GEOLOGICAL AND PETROLOGICAL PROBLEMS FROM MYSORE.

By

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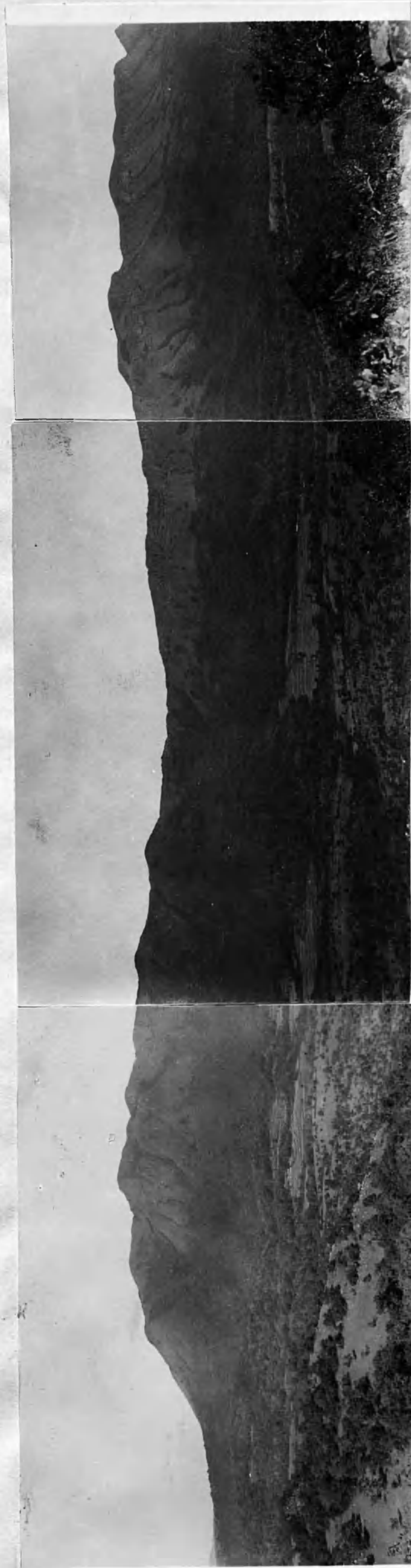
FRONTISPIECE.

A panoramic view of a portion of the Bababudan Ranges. The bands seen near the top are composed of ferruginous quartzites.



CONTENTS.

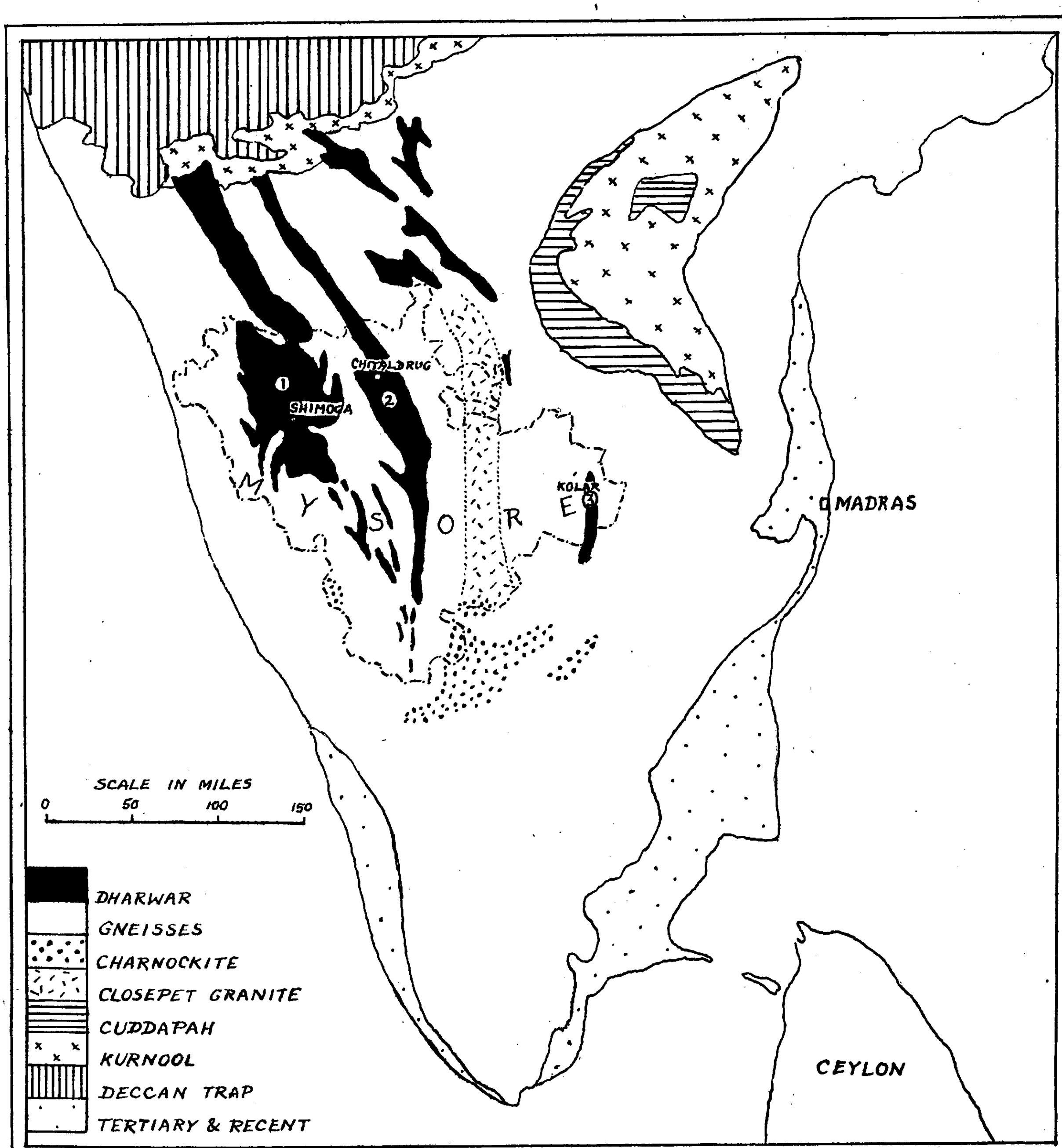
1. INTRODUCTION.

The geological formations of Mysore are confined, almost entirely, to rocks belonging to the Pre-Cambrian period. About one-sixth of the area of Mysore, (i.e. nearly 5000 sq. miles) consists of Dharwar schists, the rest being composed of granites and gneisses. The Dharwar schists occur in three well-defined bands and are designated as the Shimoga, Chitaldrug, and Kolar Belts, after the names of the important towns situated on the respective belts. As will be seen from the accompanying map (Plate I), they enter the State from the north, and the first two which run in a south-south-easterly direction, gradually approach each other and almost meet towards their termination in the southern parts of the State, mainly because of the change in trend of the Chitaldrug Belt. Apart from these main belts, there are numerous small patches and fragments of Dharwar schists scattered about in the gneissic area.

The Dharwar System in Mysore is divided into an upper and a lower division on lithological and stratigraphical grounds. The lower division is formed essentially of rocks characterised by the presence of hornblende such as hornblende schist and epidiorite; chlorite is common in the upper division which is composed of rocks such as chlorite schist and mica-chlorite schist. Apart from the schistose rocks, the Dharwars also comprise conglomerates , banded ferruginous quartzites, quartzites, and limestones, and all these have so far been considered in Mysore to be primarily igneous in origin. The writer does not, however, agree with this view, and in the following pages evidences will be given to prove that the conglomerates, quartzites, and ferruginous quartzites of the schist

PLATE I.

Sketch map illustrating the main geological features of South India. The Mysore State is wholly in the region of Pre-Cambrian formations.



CHITALDRUG
SHIMOGA
MYSORE
KOLAR
MADRAS
CEYLON
SCALE IN MILES
0 50 100 150
DHARWAR
GNEISSES
CHARNOCKITE
CLOSEPET GRANITE
CUDDAPAH
KURNOOL
DECCAN TRAP
TERTIARY & RECENT

bands are of sedimentary origin.

The schistose acidic rocks including some sericitic quartzites and micaceous gritty schists which are associated with the Dharwar schists, were formerly differentiated as belonging to the Champion gneisses, but now they are included among the Dharwars.

All the various types of granites and gneisses of Mysore are intrusive into the schists. They are considered to be of four different epochs of intrusion and are classified as follows, beginning with the oldest:

i. Champion Gneiss - a series of highly crushed micaceous granite-gneisses, frequently associated with minor injections and acidic flows, and characteristically containing blebs of opalescent quartz.

ii. Peninsular Gneiss - a complex of different biotite granites and a composite series of gneisses. It is the most extensive and widely distributed type in the State.

iii. Charnockite - these are found in the southern parts of Mysore, and comprise granulitic hypersthene-bearing rocks of varying composition, ranging from a granite to a hypersthenite.

iv. Closepet Granite - a coarse, pink or grey porphyritic granite.

Subsequent to the formation and folding of the Archaean complex, the rocks have been cut through by numerous basic dykes, chiefly dolerites, which are of Cuddapah age.

The writer has recently been studying some of the constituent rocks of the Shimoga, and Chitaldrug Schist Belts, as well as of the Peninsular Gneisses and Closepet Granites. The results of this examination are published in separate papers. What follows is a summary of the main features of this work.

2. SHIMOGA SCHIST BELT.

The Shimoga schist belt occupies a large part of the Kadur and Shimoga Districts, and extends northwards through the Dharwar District of the Bombay Presidency. The name "Dharwar Schist" was given by Bruce Foote after examining the northward extension of this belt.

This belt contains very well developed beds of conglomerates, banded ferruginous quartzites, quartzites, and limestones. All these rock types have so far been considered in Mysore to be igneous in character, though elsewhere similar rocks are usually assigned a sedimentary origin. According to Smeeth and Sampat Iyengar, two of the chief workers on the geology of Mysore, these rocks have been formed from igneous material by metamorphic and metasomatic changes. This is also the prevailing view of the Mysore Geological Department.

The writer recently made a careful study of the ferruginous quartzites, quartzites, and conglomerates of this belt and was able to find several characters which indicated that these rocks are of normal sedimentary origin.

I. THE BANDED FERRUGINOUS QUARTZITES.

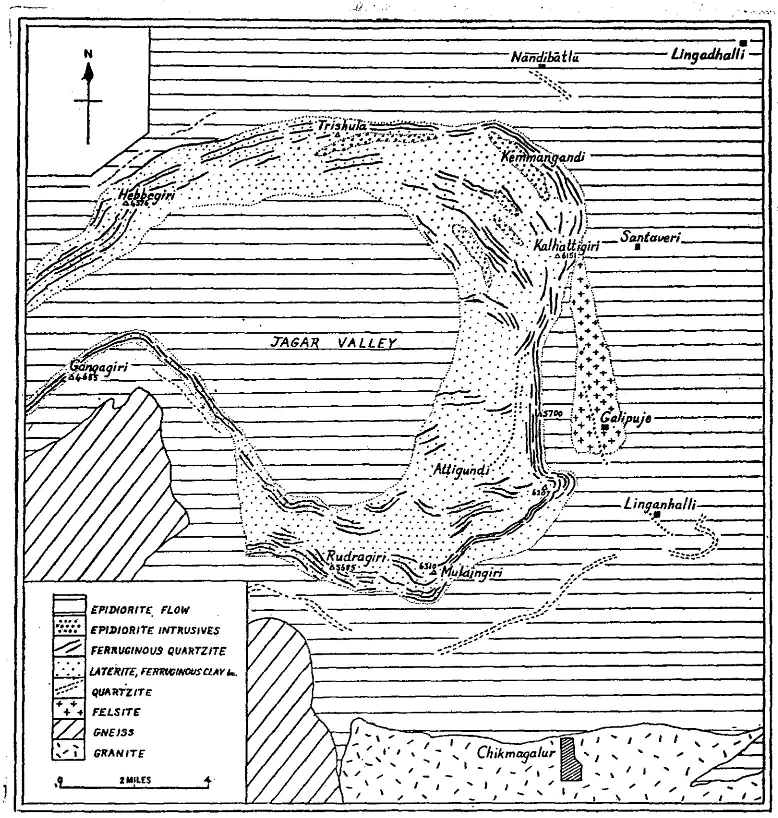
One of the best areas for examining the banded ferruginous quartzites is the Bababudan Hills, which form a well-marked and conspicuous range in the Kadur District. The range is disposed in the form of a horse-shoe (Plate II), with the opening on the north-west at Hebbe. The longer diameter of the more or less ring-shaped complex is about fourteen miles

PLATE II.

FIG.1. Geological sketch map of the Bababudan ranges and environs.

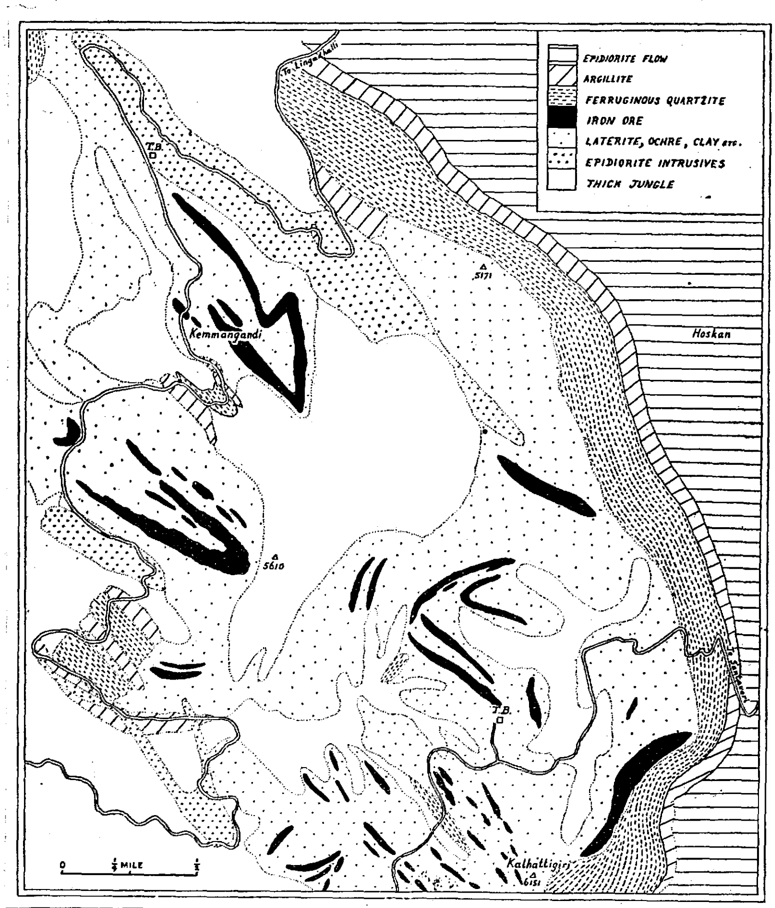
FIG. 2. Geological sketch map of a portion of the Bababudans, indicating the geology of the area and the distribution of the chief deposits of Iron Ore.

(Both from the Writer's paper on "The iron-formations of the Eastern Bababudans" Half-yearly Journal of the Mysore University; Vol viii, 1935)



N
Nandibatlu
Lingadhalli
Trishula
Kemmangandi
Hebbegiri
Santaveri
Kalhattigiri
JAGAR VALLEY
Gangagiri
Galipuje
Attigundi
Linganhalli
Rudragiri
Mulaingiri
EPIDIORITE FLOW
EPIDIORITE INTRUSIVES
FERRUGINOUS QUARTZITE
LATERITE, FERRUGINOUS CLAY &c.
QUARTZITE
FELSITE
GNEISS
GRANITE
2 MILES
Chikmagalur

FIG. 1



To Linganhalli
EPIDIORITE FLOW
ARGILLITE
FERRUGINOUS QUARTZITE
IRON ORE
LATERITE, OCHRE, CLAY etc.
EPIDIORITE INTRUSIVES
THICK JUNGLE
T.B.
5171
Kemmangandi
Hoskan
5610
T.B.
Kalhattigiri
6151
MILE

FIG. 2.

from east to west, and the shorter diameter nearly twelve miles from north to south. The range varies in height from 4000 to 6000 feet in elevation and contains some of the loftiest peaks in Mysore, of which Mulaingiri, with an elevation of 6310 feet above sea-level, is the highest point in the State.

The iron formations are generally confined to the higher regions of these ranges, and furnish precipitous and almost vertical escarpments, often more than 100 feet in height, on the outer margins of the hills. The thickness of the beds averages between 200 and 300 feet. The dip of the banded ferruginous quartzites is least at the north-east corner of the ranges and gradually increases towards the south and east. Near Kalhatti, the dip is about 20°, though in some parts the beds are almost horizontal. Along the eastern scarp, the average dip is low, but in places on the 6th. furlong of the 29th. mile, near Kemmangandi, the dip is vertical. The strike of the banded ironstones coincides practically with the trend of the ranges.

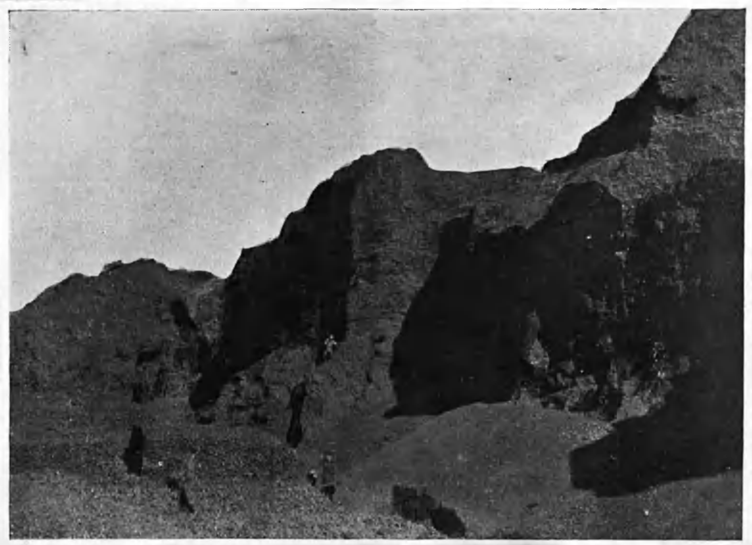
The ferruginous quartzites vary in appearance and composition, often exhibiting great differences in the nature and thickness of their component bands, and in the relative proportions of ferruginous and siliceous matter. The colour and texture of the silica bands also vary considerably. The bands may be white, grey, or various shades of red or brown; and in texture they grade from that of a dense flinty chert or jasper irresolvable even with a lens, to that of a fine-grained saccharoidal quartzite. The siliceous layers are sometimes formed of a fibrous aggregate of quartz crystals, the fibres growing at right angles to the planes of bedding.

PLATE III.

Fig. 1. View from Attigundi of a portion of the Bababudans, showing the characteristic scenery of these hills. The slopes are smooth and grass-covered, while the valleys are thickly forested. The third peak on the left is Mulaingiri, 6310 ft. above sea-level, and the highest point in the Mysore State.

Fig. 2. Photograph of a part of the Kemmangandi iron mines.

1



2

The laminae in the ferruginous quartzite bands are composed wholly or predominantly of ferruginous or siliceous matter, but more often the layers are formed of intimately intermingled iron minerals and quartz, the iron oxides occurring in the form of crystals, grains or irregular patches, either scattered indiscriminately through a base of finely crystalline quartz, or, as is more common, concentrated in lines following the banding. Conspicuous colour bandings are often seen; layers of black haematite or magnetite sometimes alternate with bands of red, pink, grey or white siliceous matter, and the rocks are then of a very handsone appearance. Such types have been designated "calico" rocks in South Africa. The bright red colours of the siliceous layers are found on microscopic examination to be due to small particles of oxides of iron.

The bands are usually regular and parallel. The writer observed that in some cases, certain layers were crumpled into minute folds, while those above and below them were

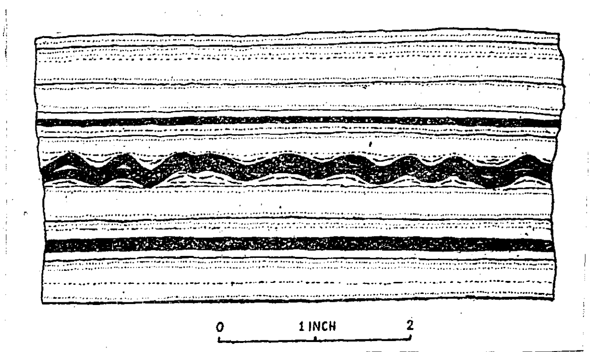


FIG. 1

unaffected.(Fig. 1). Microsections cut from portions of such folded bands show that some of the thinner layers are broken (Plate IV, Fig. 2). These are of the nature of intraformational folds caused probably by submarine quakes during the period of deposition. The uppermost layers if disturbed immediately after their deposition, would be thrown into a series of minute folds, while the slightly earlier formed lower layer which is now of harder consistency would be less yielding and so gets broken up. After the disturbance was over, the succeeding layers would again be normally deposited.

Mineralogy.

Quartz. - Silica occurs in large amounts and is now in the form of quartz. The mineral generally forms granoblastic aggregates. A mosaic texture with straight boundaries is common, but rarely the grains are seen to be interlocking. The grain size varies; in the cherty layers, the grains are very minute but ordinarily they are much coarser. The quartz layers are sometimes further laminated, each lamina having a different grain size. Streaks of iron ore inclusions often pass uninterruptedly through contiguous grains of quartz, and from this it is inferred that the silica was originally deposited as a gel and later became crystalline.

The writer has collected from various parts of the Bababudans, specimens of fibrous quartz. The fibres are usually disposed at right angles to the plane of bedding (Plate V, Fig. 4), and are separable in some cases. The layers of fibrous quartz frequently exhibit a chatoyant lustre. In thin slices, these layers are seen to contain fibrous amphiboles and it is clear that the quartz is replacing the amphiboles.

Iron Ore Minerals. - Haematite is the most common iron ore mineral occurring in the quartzites, so that most of the ferruginous rocks in the Bababudans may be described as haematite-quartzites. Magnetite occurs usually as minute octahedra, especially near intrusive contacts. Martite has been recognised in some places.

Bababudanite. - This is a soda-amphibole which was considered to be a variety of riebeckite rich in magnesia (Sampat Iyengar, 1908, p.73). This mineral was reported to occur only in the western portion (Gangagiri branch) of the Bababudans. Jayaram noticed its occurrence in the neighbourhood of Attigundi (1923, p.41). In 1932, the writer obtained very good specimens near Kemmangandi and Kalhatti, on the eastern slopes of the ranges.

Bababudanite is a shining black mineral with an almost adamantine lustre when quite fresh. It frequently appears dark brown in colour, but this is due to haematite or limonite which is deposited on the surface and along the cleavages. The crystals are prismatic with an acicular habit, sometimes occurring in bands with a cross-fibre texture (Plate V, Fig. 3). Perfect prismatic cleavages intersect at an angle of 126°. The specific gravity of the mineral is 3.31.

An analysis of this mineral has been published by Smeeth (1908, pp.91-92), but since it totals only to 97.68, it was considered necessary to obtain a new and more accurate analysis.

Smeeth obtained the mineral for analysis by the following method. The amphibole-bearing ferruginous quartzite was crushed and the magnetite removed by a magnet; the residue was treated with dilute hydrochloric acid to remove the remaining oxides of iron, and then a heavy liquid was used to separate the amphibole. The writer tried this method of separation, but an examination of the concentrate showed that quartz was associated with the bababudanite, not so much as inclusions but as fragments moulded on the amphibole, and so [illegible]

TABLE I.

	I	A	B	C	D	II
SiO_2	49.80	51.15	54.01	55.03	55.02	54.48
Al_2O_3	1.56	-	0.23	0.49	4.75	2.10
Fe_2O_3	18.62	14.92	15.70	15.47	10.91	15.79
FeO	10.59	9.80	9.42	7.39	9.46	5.02
MgO	9.30	10.80	10.01	11.48	9.30	12.11
CaO	0.45	1.12	1.52	0.98	2.38	1.04
Na_2O	8.80	6.52	6.22	6.38	7.62	6.34
K_2O	tr	0.63	0.35	0.80	0.27	0.32
H_2O	0.65	4.77	2.25	1.98	-	0.40
MnO	-	0.30	0.14	-	tr	0.08
	99.77	100.01	99.85	100.00	99.71	97.68

I. Bababudanite, Kemmangandi, Bababudan Hills, Mysore. Analyst: W.H.Herdsman.

A. Crocidolite, Dochfour, Scotland. Quoted from Dana's System of Mineralogy, Sixth Edition, 1911, p.400.

B. Rhodusite, Asskys River, Minussinsk District, Siberia. Quoted from Journ. Chem. Soc. 1908, Vol.94. Abstracts Part II, p.40.

C. Rhodusite, Rhodus Island. Quoted from First Appendix to Sixth Edition of Dana's System of Mineralogy, p.29.

D. Crossite, Berkeley, California. Analyst: W.S.T.Smith, ibid, p.20.

II. Bababudanite, Gangagiri branch, Bababudan Hills, Mysore. W.F.Smeeth, Rec. Mys. Geol. Dept., 1908, Vol.IX, pp.91-92.

this procedure was rejected. The same reason rendered heavy liquid separation also unsuitable for obtaining a pure sample of the mineral. Recourse was therefore had to the tedious

PLATE IV.

FIG. 1. x 10. Ordinary light. Section of banded ferruginous quartzite.

FIG. 2. x 10. Ordinary light. Section of a portion of an intraformational fold. One of the thin laminae is seen to be folded and broken.

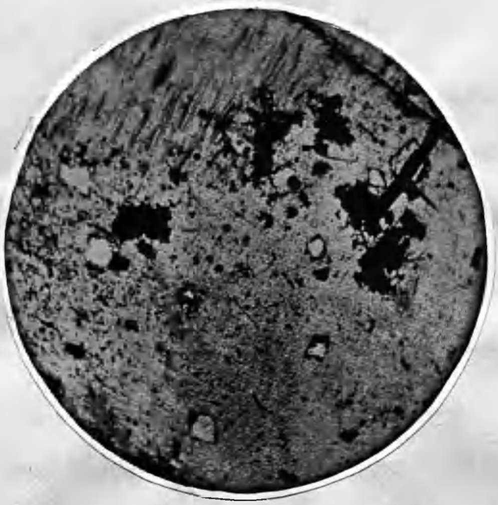
FIG. 3. x 22. Section of hornfelsed argillite. The banded nature of the rock is visible. The amphiboles show a decussate arrangement.

FIG. 4. x 10. Ordinary light. Rhombohedral areas in the ferruginous quartzite which probably represent pseudomorphs after siderite.

1

2

3



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method of hand-picking. The bababudanite-bearing rock was first crushed and the fine dust got rid of by sieving. The magnetite was removed by a magnet, and the quartz was separated by using bromoform. The heavy residue was placed in small portions under a lens, and the mineral picked out with a moistened mounted needle. Since the amphibole was often of hair-like fineness, this procedure was extremely slow and it took nearly two months to collect just enough material for a careful chemical analysis. The analysis was made for the writer by Mr. W. H. Herdsman, and the results are given in column I of Table I. For purposes of comparison, analyses of crocidolite, rhodusite, and crossite, are placed alongside. In column II, the only other existing analysis of bababudanite is given.

The new analysis of bababudanite given here, except for a slight excess in magnesia, agrees fairly well with the following formula:

$$4NaFe'''(SiO_3)_2 .\ 2FeSiO_3 .\ 3MgSiO_3$$

The mineral differs from riebeckite in containing a high percentage of magnesia, and from glaucophane in its low alumina content. It resembles the analysis of crocidolite from Dochfour (A in Table I) fairly closely, but differs from this mineral in optical properties. The nearest approximation in both chemical composition and optical characters is to rhodusite. According to Isküll, the composition of rhodusite may be expressed as an isomorphous mixture of the two molecules

$$Na_2Fe_2Si_4O_{12} \text{ and } 5(Mg,Fe,H_2,Ca,Mn)SiO_3$$

The analysis which the writer has given above for bababudanite if written in similar form would become

$$2Na_2Fe_2Si_4O_{12},\ 5(Mg,Fe,H_2,Ca)SiO_3.$$

The optic plane and Z are normal to 010. There is a strong dispersion of X, Y, and optic axes. This dispersion and the intense pleochroic colours exhibited by the mineral, make accrate measurements very difficult.

$$(-)\ 2V = \text{about } 60^\circ$$

$$\gamma - \alpha = .013 \text{ to } .014$$

$$\beta - \alpha = \text{about } .018$$

$$X \wedge c = \text{about } 3^\circ$$

X = dark Prussian blue

Y = yellow

Z = deep violet blue

Acmite. - In the course of the writer's examination of the Bababudans, a yellowish or brownish green mineral was discovered near Kemmangandi as well as near Kalhatti. This is usually associated with bababudanite. It is a platy mineral with a sort of schiller lustre. It alters into a yellow ochreous material. The crystals are prismatic. The mineral is monoclinic with 110 cleavages, and parting on 010. The prismatic cleavages intersect at an angle of about 90°.

The optic plane is parallel to 010. The mineral is pale yellowish green in thin sections, and non-pleochroic. It is optically negative.

$$(-)\ 2V = 82^\circ$$

$$\gamma - \alpha = .042$$

$$\gamma - \beta = .018$$

$$X \wedge c = \text{about } 2^\circ \text{ to } 3^\circ$$

A specimen of the mineral collected by the writer from near Kalhatti was analysed by Herdsman with results which are given in Table II.

TABLE II

	I	II	III
SiO_2	52.75	51.35	52.22
Al_2O_3	0.35	1.59	0.64
Fe_2O_3	33.00	32.11	28.15
FeO	1.42	2.59	5.35
MgO	0.24	-	1.45
CaO	0.80	tr	2.19
Na_2O	9.70	11.39	10.11
K_2O	tr	tr	0.34
H_2O +	1.00		
H_2O -	0.50		
CO_2	-		
TiO_2	-		
MnO	-	0.37	0.54
P_2O_5	tr		
	99.76	99.40	100.99

I. Acmite, Kalhatti, Bababudan Hills. Analyst: W.H.Herdsman.

II. Acmite, Rundemyr. Quoted from Dana's System of Mineralogy, Sixth Edition, 1911, p.365.

III. Aegirine, Kangerdluarsuk, ibid.

The crystallographic and optical characters indicate that the mineral belongs to the pyroxene group. From Table II it will be seen that in chemical composition it corresponds closely to acmite, but non-pleochroic acmite is very rare and has not been recorded except from the Hawaiian Islands (Washington, 1923, p.107).

PLATE V.

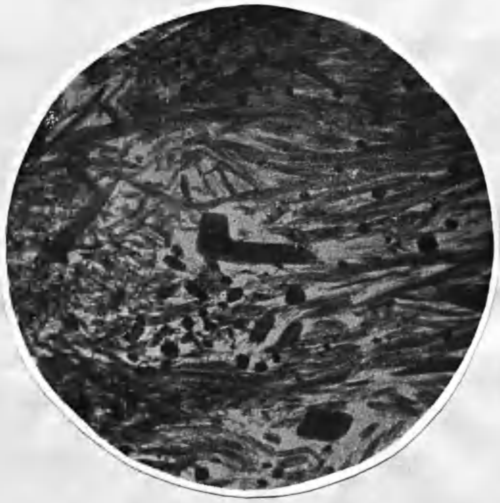
FIG. 1. × 10. Ordinary light. Bababudanite in Ferruginous quartzite. The crystals are disposed right across the bands.

FIG. 2. × 22. Ordinary light. Bababudanite-magnetite schist.

FIG. 3. × 10. Ordinary light. Portion of a layer of fibrous bababudanite.

FIG. 4. × 22. Crossed nicols. Section of a band of fibrous quartz.


1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3


4

Cummingtonite, Asbestos, Crocidolite, Pyrites, Apatite. - All these minerals are present in small quantities and with their usual properties.

Bababudanite-Magnetite Schist.

Intercalated with the ferruginous quartzites are thin layers of rocks which contain amphiboles like bababudanite. In some bands the amphiboles are present as a felted aggregate of fibrous crystals, and in others are more coarsely crystalline. Magnetite and quartz are present in varying proportions (Plate V, Fig. 2).

A specimen of bababudanite-magnetite schist was analysed and it will be seen from Table III that it compares very well ~~well~~ with the amphibole-magnetite rocks of the Lake Superior region.

The view that these amphibole-magnetite schists represent trap flows is suggested by Smeeth (1908a, p.23) and Sampat Iyengar (1908, p.72). These schists are supposed to be remnants of basic rocks which by alteration have yielded the banded ferruginous quartzites. It will be seen from Table III, that the analysis of bababudanite-magnetite schist bears no resemblance to an igneous rock; on the other hand, it compares very favourably with the rocks occurring as intercalations in the Lake Superior banded ironstones of Michigan and Wisconsin, and which are considered to be of sedimentary origin. P and Q are partial analyses of somewhat similar amphibole bearing rocks from the Singhbhum District, India. In these two analyses, only the percentage of metallic iron has been determined and so to facilitate comparison, the percentages of metallic iron in the other analyses have been calculated.

TABLE III.

	I	A	B	C	D	P	Q
Fe	34.3	37.8	36.6	41.1	34.5	35.2	36.4
SiO_2	44.15	39.17	42.90	33.89	46.25	38.80	37.28
Al_2O_3	0.25	1.14	-	1.15	0.92	0.20	0.40
Fe_2O_3	40.20	40.42	34.77	49.43	30.62	-	-
FeO	7.98	12.33	15.82	8.46	16.92	-	-
MgO	3.11	1.90	2.62	2.40	2.13	4.32	2.46
CaO	tr	1.37	1.33	3.16	1.69	2.55	2.35
Na_2O	2.60	-	-	-	-	-	-
K_2O	tr	-	-	-	-	-	-
H_2O +	0.05	2.56	0.47	1.50	0.42	-	-
H_2O -	1.60						
TiO_2	tr	-	-	-	-	-	-
P_2O_5	tr	tr	tr	-	0.07	-	0.05
MnO	-	0.55	1.73	0.34	1.01	-	-
CO_2	-	-	-	-	-	-	-
	99.94	99.44	99.64	100.33	100.03		

I. Bababudanite-magnetite schist, Bababudan Hills, Mysore. Analyst: W.H.Herdsman.

A, B, C. Magnetitic slates, Wisconsin. (Irving and Van Hise, 1892, p.197)

D. Grünerite-magnetite schist, Michigan. Analyst: H.M.Stokes. (Van Hise, Bayley and Smyth, 1897, p.338)

P. Iron ore-amphibole rock, Badampahar Iron Mines, Noamundi, Singhbhum District, India. (Percival, 1931, p.199)

Q. Actinolite bearing recrystallised banded haematite silica rock, Badampahar. (Percival, 1931, p.224)

It will be noticed that bababudanite -magnetite schist contains 3.11 per cent of MgO as against a trace of CaO. The dominance of magnesia over lime is suggestive of a sedimentary origin. Van Hise and Leith consider that the Lake Superior iron-bearing formations must have been chemically precipitated because the average proportion of magnesia to lime is over 5 to 1 (1911, p.506). A similar calcium-magnesium ratio has been observed in the Noamundi area by Dr. Percival (1931, p.200), who is of opinion that the banded iron ores of that place have originated as chemical sediments. The dominance of ferric over ferrous iron noticed in the bababudanite-magnetite schist, when considered in conjunction with the magnesia-lime ratio, strengthens the view that these rocks must have had a sedimentary origin.

A striking point of difference which the analysis of the Mysore schist exhibits is in the presence of 2.60 per cent of Na_2O. The rocks adjoining and underlying the banded ferruginous quartzites are many of them rich in soda, as may be seen from the prevalence of albite and acid oligoclase in them. The writer considers that the soda content of the bababudanite-magnetite schist is ascribable to the sediments being derived these rocks of spilitic affinities.

The bababudanite-magnetite schists are often only about an inch or two in thickness, and are impersistent. They bear no resemblance chemically, mineralogically or texturally to the epidiorites of the area. The writer is of the opinion that some of the bands of the ferruginous quartzites must originally have had different composition, and the trans-formation of these bands by metamorphic agencies has produced different combinations of minerals. During recrystallisation, due to metamorphic differentiation, there has been a tendency for minerals of the same kind to segregate, and that explains why some layers are rich in a single mineral like bababudanite.

Mode of Origin of the Ferruginous Quartzites.

All the geologists of Mysore who had so far examined these rocks were of the opinion that the ferruginous quartzites were the result of some kind of metamorphic action on basic rocks. They were supposed to have been formed by the gradual alteration of "hornblendic beds which are of the nature of amphibolites" (Smeeth, 1908[a], p.21), or by the metamorphism of "aphanitic greenstones" (Slater, 1908, p.56). The occurrence of amphiboles like bababudanite and cummingtonite in the ferruginous quartzites, induced Sampat Iyengar to consider that these banded rocks were derived by the alteration of bababudanite and cummingtonite schists (1908, p.73). In this view Smeeth also later concurred. These amphiboles were believed to be original and they were supposed to break up, under the influence of thermal metamorphism, into oxide of iron and silica, which later crystallised as quartz and magnetite giving rise to the banded ferruginous quartzites.

In 1932, the writer while examining the Bababudan region, made an important discovery. He found that the occurrence of bababudanite was confined only to narrow zones always at the immediate contact of the ferruginous quartzites with the intrusive epidiorites. Further, the fresh and glistening crystals of this amphibole were often seen to be disposed right across the already existing bands in the quartzites (Plate V, Fig. 1). These facts definitely suggested that bababudanite was a later mineral developed near the intrusive contacts of the epidiorites, and had nothing to do with the origin of the banded ferruginous quartzites.

In view of the suggestion made by Slater that the banded ferruginous quartzites have been produced through the metamorphism of layers of a rock described by him as "aphanitic greenstone", the writer carefully examined the occurrences of this rock, not only from what was considered by Slater as the type area near the 23rd milestone on the Chikmagalur-Lingadhalli ghat road, but also from several other exposures in the road sections between Mulaingiri (△6310) and Kondekhan (13° 33' : 75° 46'). The writer found that these are usually thin intercalations, often exhibiting very fine bandings. The rock is dark in colour and mixed with abundant ferruginous dust. There is practically no grit. The specific gravity ranges between 2.51 and 2.75. Sections cut from this rock do not show any igneous character at all. The rock could best be described as a mudstone or argillite. It is normally soft but has been hornfelsed near igneous contacts, with the result that the rock is extremely compact and tough, with a sub-conchoidal splintery fracture.

These observations were of no small significance in the genetic considerations of the banded ferruginous quartzites. An explanation different from that of the accepted one in Mysore, had therefore to be found for the origin of these rocks.

Then again, the banding of the ferruginous quartzites has been attributed in Mysore, to lit-par-lit injections of quartz veins into the ferruginous amphibolites, the regularity of the banding being supposed to be augmented by subsequent pressure which acted upon the whole mass of the schists (Sampat Iyengar, 1908, p.76). The writer considers it extremely improbable that the banding in such a large formation could have developed by the mere in situ alteration of a basic schist or by the lit-par-lit injection of quartzose material. The layers are not usually monomineralic; there are all stages and gradations and, when some of the bands are examined under the microscope, the individual layers are themselves seen to be composed of more minute stratification. The writer is of the opinion that the ironstones were at one time in a gelatinous condition, and that a reaction analogous to the Liesegang phenomenon took place giving rise to the very fine banding which is such a conspicuous feature of these rocks.

Conclusion.

The official opinion in Mysore regarding the origin of the ferruginous quartzites is, that they are the metamorphic derivatives of basic igneous rocks. For reasons given above, the writer has come to the conclusion that this view is untenable, and that these rocks are sedimentary in origin. The silica and iron, part of which might have been derived from the contemporaneous Lingadhalli flows, have been deposited as chemical precipitates, and the fine banding of the rock has originated by processes similar to the Liesegang phenomenon. Some of the reasons which suggest a sedimentary origin of the ferruginous quartzites are: the secondary nature of the bababudanites and the bababudanite-magnetite schists, and the calcium-magnesium ratio in these rocks; the presence of thin beds and intercalations of argillites; the very fine banded character of the rock; the occurrence of intraformational folds; and the indications of the former presence of siderite (Plate IV, Fig. 4).

II. THE QUARTZITES.

In referring to the quartzites occurring in the Mysore State, Dr. W. F. Smeeth, one of the former Directors of the Mysore Geological Department, has stated: "There can be little doubt that many of the quartzites are crushed and recrystallised quartz veins and quartz porphyries, and possibly felsites, and it is at least open to question whether we have any which are genuine sedimentary rocks" (Smeeth, 1916, p.10). Sampat Iyengar considered that these quartzites were formed by the crushing of quartz reefs (1908,p.72)

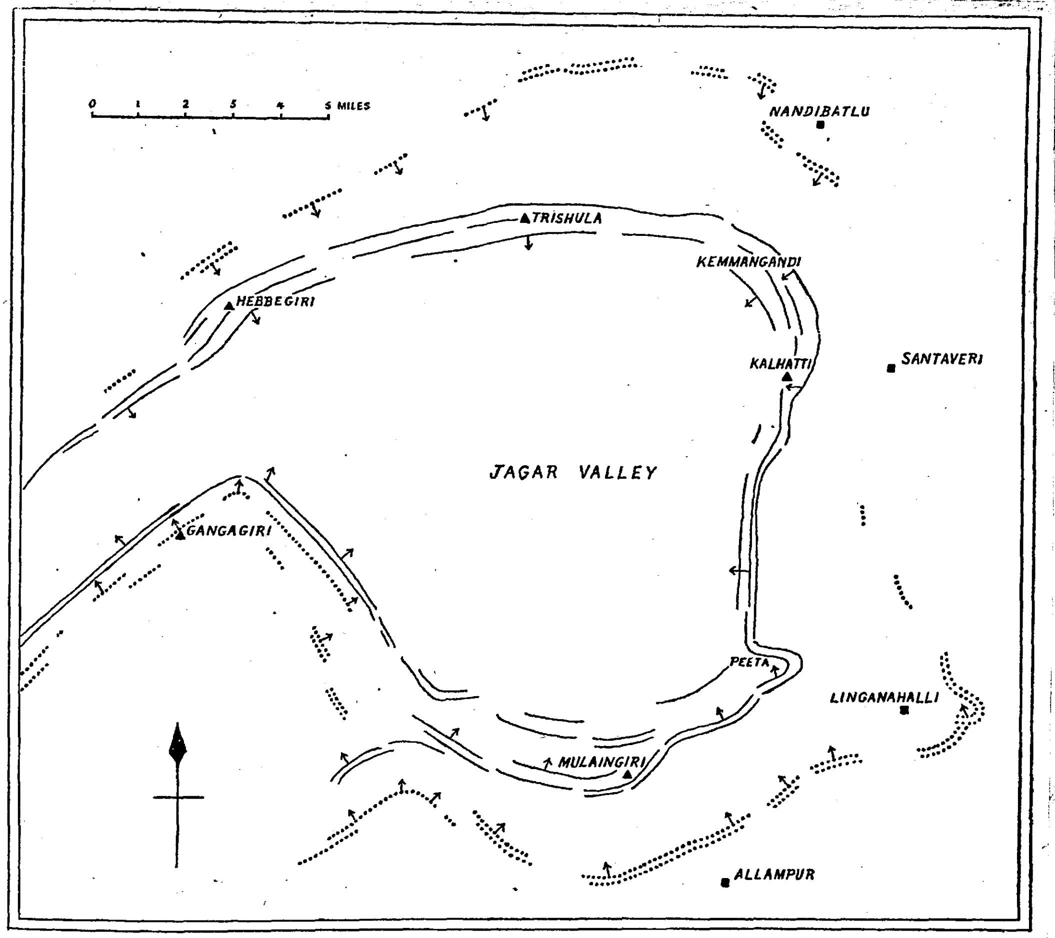
In the course of a recent examination of the quartzites occurring in the neighbourhood of the Bababudan Hills, the writer obtained certain evidences which indicate that these rocks are of sedimentary origin.

The quartzites are generally white in colour, but often they are of various shades of brown. The texture is saccharoidal. The rocks are ordinarily compact, but weathered specimens crumble into a granular sand. In thin sections, the individual grains are often set off by the matrix which is sometimes ferruginous. The grains are not quite

PLATE VI.

Sketch map of the Bababudan area showing the parallelism in trend lines between the banded ferruginous quartzites and the adjoining quartzites. The arrows indicate directions of dip.

(From the writer's paper on the "Quartzites of the Bababudan Area" Current Science, Vol IV, 1935)



BANDED FERRUGINOUS QUARTZITE ·········· QUARTZITE uniform in size.

The runs of quartzites are remarkable in that they follow both in the directions of strike and dip, the banded ferruginous quartzites which have been considered by the writer for reasons given earlier, to be sedimentary deposits. Plate VI gives the main trend lines and directions of dip of the banded ferruginous quartzites , as well as of the nearest quartzites. It will be seen from this map, that in spite of the discontinuity of the quartzite runs here and there, there is a general parallelism to the banded ferruginous quartzites which have a more or less ring-shaped outline. This agreement in trend is brought out very clearly by the bend in the quartzites near Linganahalli, which closely corresponds to the kink which is noticed in the ferruginous quartzites near Peeta in the Bababudans.

The quartzites south of Allampur and immediately to the north of Chikmagalur, are pebbly in character. The pebbles vary in size from a fraction of an inch to nearly six inches across. Sampat Iyengar was of the opinion that these rocks were "pseudo-conglomerates", though he has admitted that the rounding of the quartz pebbles is so perfect that it could be very easily mistaken for a sandstone. In support of his view, he states: "Two or three of the pebbles have undergone further crushing into smaller pieces so that, at present, the rock section (Z_3 661) has assumed the form of a quartzite conglomerate. But the simultaneous extinction under the microscope of three or four rounded pebbles of quartz in close contiguity, give the clue to the crushed nature of the large pieces of quartz" (Sampat Iyengar, 1908, p.72).

The writer fails to understand how, after pressure had acted on the pebbles and rounded them, they could still preserve their original crystallographic orientation.

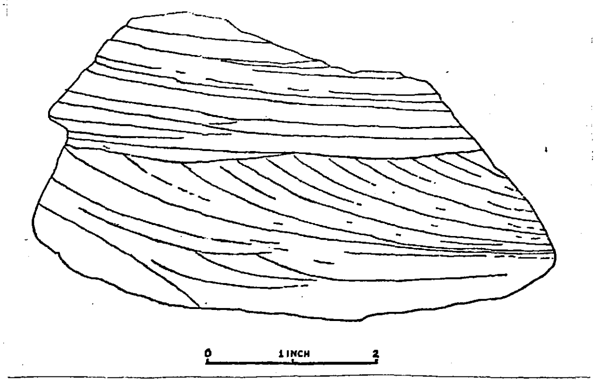


FIG. 2

The most remarkable feature noticed by the writer in the quartzites is the occurrence of cross-bedding. Very good specimens were collected from the quartzites north of Allampur. The above figure is a sketch of one of the specimens. The bedding planes are seen in these rocks because of the deposition of ferruginous material along them.

These facts of observation therefore definitely suggest that the quartzites are not of vein origin, as has hitherto been considered in Mysore, but are ordinary sedimentary arenaceous rocks.

III. THE CONGLOMERATES.

Description.

Till the year 1908, the conglomerates occurring in the various schist belts were considered to be sedimentary. Later, Smeeth examined the Mallapanhalli and Aimangala conglomerates of the Chitaldrug Schist Belt, and pointed out certain evidences which according to him, were in favour of their being considered as autoclastic in character and not of the nature of true sedimentary conglomerates (Smeeth, 1910, pp.15-18,34-35). This idea was soon extended to all the other conglomerates of Mysore; everyone of these was shown to fit in with the 'autoclastic' theory, and the original suggestion of some of these being sedimentary came to be completely abandoned.

The Shimoga Schist Belt contains several very well-developed beds of conglomerates, of which the most important is the occurrence at Kaldurga (Vide Plate VII). Bruce Foote (1882, p.195; 1900, pp.29-31) and Wetherell (1903, p.97) considered these conglomerates were sedimentary, but Slater thought that the matrix of the conglomerates was composed of quartz porphyry (1906, p.4). Ten years later, Smeeth made an examination of the Kaldurga area, and came to the conclusion that the conglomerates were autoclastic and not sedimentary, though he admitted that "a few portions which show very rounded pebbles of quartzite in a schistose matrix are difficult to explain"(Smeeth, 1915, p.25). Sampat Iyengar also studied these rocks and reiterated the autoclastic origin of the conglomerates which he considered as "a mixture of various complexes brought about by crush and shear movements operating on the previously existing schist rock and on the igneous intrusives into them" (Sampat Iyengar, 1917, p.115). Jayaram also was of this opinion, and according to him, this conglomerate was "very instructive for studying the pebble formation in an igneous rock, which must have had a viscous flow condition favourable for the formation of phenocrysts,

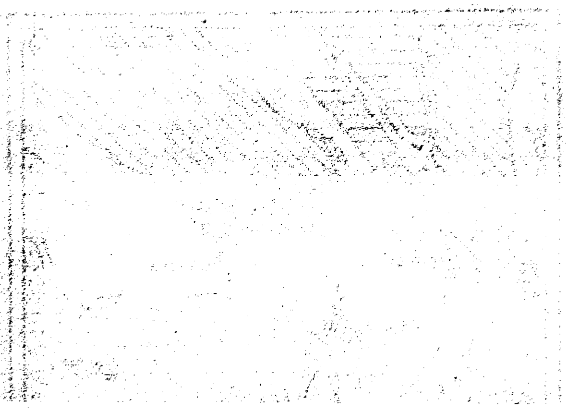
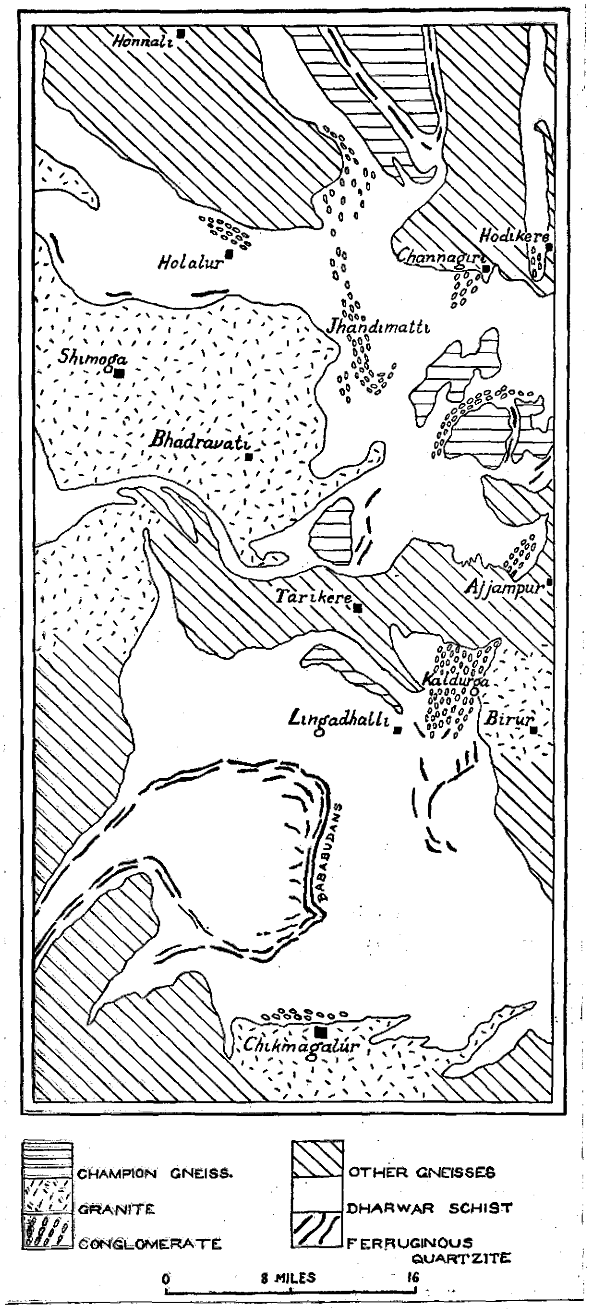


PLATE VII.

Geological sketch map of a portion of the Shimoga Schist Belt, showing the distribution of the main outcrops of conglomerates.

(From the writer's paper on "The Conglomerates and Grits of Kaldurga, Kadur District, Mysore". Proc. Ind. Acad. Sci. Vol ii, 1935)


Honnali
Holalur
Channagiri
Hodikere
Jhandimatti
Shimoga
Bhadravati
Tarikere
Ajjampur
Kaldurga
Lingadhalli
Birur
BABABUDANS
Chikmagalur
CHAMPION GNEISS.
GRANITE
CONGLOMERATE
OTHER GNEISSES
DHARWAR SCHIST
FERRUGINOUS QUARTZITE
0
8 MILES
16

knots, acid and basic segregations, and schlieren that have on subsequent shearing assumed the conglomerate form" (Jayaram, 1922, p.64).

No further work has been done since then on these conglomerates and so the autoclastic theory remains at present the official opinion of the Mysore Geological Department regarding the origin of these rocks. It was with a view to throw some definite light on the problem of the origin of the conglomerates, that the writer undertook a detailed study of the Kaldurga area.

Plate VIII illustrates the geology of Kaldurga and its environs. The conglomerates and grits overlie the associated spilites and keratophyres. They could be divided into two series: a lower, characterised by the abundance of chlorite, and an upper, which is more gritty and in some cases felspathic. The lower division is typically schistose, whereas exposures of rocks belonging to the upper division are bouldery, and resemble granitic outcrops. Many of the huge boulders stand out as prominent tors and form the range of hills from Rajanhalli to Mundre.

Due to crushing, the lower chloritic schists often present, under the microscope, the typical appearance of a sheared grit (Plate X, Fig.1). In the conglomerates of the upper division, it is not uncommon to see pebbly bands alternating with very fine-grained non-pebbly bands. To a casual observer, these bands suggest rocks of different composition, but an examination of slices cut from them, proves their identity; the finer bands represent the material which ser-

PLATE VIII.

FIG. 1. Geological sketch map of Kaldurga and surroundings.

FIG. 2. Section along A-B in Fig. 1.

(From the writer's paper on "The Conglomerates and Grits of Kaldurga, Proc. Ind. Acad. Sci. Vol ii, 1935)

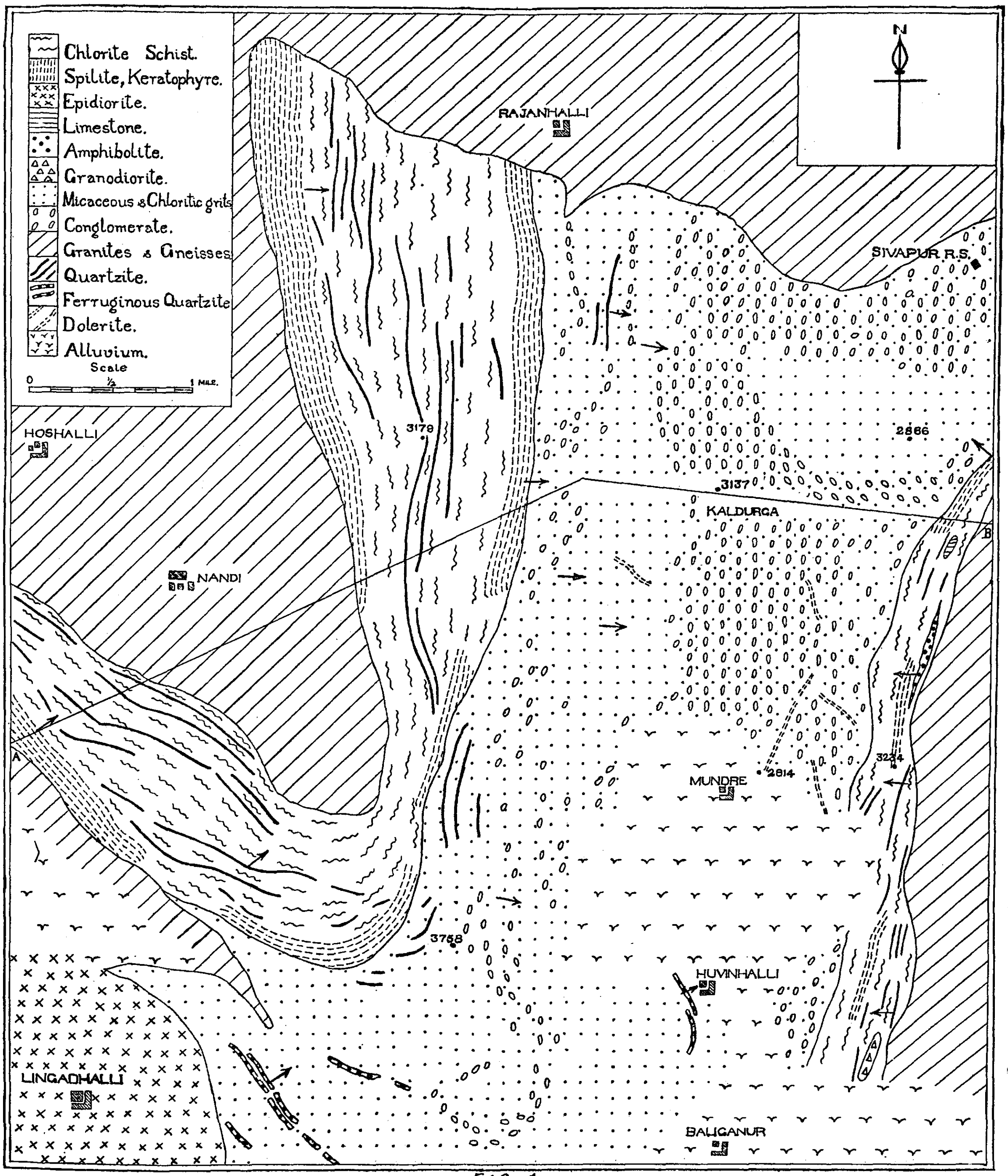

Chlorite Schist.
Spilite, Keratophyre.
Epidiorite.
Limestone.
Amphibolite.
Granodiorite.
Micaceous & Chloritic grits
Conglomerate.
Granites & Gneisses
Quartzite.
Ferruginous Quartzite
Dolerite.
Alluvium.
Scale
0
½
1 MILE.
N
RAJANHALLI
SIVAPUR R.S.
HOSHALLI
NANDI
3179
2866
3137
KALDURGA
B
A
3234
MUNDRE
2814
3758
HUVINHALLI
LINGADHALLI
BALIGANUR

FIG. 1

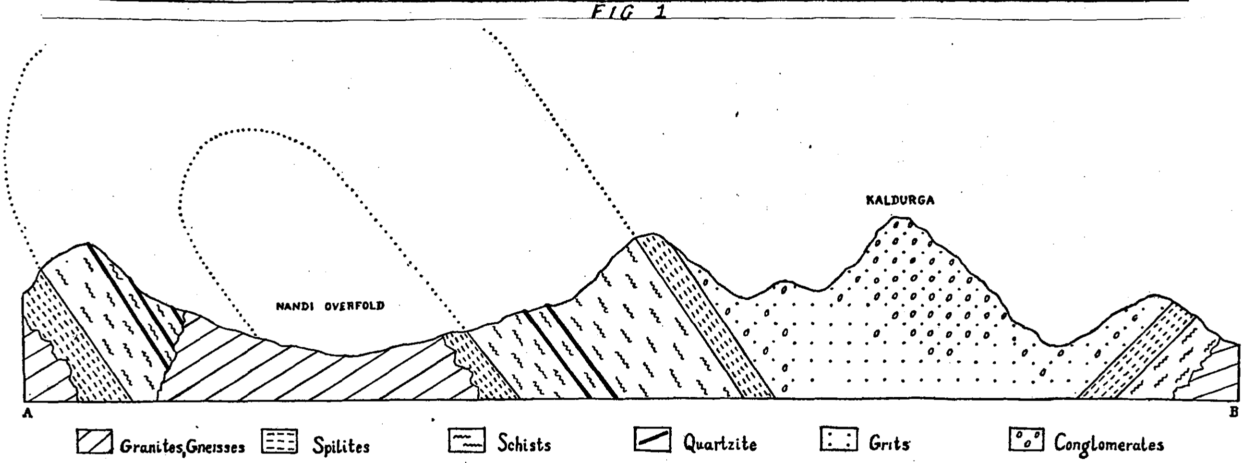

KALDURGA
NANDI OVERFOLD
A
B
Granites, Gneisses
Spilites
Schists
Quartzite
Grits
Conglomerates

FIG. 2.

ves as the matrix in the pebbly layers.

Extremely fine varieties of pebbly grits are seen on the hills about a mile west of Baliganur. The outcrops in this place exhibit graded bedding. The rock here has layers about a foot in thickness, one overlying the other.

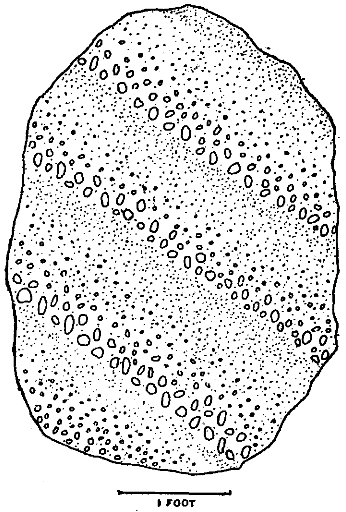


FIG. 3.

Each layer starts with a more or less coarse pebbly character and gradually becomes finer and finer, till the next layer again starts abruptly with coarse pebbles grading on into fine (Pichamuthu, 1935a, p.431). In some cases a crude current bedding was observed which also exhibited grading.

The coarse grits are composed of small fragments of various types of rocks. This is well seen in thin sections (Plate X, Fig. 2). Many of the individual grains in the grits are composed of quartzite, but small fragments of granite, spilite, keratophyre and phyllite are common. The rock has been subjected to pressure, resulting in many of the fragments flattened and drawn out, but their boundaries are quite distinct and do not merge into the matrix.

The Pebbles and the Matrix.

The conglomerate contains pebbles of various sizes. In some cases they are as much as 12" to 18" in diameter, and they grade down into very small sizes in the pebbly grits. In certain areas pebbles are abundant, and in others , their occurrence is sporadic. In the same outcrops it has been noticed that some bands are very rich in pebbles and that these bands alternate with others which do not contain any. The pebbles may be of various shapes but oval and rounded ones are of frequent occurrence; and almost everyone of them exhibits some degree of polishing.

The conglomerate is often crowded with pebbles of a varied petrographical character. Plate IX is a photograph of a specimen about 6" x 9", collected by the writer from the south of Kaldurga. This hand-specimen contained nearly thirty pebbles composed of such different types as granite, microgranite, pegmatite, quartz-felspar porphyry, vesicular spilite, gneiss, quartz schist, and quartzite.

As the result of a careful collection from this area the writer obtained pebbles of granite, gneiss, pegmatite, aplite, microgranite, granodiorite, granophyre (Plate X, Fig. 3), amphibolite, hornblende schist, serpentine, quartz-felspar porphyry (Plate X, Fig. 4), felsite, rhyolite, keratophyre, albite dolerite, spilite, quartzite (Plate X, Fig. 5), quartz schist, magnetite quartzite (Plate XI, Fig. 1), phyllite, and limestone (Plate XI, Fig. 2).

The matrix of the Kaldurga conglomerate is not quite

PLATE IX.

$\frac{3}{4}$ natural size. Hand-specimen of Kaldurga conglomerate containing eight different kinds of pebbles. 1. Granite. 2. Gneiss. 3. Microgranite. 4. Pegmatite. 5. Quartz-felspar porphyry. 6. Spilite. 7. Quartz schist. 8. Quartzite.


1
1
4
7
8
1
6
8
1
1
5
2
1
1
3
2

uniform in composition throughout the area. It grades from chlorite and mica-chlorite schist, through gritty chlorite and mica schists, to quartz schists. In the upper division, the matrix may in some places be designated as an arkose because of the presence of grains of albite. Some of the grits which contain a good deal of chloritic and micaceous minerals could be described as greywackes. Ferruginous material is abundant in some cases. Calcite occurs in grains and in irregular patches. Minute rutiles are common, especially when the matrix contains plenty of chlorite and mica. Muscovite is often present in abundance (Plate XI, Fig. 3).

Mode of Origin of the Conglomerates.

After a detailed study of these conglomerates both in the field and in the laboratory, the writer has come to the conclusion that the autoclastic theory cannot be applied to explain the origin of these rocks. The following are some of the data which definitely suggest a sedimentary origin.

i. Shape and rounding of pebbles.- From Plate IX, the water-worn appearance of the pebbles can be readily inferred.

ii. Sharp boundary between pebbles and matrix.- From slightly weathered specimens, the pebbles can be easily dislodged, when they leave smooth-walled depressions. The boundaries of the pebbles are usually clean and marked by films of chlorite. This sharp demarcation is well-seen even under the microscope (Plate XI, Figs. 4 and 5).

iii. Varied assemblage of pebbles.- The occurrence of different types of rocks as pebbles has been explained by the

PLATE X.

FIG. 1. Ordinary light. Sheared chloritic grit. The colourless areas are formed of quartz and the dark portions, mostly of chlorite. × 22.

FIG. 2. Ordinary light. Grit, 1 mile west of Baliganur. A fragment of spilite is present. The colourless areas are fragments of vein quartz and quartzite. × 22.

FIG. 3. Crossed nicols. Section of granophyre pebble. A crystal of plagioclase is surrounded by micrographic intergrowth. × 30.

FIG. 4. Crossed nicols. Section of pebble of quartz-felspar porphyry. The felspars are albites. × 22

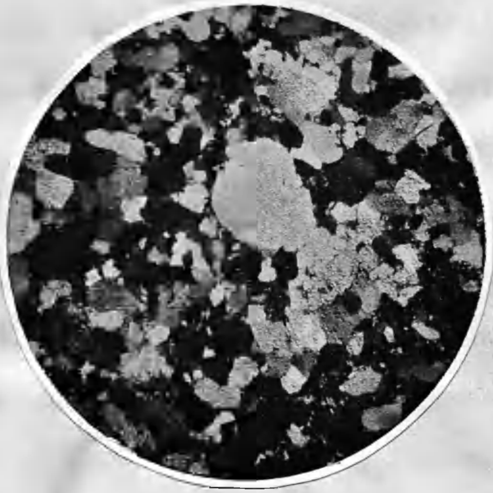
FIG. 5. Crossed nicols. Section of quartzite pebble with typical mosaic texture. × 22.

1

2

3

4



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supporters of the autoclastic theory as due to the crushing of a complex containing different rocks as xenoliths. While prepared to admit that some of these rock types can occur as xenoliths in granite, the writer fails to see how so many different pebbles can be found aggregated within the space of a few square inches, for this implies the breaking up of the xenoliths and a bodily migration of the pebbles caused by thorough churning of the rock during or after the formation of the pebbles; these are assumptions which are extremely improbable.

iv. Difference between pebbles and matrix.- Well-marked differences between pebbles and matrix are naturally to be expected when there are so many types of rocks represented among the pebbles. This difference is not easily noticed when pebbles of granite or gneiss are found in the upper division of the conglomerates, or when pebbles of schist occur in the lower division. But identity between pebbles and matrix cannot be proved by selecting one out of the several types of the pebbles occurring in the conglomerate and showing its resemblance to the matrix. To consider all the other varieties of pebbles which do not conform with the matrix as xenoliths or segregations (as has so far been done in Mysore) is also, in the writer's opinion, inadmissible.

A very suggestive difference between the pebbles and the matrix is furnished by the distribution of rutile. Grains of this mineral are abundant in the matrix but are decidedly of sporadic occurrence in almost all the pebbles.

Also, the matrix of the Kaldurga conglomerate is often schistose as the result of pressure, but there is no parallelism or relationship between this schistosity and the banding of the quartzite or gneiss pebbles; these are arranged anyhow.

Veins occurring in the pebbles stop abruptly at their boundary with the matrix. This is very well seen both in the field and in microsections.

v. Alternation of pebbly and non-pebbly bands.- This alternation often imparts a banded nature to the outcrops. The non-pebbly layers are somewhat deeper in colour than the pebbly bands. Slater observed this feature but did not offer any explanation (Slater, 1906, p.3). Sampat Iyengar in attempting to account for it by invoking purely igneous phenomena, has suggested that this banding is the result of "an initial segregation into layers of normal, acid and basic portions in the gneissic granite"-- a very difficult explanation. The writer considers that this banding can be satisfactorily accounted for by the sedimentary theory, as it is a phenomenon met with in many normal conglomerates. The pebbles are obviously not supplied uniformly, and at certain stages only finer material is deposited. That there is no other difference between these bands could be readily seen under the microscope, for the material composing the fine-grained bands is identical with the matrix cementing the pebbles in the conglomeratic bands.

vi. Graded and current bedding.- The recognition by the writer of graded bedding and current bedding for the first time in Mysore, is convincing proof that this formation is sedimentary.

vii. Absence of pebbles of age posterior to the matrix.- Hill, who was one of the earliest British geologists who recog-

PLATE XI.

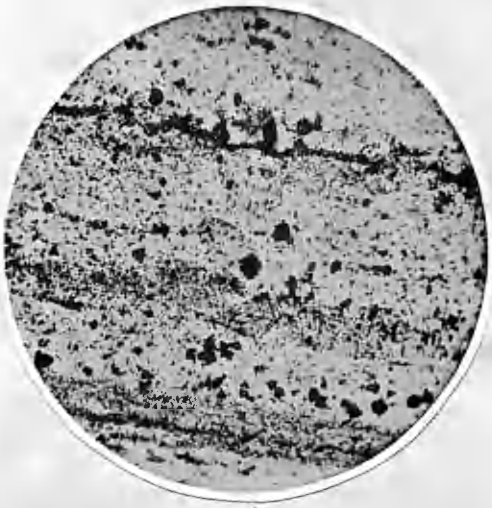
FIG. 1. Ordinary light. Section of magnetite quartzite pebble. It is not so ferruginous as the typical haematite and magnetite quartzites of the Bababudans. The banding is emphasised by the parallel arrangement of minute octahedra of magnetite. × 22.

FIG. 2. Ordinary light. Section of limestone pebble. Chlorite and magnetite are associated. × 22.

FIG. 3. Ordinary light. A portion of the matrix. The abundant colourless mineral is muscovite, which is associated with chlorite. × 22.

FIG. 4. Crossed nicols. The texture illustrates the sharp boundary between a granite pebble and the fine-grained quartzose matrix. × 22.

FIG. 5. Ordinary light. The dark thin line separating the pebble from the matrix is composed of chlorite. × 22.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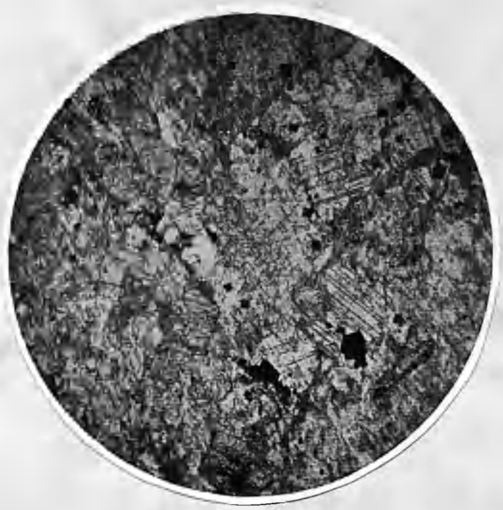
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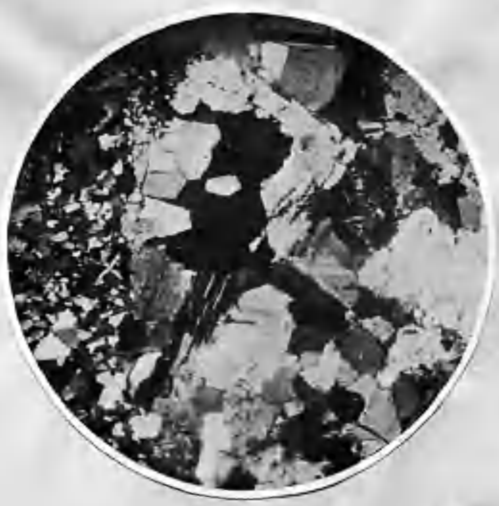
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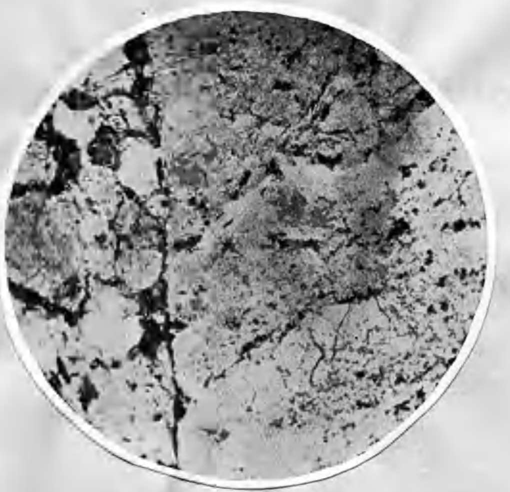
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nised the occurrence of crush-conglomerates, states that "in doubtful cases, the only safe test of original deposition is the presence of foreign fragments sufficiently large to escape being confounded with the materials which form the matrix. Similarly, the most satisfactory proof of deformational structure is the inclusion of igneous boulders derived from rocks posterior in age to the matrix" (Hill, 1901, p.327). The only rocks which are distinctly of later age in the Kaldurga area, are the granites of the Tarikere valley, and those occurring near Kadur and Birur. These granites contain plenty of orthoclase and microcline, and it is very significant that the granite pebbles occurring in the conglomerates do not bear these felspars.

Regarding the pebbles of ferruginous quartzite, examination of parts of the Shimoga belt has convinced the writer, that the banded quartzites were not deposited at one particular period, but that there were varying intervals of time between the deposition of the several beds. In the Kaldurga area, the banded ferruginous quartzites are distinctly older than the conglomerates, and hence their occurrence as pebbles is naturally to be expected.

The presence of pebbles of vein quartz and the occurrence in the area of runs of vein quartz, has caused some confusion; but it must be recognised that the veins are not all of the same age. Those connected with the intrusion of the later granites are, of course, later than the conglomerates, and they do not show any signs of pebble formation.

viii. The evidence of the grits.- The assemblage of varied types of rocks occurring as pebbles in the conglomerate has already been mentioned. This phenomenon is sometimes more characteristically noticed in the associated grits. The small fragments making up the grits are often of different petrographic types. In slices cut from one hand-specimen, the writer has recognised fragments of granite, pegmatite, micropegmatite, keratophyre, quartz grains, and quartzites of different grain sizes. Several of these are often seen within the compass of a single microsection (Plate X, Fig. 2). The boundaries of these fragments are quite distinct. It would be extremely difficult to explain this intimate mixture of various types of rocks by considering that they are crushed xenoliths. Deposition under water is indicated.

The above-mentioned data definitely indicate that these conglomerates in the Shimoga Schist Belt are of normal sedimentary origin. After their formation they have been subjected to severe dynamic metamorphism, and as result of this, the rock has often developed a schistose structure and the pebbles rolled out, elongated, flattened, or converted into lenticular shapes. It is these evidences of pressure which are mainly responsible for these rocks having been considered so far as examples of crush-conglomerates.

IV. EPIDIORITES.

Epidiorites occur both as flows and intrusives in the Shimoga belt, but no detailed petrological descriptions of these rocks have hitherto been published. They are strongly developed in the Bababudan area and their distribution may be seen from Plate II.

Epidiorite Flows.

A large area to the east of the Bababudan ranges is covered by rocks which are referred to in the publications of the Mysore Geological Department as the Lingadhalli trap, Santaveri trap, hornblendic lava, hornblende schist and so on. The writer examined these rocks from Chikmagalur to Lingadhalli and Nandibatlu and found that they are all epidiorites with only minor differences. The rock is chiefly composed of a pale green hornblende which is often fibrous. The plagioclase is often of an acid variety. A little quartz is commonly present. Granular epidote is usually abundant; the mineral is sometimes idioblastic. Ilmenite occurs invariably altered to leucoxene.

The rocks occurring to the south and south-east of the Bababudan ranges, have been differentiated into a coarse and a fine type. The writer traversed this region and found that this classification is unwarranted since there is no defined boundary separating the coarse from the fine textured rocks.

These epidiorites underlie the iron formations of the Bababudans. A specimen selected at the foot of these hills, below the ferruginous quartzites was analysed by Mr. W.H.Herdsman and the results are given in column I of Table IV. Column II is an analysis of the epidiorite from near Santaveri. This analysis is rather incomplete since H_2O +, H_2O -, and CO_2 have not been determined.

The Mysore geologists were of the opinion that these rocks were not amygdular, and that the 'spots' and patches present in them were due to crushing of quartz phenocrysts (Slater,

TABLE IV.

	I	II
SiO_2	56.10	51.82
Al_2O_3	13.47	9.77
Fe_2O_3	1.82	3.93
FeO	9.77	6.54
MgO	4.01	10.51
CaO	6.90	9.73
Na_2O	2.32	1.03
K_2O	0.74	0.16
H_2O +	2.40	n.d.
H_2O -	0.40	n.d.
CO_2	-	n.d.
TiO_2	1.80	1.54
MnO	0.16	tr
P_2O_5	0.16	n.d.
	100.05	

I. Epidiorite, 7th. furlong, 30th. mile on the Chikmagalur-Lingadhalli ghat road. Analyst: W.H.Herdsman.

II. Epidiorite, Santaveri.

1906, p.12) or _in situ_ alterations of porphyritic crystals of hornblende (Slater, 1908, p.48). According to Sampat Iyengar, some of the 'spots' were amygdular, some were due to the _in situ_ alterations of plagioclase phenocrysts, and some others were formed by the brecciation of quartz or epidote veins (Sampat Iyengar, 1908, p.70).

PLATE XII.

FIG. 1. Vesicles in the epidiorite flows with very regular rounded or oval outlines. The infilling minerals are concentrically arranged.

FIG. 2. The vesicles are often connected by feeder veins. As the result of contact metamorphism, tufts of fibrous actinolites are developed on the borders of the vesicles.

FIG. 3. A compound vesicle with zonary deposition of the infilling minerals. A thin vein connects the cavities.

FIG. 4. Vesicle showing 'ghosts' of former chalcedony. The grains of quartz are optically continuous through them. The centres of the vesicles are filled by chlorite.

FIG. 5. Vesicle with 'titanomorphite' border. An inner lining (dark) is broken into several fragments and healed by epidote and quartz.

FIG. 6. Vesicle filled almost completely by epidote.

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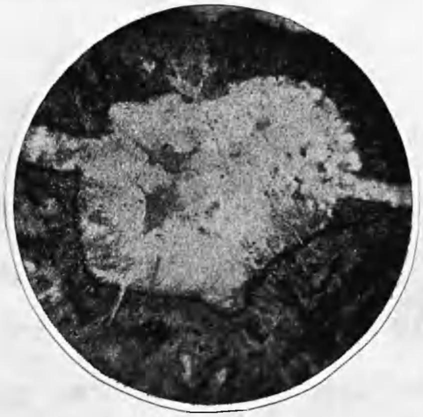

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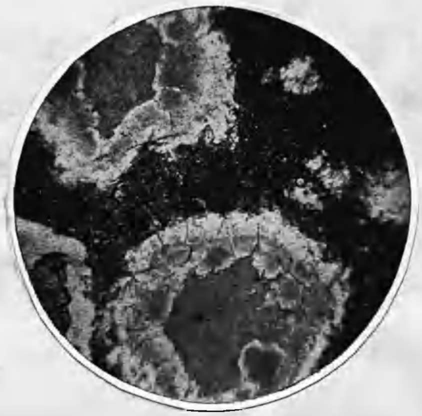

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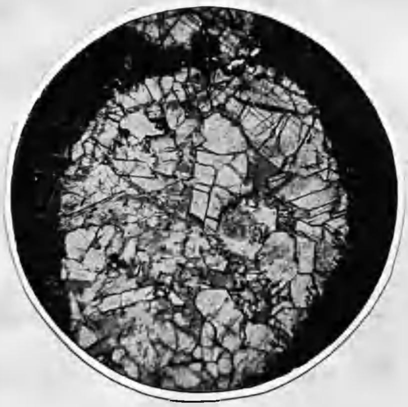

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Because of such great differences of opinion regarding the mode of origin of these 'spots', the writer undertook a careful examination of the patches so as to throw some definite light on their genesis.

The average size of these 'spots' ranges between 0.25 cm. and 0.5 cm. Most of the vesicles are generally spherical or oval (Plate XII, Fig. 1), but some are irregularly shaped. Compound vesicles formed by the fusion of two or more cavities are also frequently met with. Small veins, composed of the same minerals as fill the vesicles, are sometimes found connecting the cavities (Plate XII, Fig. 2).

The vesicles have usually a dark border of titanomorphite which, in reflected light, is fluffy white, being composed of specks of leucoxenic material and granules of sphene.

The following minerals were recognised by the writer in the vesicles: delessite, penninite, actinolite, epidote, zoisite, clinozoisite, quartz, pyrites, magnetite, and calcite (Pichamuthu, 1932,pp.129-131).

Slater, while surveying the Lingadhalli area in 1905, came across a colourless mineral of somewhat radiating habit and low relief, and as the result of a casual microscopic examination, identified it as a zeolite (Slater, 1906, p.14). The writer made a study of this mineral recently (Pichamuthu, 1935f , pp.157-160). In hand specimens, the mineral is white in colour with a vitreous lustre, and shows traces of a cleavage. The specific gravity as determined on small grains by the methylene iodide-benzol column, was found to be nearly

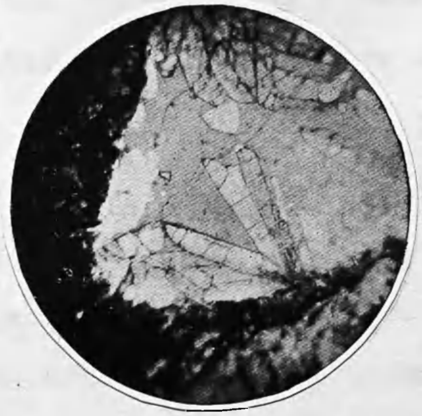
PLATE XIII.

FIG. 1. Ordinary light. A vesicle in the epidiorite flow showing crystals of epidote growing from the borders.

FIG. 2. Ordinary light. Vesicle filled completely by calcite.

FIG. 3. Crossed nicols. Vesicle filled mostly by plagioclase felspar. x 16.

FIG. 4. Crossed nicols. A portion of the above amygdale magnified. x 36.



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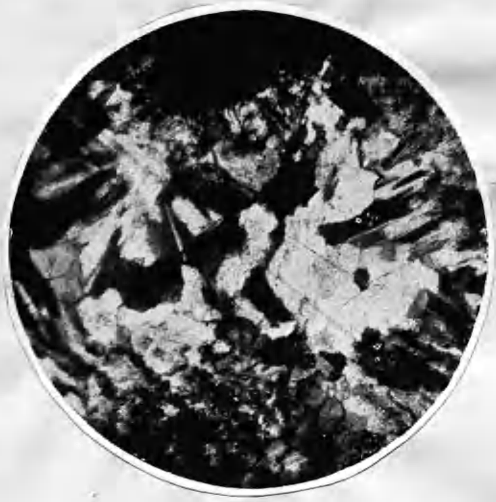

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2.65, just a little less than quartz. Under the microscope, the mineral is colourless but somewhat dusty, and often radiating or fan-shaped. The average refractive index in white light is 1.545. Between crossed nicols multiple twinning is frequently well seen. The mineral exhibits very low polarisation colours, the birefringence being nearly 0.008. The angles of extinction are small. The optic axial angle and the optical character of the mineral were both determined on the Federow Universal Stage; 2V = 85° 44', and the sign negative. Uncovered sections were stained with malachite green after gelatinisation, but the mineral was free from stains even after prolonged treatment.

The above physical and optical characters show that the mineral does not belong to the zeolite group, but that it is one of the plagioclase felspars. The optic axial angle, specific gravity, refractive index, the small angles of extinction, and the sign of the mineral, all these data narrow it down to a plagioclase of composition Ab_{65} An_{35}, a type intermediate between oligoclase and andesine.

In view of the secondary nature of this felspar, its frequent radiating habit, and the easy conversion of zeolites into felspars, the writer considers it extremely probable that it has been formed by the alteration of some zeolitic mineral which originally filled the vesicles of the Lingadhalli traps.

The siliceous infillings of the cavities are now composed entirely of quartz. But in several vesicles careful examination reveals the banded form of deposit so characteristic of chalcedonic infiltrations. The chalcedony, however, has been completely transformed into quartz, but its former presence is now indicated by "ghosts" (Plate XII, Fig. 4).

All these characters and others, such as the occurrence of compound vesicles, and the zonal deposition of the infilling minerals (Plate XII, Fig. 3), indicate that these 'spots' are true amygdales. The Lingadhalli traps are, therefore, typical lava flows, with steam cavities filled in by secondary minerals.

Associated with these epidiorites, there are certain basic rocks characterised by the presence of laths of albite. They are sometimes doleritic in texture, but usually basaltic. No pyroxenes are present, the mafic mineral being chiefly chlorite or hornblende. These belong to a spilitic type.

Epidiorite Intrusives.

The banded ferruginous quartzites of the Bababudans are intruded by sills and dykes of epidiorite, which originally might have been quartz dolerites. These rocks have been wrongly identified and described as 'diorite porphyry' in the publications of the Mysore Geological Department, presumably because of the occurrence of prisms of hornblende in them. A microscopic examinations of thin sections of this rock, reveals the secondary character of the hornblende which exhibits sieve structure. The texture of the rock is ophitic. The felspars are albitised. Plates of ilmenite altering to leucoxene are common.

The chemical composition of the intrusive epidiorite can be seen from column I of Table V. A and B are analyses of quartz dolerites described by Dr. Tyrrell from Arran and with which the Mysore rock agrees very closely. Under column P is given, for comparison, the average chemical

TABLE V.

	I	A	B	P
SiO_2	54.40	54.52	54.00	52.46
Al_2O_3	14.27	14.53	13.09	16.77
Fe_2O_3	2.35	2.21	3.53	3.92
FeO	9.50	6.06	8.45	5.44
MgO	5.75	5.61	3.49	5.20
CaO	4.90	8.08	5.55	6.23
Na_2O	2.94	3.66	3.27	2.58
K_2O	1.92	1.14	1.80	1.39
H_2O +	2.10	0.93	1.71	3.28
H_2O -	0.20	1.95	1.26	
TiO_2	1.20	0.87	2.83	0.45
P_2O_5	0.10	0.21	0.31	0.16
MnO	0.25	0.24	0.37	-
CO_2	-	-	0.25	2.14
S	tr	-	-	-
FeS_2	-	-	0.14	-
BaO	-	0.02	0.02	-
	99.88	100.03	100.07	100.02

I. Epidiorite, Kemmangandi, Bababudan Hills. Analyst: W.H.Herdsman.

A. Quartz dolerite, dyke, Arran. Analyst: E.G. Radley. (Tyrrell, 1928, p.254).

B. Quartz dolerite, sill, Arran. Analyst: E.G. Radley. (Tyrrell, 1928, p.147).

P. Keewatin greenstone, average composition. (Zappfe, 1912, p.149)

composition of the basic Keewatin greenstones which are intrusive into the Lake Superior iron-bearing formations of the

Gunflint district, and which have been described as metadolerites and metabasalts by Clements (1903).

One of the effects of the intrusion of the epidiorites is seen in the induration of the haematite quartzites which become highly compacted and tough. The banding of the quartzites has been emphasised, and the ironstones in the neighbourhood recrystallised. Observations made by the writer in the Bababudan area make it clear that magnetite is predominant in the ironstones near the epidiorite intrusions, and hence its origin is directly traceable to the influence of contact metamorphism.

The most conspicuous example of change ascribable to the intrusion of the epidiorite, is in the development of amphiboles like bababudanite and cummingtonite. As has been mentioned earlier, these minerals were considered by Smeeth and Sampat Iyengar to be original, but recent field examination by the writer has shown that they are developed only in zones near the contact of the epidiorite intrusives.

V. FELSITES.

To the east of the Bababudan ranges, there is an area of about ten square miles which is occupied by a dark compact rock. Apart from a mere mention of the occurrence of this rock, no petrological description has been given in the Records of the Mysore Geological Department. There are very good exposures of this rock near Galipuje (Vide Plate II). The specific gravity of the rock is 2.74.

TABLE VI.

	I	A	B	II
SiO_2	70.60	70.70	69.48	72.73
Al_2O_3	11.50	11.78	11.99	10.57
Fe_2O_3	3.02	1.32	2.54	5.80
FeO	3.16	3.45	2.46	
MgO	0.12	0.53	1.16	0.98
CaO	3.00	1.30	1.72	2.19
Na_2O	3.26	2.48	3.33	3.09
K_2O	2.23	4.71	4.01	2.71
H_2O +	1.00	1.14	1.56	-
H_2O -	0.50	0.50	0.32	-
CO_2	0.90	0.51	1.34	-
TiO_2	0.58	1.27	0.14	1.07
MnO	0.14	0.07	0.20	0.40
P_2O_5	0.10	0.26	0.08	-
S	-	0.08	-	-
FeS_2	-	-	0.05	-
	100.11	100.10	100.38	99.54
Sp.Gr.	2.74			2.73

I. Felsite, Galipuje, Kadur District. Analyst: W. H. Herdsman.

A. Felsite, South of Coire Buidhe, Mull, Scotland. Analyst: F.R.Ennos. (Bailey and Clough, 1924, p.20)

B. Felsite allied to keratophyre, Lennoxtown, Stirlingshire. Analyst: E. G. Radley. (Clough, 1925, p.185)

II. Quartz Porphyry, West of Sulekere tank, Shimoga District, Mysore.

Under the microscope, the rock is composed of abundant granoblastic quartz with flakes of biotite arranged as in a schist. The slide is peppered with minute grains of magnetite. Idiomorphic crystals of albite are common; since the rock has been subject to dynamic metamorphism, these crystals are sometimes broken. The albites are often bordered by biotite. Apatite in acicular crystals occurs as an accessory.

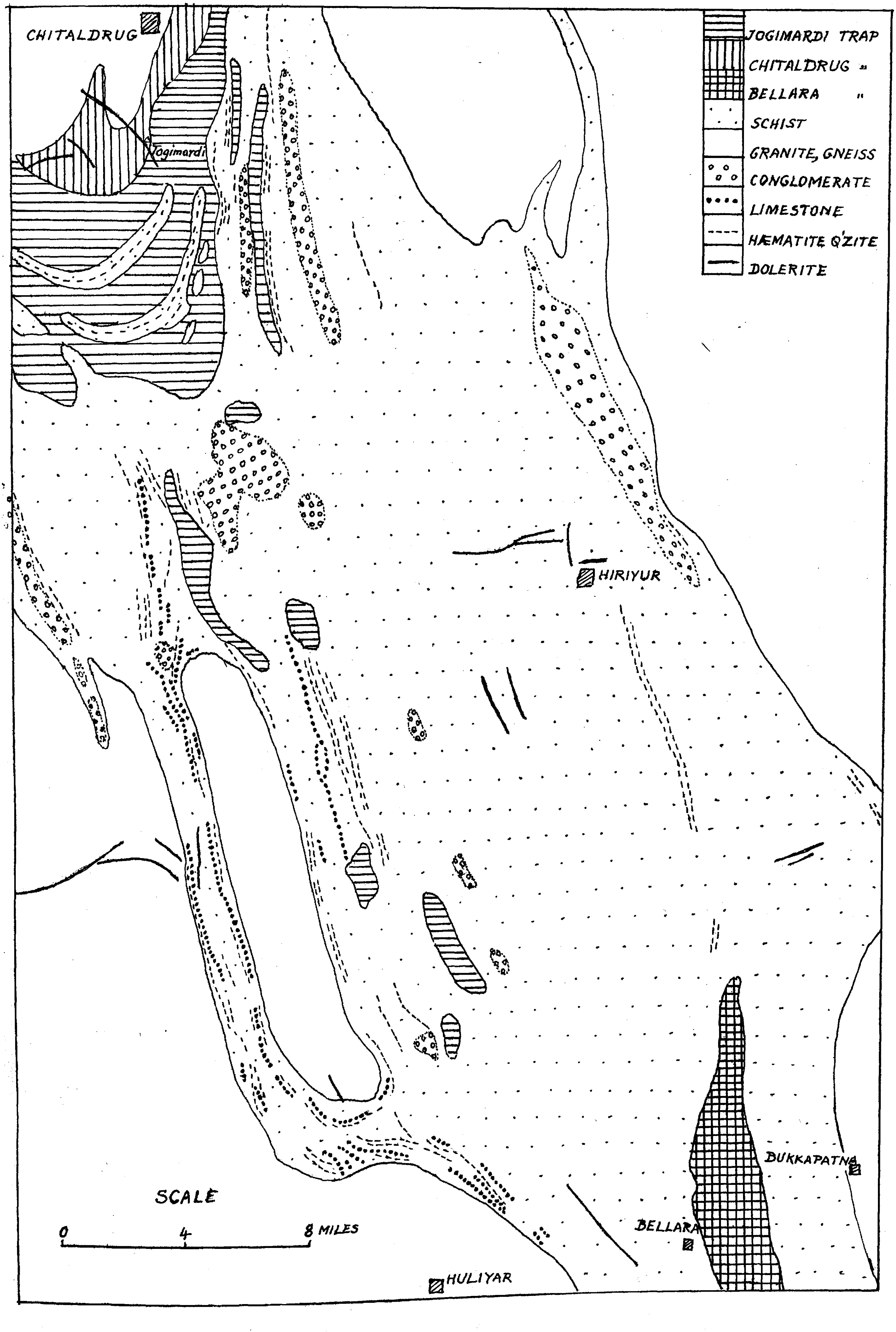
This rock had not so far been analysed and so an analysis was made for me by Mr. Herdsman. The results are given in column I of Table VI. A and B are analyses of felsites from Scotland. B is allied to a keratophyre and contains porphyritic crystals of albite-oligoclase replaced by calcite and chlorite, in a microlithic to patchy felsitic matrix composed of alkali felspar and quartz with chlorite and magnetite -- a description which agrees well with the Galipuje rock. P is an analysis of quartz porphyry collected by Sen from near the Sulekere tank, which is further north in the same Shimoga Belt (Sen, 1916, p.153). This resembles the Galipuje rock very closely.

3. CHITALDRUG SCHIST BELT.

The Chitaldrug Schist Belt runs through the middle of the State with a north-north-west trend in the Chitaldrug District, where it has a maximum width of about 25 miles, and passes southwards through the Tumkur and Mysore Districts in which it becomes split up into narrow bands finally disappearing a few miles south of Seringapatam. The belt extends north of the State into the Bombay Presidency, the total length in Mysore being about 170 miles and the area nearly 2000

PLATE XIV.

Geological sketch map of a portion of the Chitaldrug Schist Belt showing the distribution of the chief outcrops of trap rocks.



JOGIMARDI TRAP
CHITALDRUG "
BELLARA "
SCHIST
GRANITE, GNEISS
CONGLOMERATE
LIMESTONE
HÆMATITE Q'ZITE
DOLERITE
CHITALDRUG
Jogimardi
HIRIYUR
BUKKAPATNA
BELLARA
HULIYAR
SCALE
0
4
8 MILES

square miles.

TRAP ROCKS.

Forming a part of the schist belt, there are certain basic rocks with somewhat similar field characters which have been referred to in the Records of the Mysore Geological Department as the Bellara trap, the Jogimardi trap, the Chitaldrug grey trap, trappoidal hornblende schist etc., but no attempt had so far been made to make a comparative study of these somewhat isolated outcrops (Vide Plate XIV); nor had their chemical or petrographical characters been worked out. It was to remedy these omissions that the writer undertook a study of these rocks. The work was greatly facilitated by the courtesy of the Director of Geology in Mysore who kindly placed at the writer's disposal, microsections, museum specimens, and field note books of the Departmental geologists.

Jogimardi Trap.

Very brief references to this type are made by Bruce Foote (1888, p.53; 1900, pp.18,20), Sambasiva Iyer (1899,p.100) and Smeeth (1899, p.169). Sampat Iyengar (1905, pp.77-82) was of the opinion that these rocks belonged to a volcanic series which intruded and flowed out over the top of the schists. The patches of chlorite schist that were found in their midst were supposed to represent such portions as were not covered by the flow, or that were covered but subsequently had the lava cap removed by denudation. Later, Smeeth came to the conclusion that these traps were not lava flows but that they occurred as dykes and intrusive sheets in the Chitaldrug schists (Smeeth, 1910, pp.21-24).

Textural differences are noticed in these rocks. Many of them are very compact and fine-grained and some of the slices could be described as a glass. The coarser rocks exhibit ophitic and sub-ophitic textures. Porphyritic types are also met with, the phenocrysts being of big plagioclases.

Augite relicts are seen but are usually altered to pale hornblende or chlorite. Beginning with the augite, which in thin sections is practically colourless, it is seen that it first alters into a yellowish-brown hornblende with very faint pleochroism. This is changed at the periphery to a green or pale green hornblende which has a more pronounced pleochroism from yellow to yellowish-green to green. This green hornblende is however often formed directly from the augite without the intermediate stage. Sometimes the secondary hornblende is replaced by a group of small crystals of hornblende which are commonly prismatic or acicular in form. Such pale green acicular crystals are occasionally found as a fringe to the larger crystals when these present a somewhat frayed appearance. In some of the schistose types, the whole of the new mineral is seen to be composed of a bundle of fibrous crystals. The hornblende is often twinned.

The plagioclases are usually turbid due to saussuritisation. According to the texture of the rock, the felspars are found either as minute laths or as coarse grains and sometimes as idiomorphic crystals. In some of the rocks which have been recrystallised, there is a partial clarification, but in other cases they are altering usually into a low polarising epidote, probably clinozoisite. Occasionally radiate aggregates of felspar crystals intersecting one another at the middle, are present.

Quartz xenocrysts are common; they usually possess a reaction rim of what is at present a zone of tufts and radiating needles of fibrous hornblende. The colour of these crystals of hornblende near the quartz grains are much paler than those farther away from them.

Pale yellow epidotes polarising in bright colours are seen in a few sections. Some of the idiomorphic epidotes associated with patches of chlorite, are zoned, the borders being usually more ferriferous than the cores; this is indicated by the lower polarisation colours in the centre and the higher colours in the outer zones. The more common variety, however, is colourless and both zoisite and clinozoisite may be recognised. These minerals have been formed by the decomposition of the felspars and the pyroxenes.

Calcite is not common but where the alteration is advanced, plenty of this mineral is found associated with chlorite and leucoxene.

Sphene occurs in small grains. Of the iron ores, ilmenite is the most common. It is sometimes seen altering at the periphery into sphene, but more commonly into leucoxene. Magnetite and pyrites are present in small quantities.

From the above description, it will be seen that the Jogimardi trap is an altered doleritic rock which can be designated as a diabase.

The first three analyses in Table VII give an idea of the chemical composition of these rocks.

TABLE VII.

	1	2	3	4	5
SiO_2	48.52	47.44	47.56	52.60	47 53
Al_2O_3	13.80	16.28	18.40	10.12	19.97
Fe_2O_3	3.65	3.27	2.04	3.84	2.86
FeO	9.83	9.76	10.00	12.73	8.74
MgO	5.88	5.20	6.66	6.17	2.14
CaO	10.92	11.22	13.28	9.36	12.59
Na_2O	3.70	2.94	2.29	2.27	1.53
K_2O	0.32	0.34	0.31	tr	0.18
TiO_2	1.04	0.90	0.68	1.12	1.93
P_2O_5	0.10	0.09	-	-	-
MnO	0.14	0.18	0.05	0.03	0.30
Loss on ignition	2.12	2.19	0.52	1.60	2.03
	100.02	99.81	101.79	99.84	99.80
Sp. Gr.	3.12	3.06	3.05	2.94	3.14

1. Fine-grained Jogimardi trap.
2. Porphyritic Jogimardi trap.
3. Medium-grained Jogimardi trap.
4. Dark hornblendic trap of Chitaldrug.
5. Bellara trap.

(All analyses by E.R.Tirumalachar)

Dark Hornblendic Trap of Chitaldrug.

The earlier observers considered the Jogimardi trap to extend right up to the Chitaldrug granite. It was Sampat Iyengar who first recognised the existence of two types of rocks in this area -- an inner zone of dark hornblendic trap next to the granite and an outer zone of the grey Jogimardi trap (Sampat Iyengar, 1905, p.71). The northern flanks of the Jogimardi hill (△3722) and the western slopes of △3060, north of Guddadrangavanhalli, are composed entirely of these rocks, which are in parts schistose.

The grey trap is intrusive into the dark hornblendic trap. Specimens collected at the contact of these two rocks show clearly the intrusive relationships. Slices cut from them show patches of the hornblendic rock caught up in a glassy grey trap which shows fluxion structure (Plate XV , Fig.3). The grey trap in these sections is formed of small laths and skeleton crystals of felspar in a glassy matrix full of spherical dots of leucoxene. The caught up portions are recrystallised, with the result that the hornblendes are quite clear with yellow to green to blue pleochroism.

In the field, the two types can be distinguished by the darker colour of the hornblendic trap, a character mainly due to the colour of the hornblende which is deep-tinted in contrast to the paler colour of this mineral in the grey trap.

In slices, the hornblende has a very well marked pleochroism from yellow to green to greenish blue. A few of the hornblende crystals are twinned. Remnant augites are not present in any of the slides of the hornblendic trap. The felspars are quite turbid due to alteration

The chief iron ore is magnetite. Sometimes a little iron pyrites is present. Ilmenite is not so abundant as in the Jogimardi trap.

PLATE XV.

FIG. 1. Section of portion of nodule in the Jogimardi trap. The texture is variolitic. Idiomorphic augites are present.

FIG. 2. Jogimardi trap near contact with the dark hornblendic trap of Chitaldrug. Numerous skeleton and rod-shaped crystals of felspar are seen in a glassy groundmass.

FIG. 3. Section showing patches of coarse hornblendic rock being caught up in the glassy Jogimardi trap. Skeleton crystals of felspar are present in the glass.

FIG. 4. Bellara trap showing ophitic texture. The felspars are almost opaque due to alteration. The lighter portions are augites changing into hornblende and chlorite.

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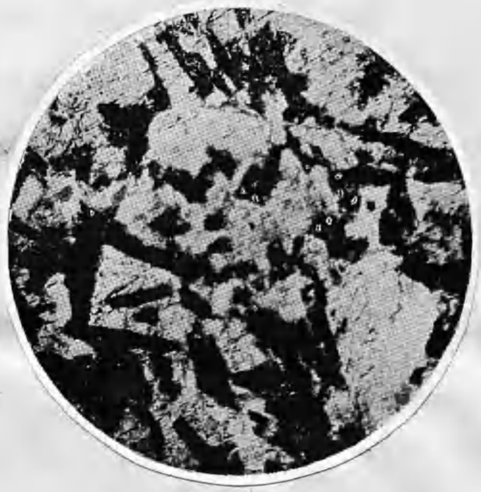

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In a few slides the ophitic texture is just discernible, making it clear that the original rock was of a doleritic nature.

These traps show evidences of contact metamorphism caused by the intrusion of the Chitaldrug granite. The felspars are clarified, the hornblende also is clear but is crowded with magnetite grains, a feature which is characteristic of contact metamorphism of diabasic rocks. The original ophitic texture is also completely obliterated.

The dark hornblendic trap of Chitaldrug can therefore be described as an epidiorite, with the ophitic texture just recognisable in a few sections and the original augites completely transformed into deep coloured hornblendes.

The chemical composition of this rock may be seen from column 4 in Table VII.

The Bellara Trap.

The main exposure of the Bellara trap is found to the south of the Jogimardi trap in the form of a lens, between the villages of Bellara and Bukkapatna (Plate XIV). The trap is clearly intrusive; the edges of the outcrop are fine-grained and tongues of the rock penetrate the chlorite schists. Good exposures of this rock are seen between the 10th and 17th milestones of the Chiknayakanhalli-Yelladkere road.

The trap is a coarse rock which under the microscope is seen to be ophitic (Plate XV, Fig. 4). Augites giving extinction angles of about 44° occur, but they are found only as remnant cores, the periphery being converted into a very pale green or practically colourless hornblende and chlorite. The felspars are very turbid due to alteration. Grains of iron pyrites are common. Ilmenite is usually altered completely to leucoxene.

In metamorphosed types, there is no residual augite, but the ophitic texture is still visible. In a further stage of alteration, the hornblende is fibrous. Segregations of chlorite with crystals of epidote occur. The schisted type of the rock is almost an amphibolite. In this the hornblende is pale green and fibrous, and there is plenty of calcite and leucoxene.

The above petrographic description indicates that the Bellara trap is a coarse diabasic rock characterised by an ophitic texture and the presence of relict augites.

The Mode of Occurrence of the Trap Rocks.

There is difference of opinion in Mysore as to whether the trap rocks are lava flows or sub-surface intrusions. The Bellara rocks are all coarse-grained and no glassy phase is met with. Fine-grained types are found in the dark hornblendic trap of Chitaldrug, and glassy varieties are seen in the Jogimardi traps. There are also very compact rocks which have all the characters of basalt, but the occurrence of these in any well-defined sheets cannot be proved in the field. Since they are not of wide-spread occurrence, the fine-grained types can only be considered as marginal variations.

The presence of amygdales, though they are not uncommon in intrusive rocks, is certainly a characteristic feature of lava flows and so, several slices of these traps which showed some structures similar to that of amygdales, were carefully examined.

In slices of Bellara trap, small patches of chlorite with crystals of epidote are sometimes seen. The absence of well-defined boundaries for these patches and the lack of a zonal arrangement of the minerals, make it improbable that these are amygdales. These represent only segregations of secondary minerals.

In the dark hornblendic rocks, there are areas which contain clear granules of quartz or felspar, and chlorite with wisps of hornblende, or there are irregular segregations of epidote, hornblende, and quartz. Somewhat similar patches in the greenschists of South Devonshire (Tilley, 1923, p.188), and in the greenstones of the Lake Superior region (Williams, 1890, p.174), have been considered to be metamorphosed amygdales, but this inference is supported by the presence in those places, of rocks which are admittedly of tuffaceous origin, or are composed of basic ashes. No such evidence is obtained from the Chitaldrug area. These chloritic patches are, therefore, to be considered as due to the alteration of felspars and pyroxenes, and formed by solid diffusion and segregation, similar to the nodules found in the dolerites of Snowdon (Williams, H., 1927, p.405). The Jogimardi trap also presents similar structures in some of the slices and the explanation given above holds good for these also.

Due to their compact nature and consequent resistance to weathering, certain nodules are often found standing out as small rounded protuberances on exposures of the Jogimardi trap. Sometimes these have dropped out leaving smooth ovoid depressions which on casual inspection look like steam cavities. Slices of these nodules were examined and they were found to be varioles and not amygdales. In these nodules, small idiomorphic crystals of augite and felspar occur in a matrix composed of acicular crystals arranged in radiating sheaves (Plate XV, Fig. 1), which may originally have been pyroxenes but are now uralitised. Under crossed nicols, the nodules do not exhibit perfect extinction crosses but only irregular dark brushes.

The writer therefore considers that the 'spots', patches and nodules met with in these trap rocks are not amygdales, but are due either to the segregation of alteration products or to the presence of varioles.

Conclusion.

The Bellara and Jogimardi traps have a great many points of resemblance, especially in the presence in both of a pale hornblende and the occurrence of relict augites. They are both usually coarse-grained with marked ophitic texture except in such of the types as have been metamorphosed, or which are at the contact zones. From Plate XIV it will be seen that a series of small exposures of trap are found between the main occurrences of the Jogimardi and Bellara traps and these in all probability belong to the same age.

The dark hornblendic trap of Chitaldrug, however, is different in that there are no residual augites, and the characteristic hornblende is deep coloured with well-marked pleochroism. It has a higher percentage of silica and lower specific gravity than the Bellara and Jogimardi traps. The contact relationships make it clear that this rock is distinctly older than the Jogimardi trap.

There is sufficient proof to show that the Bellara trap is intrusive into the schists of the Chitaldrug Belt, and that the Jogimardi trap is intrusive both into the schists and the dark hornblendic traps of Chitaldrug; but there is neither microscopic nor field evidence to show that any of these traps are lava flows.

4. GNEISSES AND GRANITES.

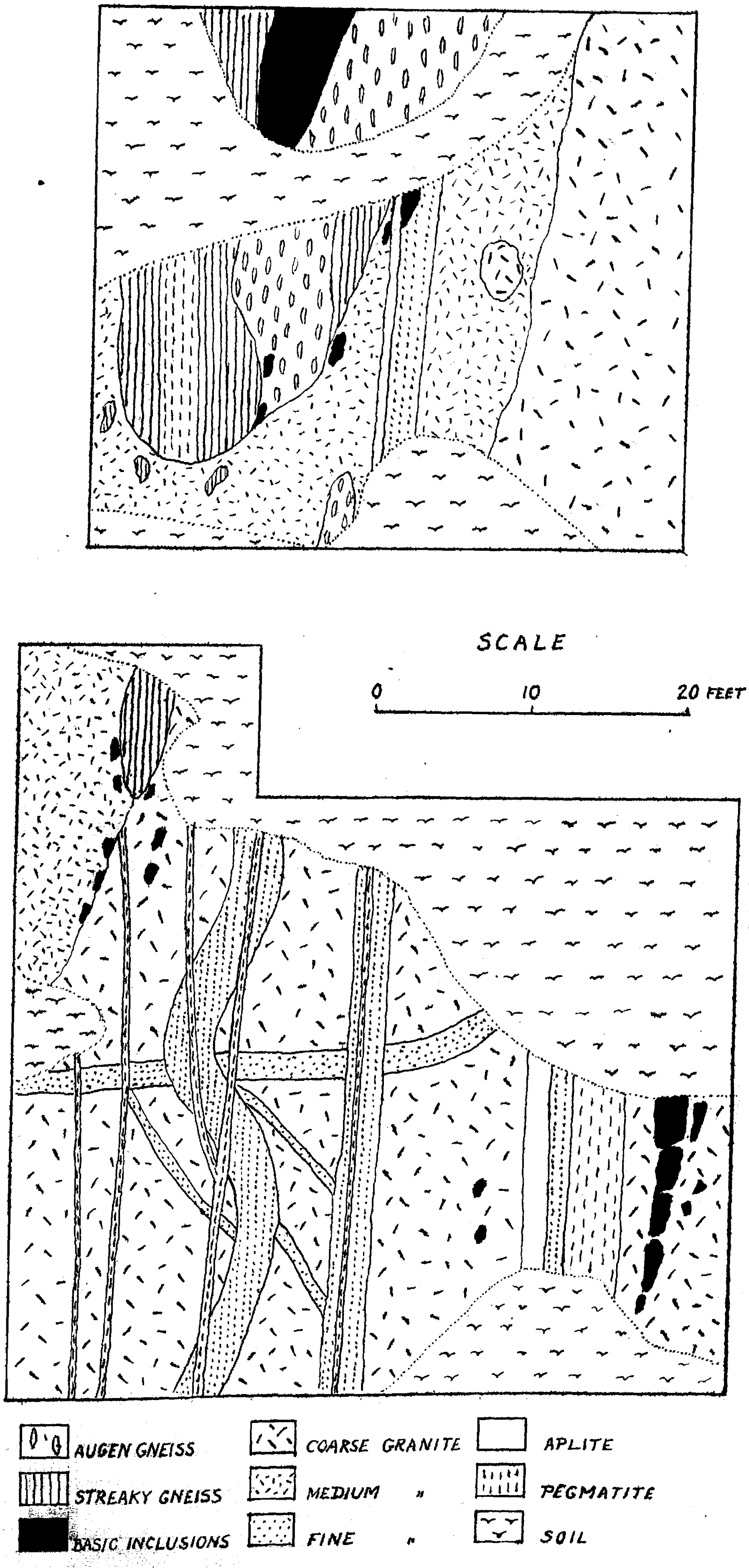
As mentioned in the introduction, the gneisses and granites of Mysore are classified into four divisions, which are, starting with the oldest, named as follows: i) Champion Gneiss, ii) Peninsular Gneiss, iii) Charnockite, and iv) Closepet Granite. A brief summary of the studies made by the writer in the second and the fourth of these groups, is given here.

I. PENINSULAR GNEISS.

The rocks in and near Bangalore belong to the Peninsular Gneiss group. The term "Peninsular Gneiss" is used in Mysore for a complex which includes many varieties of rocks. Bangalore is well situated for examining these rocks, for, practically within its limits, there are several quarries which expose to view different types of gneisses and granites with their accompanying aplite and pegmatite veins. The study is more interesting because of the abundance of schist

PLATE XVI.

Plan of selected portions from the Mount Joy quarry showing the relationships of the granites, gneisses, and basic inclusions.


SCALE
0
10
20 FEET
AUGEN GNEISS
STREAKY GNEISS
BASIC INCLUSIONS
COARSE GRANITE
MEDIUM "
FINE "
APLITE
PEGMATITE
SOIL

inclusions incorporated in these acid rocks; the ample evidences afforded of injection phenomena leading to the formation of migmatites and allied varieties of composite gneisses; and of contamination resulting in the development of hybrid rocks.

One of the most interesting quarries in Bangalore is that of Mount Joy, near Basavangudi, which is a good starting point for the study of this complex. The sketch maps (Plate XVI) of selected portions from this quarry, indicate the relationships of the different types of rocks and the distribution of the more important xenoliths.

There are two distinct varieties of gneisses here. One exhibits characteristic augen structure and the other is highly banded or foliated.

Augen Gneiss.

The augen gneiss occurs as caught up patches in the granite. This is essentially a biotite gneiss with a specific gravity of about 2.73. In thin sections, the gneiss shows protoclastic granulation. Abundant shreds of biotite and hornblende (either unaltered or passing over into biotite), sweep round the porphyroclasts of felspar and quartz. A little epidote is present. Of the accessories, apatite is abundant and titanite subordinate. In suitable sections the essentially migmatitic nature of this gneiss is well seen. Some bands are composed of hornblende, plagioclase, biotite, epidote titanite, and magnetite; these represent the layers of the original basic schists. Alternating with these, are bands which contain abundant microcline and quartz; this is the acidic material which has been injected into the schists.

There is evidence that sometimes the crystalloblasts in the centres of the augen have grown in situ, for the hornblendes and biotite laminae abut abruptly against them. Though in some cases these growing crystals have pushed the schistose layers apart, leading to the development of the augen structure, the writer considers that pressure has been the more important cause for the formation of the 'eyes'.

Banded and Streaky Gneiss.

This is a wide-spread type of rock in Bangalore, but there is not as great a development of this variety in Mount Joy as in other parts of the town. It occurs here in somewhat oval patches. The rock is commonly grey or dark grey in colour and has a specific gravity of about 2.68. The gneissic banding is very pronounced, the bands being often wavy and contorted. The earlier schists have been split into shreds and the injection of acidic material in the form of aplite and pegmatite veins between these separated layers gives this gneiss also the general characters of a migmatite (Plate XVII). While still a thick pasty mass, the rock has assumed a wavy character caused by magmatic movement as well as by pressure at depths. The effect of expansion caused by injection is indicated by the occurrence of ptygmatic folding in the pegmatite veins.

Under the microscope, these gneisses also exhibit granulation. There is a felspar with no traces of twinning and with an index of refraction less than that of Canada balsam. Very little microcline is present. Biotite is the chief ferromagnesian mineral, but a little hornblende which is altering into biotite is found. Apatite in numerous minute crystals is the chief accessory.

Granite.

The granites of Mount Joy could be differentiated into three types according to the texture exhibited by them. The coarse granite which forms the major part of the hillock, is the earliest. Patches of these are enclosed in the medium granite. Fragments of augen gneiss and streaky gneiss are found in the granites. There are also several inclusions of dark basic rocks.

The coarse granite contains hornblendes which are altering on the borders to minute flakes of brown biotite. This rock has been contaminated by the assimilation of basic xenoliths and the earlier-formed migmatites, which are in various stages of disintegration. The specific gravity of this type is 2.67, which is somewhat higher than that of the medium-grained granite. The medium granite resembles the coarse in its mineralogical contents but contains somewhat more quartz and microcline. The plagioclases are usually saussuritised, and when fresh can be identified as oligoclase. Myrmekite is of frequent occurrence.

The fine-grained granites are the youngest and occur as veins intruding the other rocks of the area. All the veins are not of the same age, as some of them intersect and displace the others. Quartz, microcline and microcline-perthite occur abundantly. Oligoclase is present in small quantities. Biotite and hornblende are the ~~are the~~ chief ferromagnesian minerals. The brown biotites are sometimes interleaved with a green variety. Micrographic and myrme-

PLATE XVII.

Migmatites from Bangalore.

FIG. 1. The photograph shows the injection of parallel veins of pegmatite (light coloured).

FIG. 2. The dark streaks are remnants of the original basic schists into which acidic material was injected.

FIG. 3. A good illustration of migmatite. It is cut by a later forked vein of pegmatite.


1


2


3

kitic structures are common.

Aplite and Pegmatite.

Several veins of aplite and pegmatite occur in the area. The pegmatite is very coarse and contains big crystals of biotite and hornblende.

Xenoliths.

As already mentioned, a very characteristic feature of the geology of Mount Joy is the occurrence of numerous inclusions of basic rocks. The specific gravity of these xenoliths varies between 2.9 and 3.1. These represent the unassimilated remnants of the original schists into which the acidic rocks intruded.

Under the microscope, most of the xenoliths are seen to be composed of hornblende and plagioclase, and those inclusions which do not possess a schistose character could be described as plagioclase amphibolites. Hornblende alters into biotite, this change being bridged by the formation of a dark brown slightly pleochroic substance which does not possess the cleavages of biotite. The quantity of biotite varies; it is more abundant near the margins of the inclusions than in the interior.

The crystals of plagioclase are more basic in the centres than in the margins. The interior of the crystals is decidedly more refracting than Canada balsam, whereas the refractive index of the borders is almost equal to, or only just a little more than balsam. The centres show alteration, whereas the outer zones are quite clear. The zones are not clearly demarcated, but the extinction positions are different; as the result of this, when the stage is rotated between crossed nicols, the extinction zone is seen gradually to widen or narrow. This phenomenon is noticeable only in sections cut from the margins of the inclusions, and indicates acidification of the plagioclases due to the reaction between the granitic magma and xenoliths.

Titanite is abundant. In thick sections this mineral is pleochroic from pink to pale green to colourless. In the micaized borders of the inclusions, apatite is more common. Epidote is frequently present. Magnetite is more abundant than pyrites.

The complete conversion of these hornblendic inclusions into biotite schist is not seen in Mount Joy, but has been noticed by the writer in the Lalbagh quarry. Excellent gradation specimens showing the various stages of this change can be collected from the quarry in the Intermediate College compound.

Conclusion.

The sharp contacts between the various kinds of gneisses and granites, and the marked contrast in their structures, indicate considerable time intervals between the formation of each of these types of rock. With such definite evidences of the successive intrusion of the component members of the Peninsular gneissic complex, it is rather difficult to consider all of them as belonging to one eruptive period, unless one imagines that the time of intrusion was so prolonged as to allow of the earlier-formed material to consolidate before the later members were intruded.

II. CLOSEPET GRANITE.

The Closepet granite occurs as a broad band, about 20 miles in width, running right across the State in a north and south direction (Plate I). The rocks comprising this division are very coarse in texture and usually porphyritic, the phenocrysts of felspar often being 2 to 3 inches in length. The felspars are some shade of pink, though grey varieties are also seen. A feature of this granite is the association of numerous porphyry dykes which are probably genetically related to the granite.

Two types of these porphyry dykes occurring near Kottatti, about six miles south of Mandya, were petrologically examined by the writer and the rocks identified for the first time.

Quartz Monzonite Porphyry.

There are two dykes of this type, one crossing the Mandya to Bannur road near the 4th furlong of the 4th mile, and the other near the 6th furlong of the 6th mile. The rock is brownish red with conspicuous flesh-coloured orthoclase phenocrysts, and smaller sized white plagioclases. Hornblende occurs in prismatic greenish-black crystals. The specific gravity of the rock is 2.61.

Due to haematite dust, the rock appears reddish under the microscope. The texture is orthophyric, the phenocrysts being set in a groundmass composed mostly of tiny rectangular crystals of felspar. Bostonitic and trachytic textures may sometimes be seen.

The borders of the crystals of orthoclase are highly charged with haematite which is the reason they are flesh-red in colour. The interior of the crystals is generally water clear. Many of the crystals are zoned, each zone being demarcated by a layer of haematite dust. Since all the zones extinguish simultaneously, there is no difference in composition; they seem to indicate only pauses during crystallisation.

The phenocrysts of plagioclase are smaller but more numerous than orthoclase. The crystals are invariably altered completely and consequently exhibit only very faint twin lamellations. In certain favourable cases they were determined to be acid oligoclases.

Hornblende is pleochroic in shades of green. The mineral is usually altered to epidote, chlorite and magnetite. A green augite is occasionally present; these are often zoned, when the interior is pleochroic from pale yellow to pale green and the outer zone, from yellowish green to dark green.

Titanite is one of the chief accessory minerals. Acicular apatites are frequently found. Zircon occurs sparingly. Magnetite and a little pyrites are present.

Epidote, chlorite, and calcite are the common secondary minerals.

The chemical composition of this porphyry will be seen from column 1 of Table VIII. A, B, and C are analyses of a few monzonitic rocks with which the Mysore rock agrees fairly closely.

TABLE VIII.

	I	A	B	C
SiO_2	64.45	64.28	64.30	64.49
Al_2O_3	17.71	16.99	17.89	15.49
Fe_2O_3	4.81	2.59	4.75	1.28
FeO		2.64		2.71
MgO	0.99	1.13	1.12	1.89
CaO	3.85	3.95	3.33	4.32
Na_2O	3.73	3.78	3.84	3.53
K_2O	4.04	3.51	3.37	4.04
TiO_2	n.d.	0.49	n.d.	0.56
Loss on ignition	0.80	0.32	1.60	1.13
	100.38	99.68	100.20	99.44

I. Quartz monzonite porphyry, Kottatti, Mandya. Analyst: C. S. Pichamuthu.

A. Quartz monzonite porphyry, Mount Guyot, Colorado. (Ransome, U.S.Geol.Surv. Prof.Pap. No. 75, 1911, p.58)

B. Banatite, Croft Hill, Charnwood Forest.(Hatch and Wells, Text-book of Petrology, Vol. I, p.227)

C. Quartz monzonite, Clancey, Montana. (Washington, Chemical analysis of Igneous Rocks, U.S. Geol.Surv. Prof.Pap. No.99, 1917, p.343.

The rock contains several inclusions of hornblende schist. These are usually recrystallised, as may be seen by the clarification of the hornblendes and the separation of magnetite. The only reaction that seems to have taken place between the inclusions and the porphyry magma is, that some of the hornblende crystals have been detached from the schist and are corroded with the separation of titanite. Apart from this, there is no marked hybridisation of this porphyry.

Tonalite Porphyry.

A dyke of tonalite porphyry crosses one of the dykes of quartz monzonite porphyry near the 6th furlong of the 6th mile on the Mandya-Bannur road. This rock does not contain phenocrysts of orthoclase. The prevailing idiomorphic constituent is plagioclase, which is quite glassy when fresh. Black lustrous prisms of hornblende are more abundant than in the other type. Biotite in well-formed six-sided crystals are visible to the naked eye. The specific gravity of the rock is 2.68.

In slices the rock is seen to have a microgranular texture, with a flecked appearance under crossed nicols. The matrix is charged with haematite dust and hence most of it is turbid or almost opaque.

Many of the plagioclase crystals are zoned. Both oligoclase and andesine occur, the outer zones, however, being more acidic. The borders are generally sericitised but the interior is water clear. Glomeroporphyritic aggregates are often seen. The felspars exhibit carlsbad, pericline, and albite twinning. The crystals are often corroded by the magma

Idiomorphic green hornblendes are common; they are sometimes zoned. This mineral is frequently seen altering to biotite or epidote. Magnetite has separated from the hornblende and is concentrated especially along the borders of the crystals. The matrix has sometimes corroded the crystals.

TABLE IX.

	I	A	B
SiO_2	65.00	66.05	65.84
Al_2O_3	14.30	15.56	13.63
Fe_2O_3	6.23	2.52	2.25
FeO		0.91	3.45
MgO	1.21	0.51	1.85
CaO	5.59	4.35	3.95
Na_2O	4.39	4.30	4.47
K_2O	2.78	3.05	1.76
Loss on ignition	0.88	2.27	2.15
	100.38	99.82	99.35

I. Tonalite porphyry, Kottatti, Mandya.
Analyst: C. S. Pichamuthu.

A. Tonalite porphyry, Ochsensprung, Tyrol.
(Washington, Chemical analysis of igneous rocks, U.S.Geol.Surv. Prof.Pap. No. 99, 1917, p. 805.)

B. Quartz diorite porphyry, Vjmoldava, Hungary.
(*ibid*, p. 353).

Eight-sided basal sections of augite occur sparingly. They are zoned and are invariably undergoing alteration into biotite, bright green chlorite, iron ore and titanite.

Quartz occurs both as large crystals and in the gr groundmass. The big grains are deeply embayed due to corrosion of the magma. They contain rows of liquid inclusions, in many of which there are moving bubbles. In the groundmass, quartz is sometimes micrographically intergrown with the felspars.

Apatite is a very common accessory. Titanite which was abundant in the quartz monzonite porphyry, is very rare here. Zircon occurs sparingly. Zoned crystals of yellowish brown allanite are sometimes seen. Magnetite is the chief iron ore.

The chemical composition of this porphyry can be seen from column I of Table IX.

The dyke of tonalite porphyry contains numerous inclusions, mostly basic, which are in various stages of disintegration and dissolution. The boundaries of these inclusions are sometimes sharp, but often the groundmass of the porphyry penetrates into them and there is a strewing of the mineral constituents of the inclusions.

The common type of inclusion contains abundant hornblende and plagioclase; the felspar is in stumpy crystals and is almost completely altered; hornblende occurs mostly in well-formed crystals. These inclusions contain plenty of acicular apatites. Quartz occurs interstitially and is sometimes micrographically intergrown with the felspars.

Some of the inclusions are light in colour and are composed mostly of big crystals of sericitised plagioclases which have also given rise by alteration to plenty of epidote. The felspar crystals have a rim of micropegmatite along their borders.

A greenish yellow type of inclusion noticed in the dyke may be described as an epidosite, as it contains only epidote and quartz. The quartz appears sometimes to have intergrown with the epidote.

Metamorphism.

During the later stages of the consolidation of the dykes, the rocks have been subject to hydrothermal metamorphism. The alteration of the felspars on the periphery as well as along the cleavages, is attributable to this cause. The extensive haematitisation is also due to hydrothermal action. The dissemination of haematite dust has imparted a flesh-red colour to the felspars and to the matrix of the porphyry dykes. Further evidences of hydrothermal change are furnished by the epidotisation and sericitisation. That these changes took place prior to complete consolidation may be inferred from the fact that the felspars occurring in the quickly-cooled margins of the dykes, are free from any traces of alteration. It is in the central portions of the dykes, where consolidation was slower, that haematitisation, sericitisation, and epidotisation are noticed.

5. CONCLUSION AND ACKNOWLEDGEMENTS.

This paper contains a summary of the results of a detailed study of some of the important rocks of Mysore. The formations in Mysore are so much metamorphosed that it is extremely difficult to unravel their past history. One of the main features of the writer's work, is the recognition of the sedimentary character of some of the rock types in the Shimoga Schist Belt, which were considered hitherto to be of igneous origin.

The writer is greatly indebted to Prof. Bailey and Dr. Tyrrell for their help and advice during the progress of some of this work in the University of Glasgow.

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