneissose types with pink feldspar phenoblasts separated by dark bands of biotite and hornblende.

Under the microscope these rocks invariably show quartz and microcline and in addition may have acid plagioclase, biotite and hornblende in variable proportions. Hornblende is generally restricted to gneissic types. In a few cases hypersthene has been found developed in the hornblende bands in this group thus establishing their relationship with the type charnockite.

Aplite-granites and Pegmatites

These are a distinct group of veins and dykes characterized by pink alkali feldspar and quartz very commonly in graphic intergrowth. These grade on the one hand into pink feldspar veins with very little quartz and on the other into quartz veins with little feldspar.

The intense permeation of these vein solutions into older rocks has changed the character of the intruded rocks often beyond recognition. The effects are akin to granitisation a feature which has led many petrographers to consider the granites themselves as intrusive and younger than the khondalites and basic igneous rocks in the area. Pegmatites and aplites are crowded in the central or valley zone and become scarse in the outer hill zones. They, like the basic intrusives, are phenomena restricted to zones of tectonic disturbances and as such they are in no way magmatically related to granites and gneisses into which they intrude.

Group D

Khondalites, Paragneisses and Schists

A number of bands of parametamorphic rocks have been recognised as detached patches running, more or less, parallel to the same foliation direction of the granite gneisses. They are composed of graphite-schists with or without garnet, cordierite, sillimanite, etc., crystalline limestones, calc-silicate rocks and magnetite deposits.

They have been met with among other near Nawa, Datum Ajlatua, Khauraha, Kui, Chando and Duba on the left side of the Koel and near Sui, Bhusaria, Kutmu and in the Betla forest on the right side of the Koel.

These rocks occur in intimate association with the charnockitic rocks in the field. In a few cases hypersthene has also been found developed as a constituent in these rocks. Further these rocks have also been abundantly traversed by pegmatitic solutions. These features have led some petrologists to ascribe the formation of charnockites to the assimilation of sediments by the granitic magmas. In our present area the phenomenon is too rare to assign any important role to this process of assimilation in the formation of charnockites. Moreover granites are older than the khondalites.

The Problem of Petrogenesis

From the above description of the various rock types it will have been seen that the development of hypersthene, though not universal, is quite common and is observed in widely varying types of igneous rocks. It is further observed that all these hypersthene-bearing types are not genetically related but belong to different geological ages. The basic intrusives are post-Khondalitic in age whereas the acidic charnockites form part of the basement complex of much earlier age. The formation of charnockites cannot therefore be attributed to any single petrogenetic process. More than one process operated in the development of the whole series. Amongst these magmatic differentiation has played a very important part though restricted to basic types.

Basic charnockites are a distinctive series of massive intrusives all characterized by the abundant occurrence of hornblende as the major constituent whereas feldspars, hypersthene and olivine occur as very minor and occasional constituents. The primary magma has thus been predominantly hornblendic in bulk composition. The complex gravitative crystallisation resulted in the sinking and resorption of hornblende crystals in the deeper and hotter portions of the magma basin thus enriching them in femic constituents. Hypersthene was being formed in place of hornblende and thus a part of the magma gave rise to hornblende-hypersthenite and at a further stage to hornblende-hypersthene-peridotite.

The upper portions of the magma basin, on the other hand, became richer in felsic constituents and a gabbroidal phase ensued giving rise to hornblende-gabbro and hornblende-norite.

These basic and ultrabasic magmas under intense stress of tectonic forces intruded into the basement and the overlying rocks along well-defined zones of overfolding and thrusting largely as massive dykes along thrust planes but have also seeped profusely through a much wider zone along planes of crushing, shearing and foliation in the basement granites. Some of the geanticlinal regions probably escaped this inter-reaction with basic magmas and have retained their original character as peninsular granites and gneisses (fig. 2).

The reaction and recrystallisation of the basic hornblendic magmas within the granite gneisses has given rise to a number of rock types ranging from dioritic to granodioritic in composition. Hornblende in many of these mixed gneisses has changed, to a variable extent to hypersthene thus giving rise to intermediate and acid members of the charnockite series. The less basic members of the series are thus only basified facies of the peninsular granites and are not differentiation products of the basic charnockitic magmas.

At this stage it may be stated that the basic charnockitic magmas have penetrated Khondalitic sediments overlying the granites in synclinal folds but no indications of any assimilation of these sediments have yet been obtained in the investigated area. The intruding magmas must have lost too much of their heat during ascent to these superficial levels to bring about any fusion and assimilation of the sediments except in deeply buried synclines. Assimilation therefore cannot be considered as a potent factor in the formation of charnockites.

The process of magmatic injection is not a local one but is of world-wide occurrence particularly in regions of intense crustal compression. The generation of basaltic magmas and their intrusion and injection into the overlying rocks has been a widespread phenomenon during every orogenesis.

The formation of hypersthene and other associated basic minerals within acidic rocks, which constitutes the most characteristic attribute of the charnockites is however a less common phenomenon. This appears to be restricted to the oldest cycles of orogenesis in the Archaean period and has apparently much to do with high grade metamorphism of plutonic depths.

These considerations point to the conclusion that the charnockitic suite of rocks is not restricted to any particular petrographic province of limited areal extent but like the Circumpacific Suite will be found developed in all the regions of the world which have suffered similar earth movements.

Received: November 1947.