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A LAYERED COMPLEX IN SITTAMPUNDI, MADRAS STATE, INDIA

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ABSTRACT

Nehru (1955) and Subrahmanyam (1956) have reported on the anorthite-bearing and associated rocks of Sittampundi, Madras State. The latter regards them as a layered igneous anorthosite-gabbro series, highly metamorphosed. The present author regards the whole series as composed of igneous, sedimentary and migmatitic rocks of the Dharwarian, Peninsular and Charnockitic periods, domed up by the alaskite intrusion of the Closepet granite period. He gives a detailed succession of the rock-types along three cross-sections of the Sittampundi complex, and holds that there is no amphibolite surrounding all the rock types. From a study of garnets and amphiboles the rocks belong to three different geological periods. The garnet-bearing rocks are not all eclogites, and the mineral assemblages of the anorthite-bearing gneisses denote them to be metamorphosed marly and pelitic sediments.

INTRODUCTION

Nehru (1955) has studied the anorthite-amphibole gneisses and associated rocks of Sittampundi, Madras State, India, and states, "Here in Sittampundi one seems to encounter a metamorphic facies in the association together of ecologites, amphibolites and anorthite-spinel rocks, rather than gabbroic rocks and anorthosites." Subrahmanyam (1956) describes them as a layered igneous anorthosite-gabbro series of the type of Bushveld Complex and the Bay of Islands, highly metamorphosed.

The Sittampundi area lies within longitudes 77° 45′, 78° 5′ and latitudes 11° 10′, 10° 23′. In order to understand the geological structure of the area, it is necessary to include the northern region to latitude 11° 31′. This will bring into discussion the rocks developed around the township of Sankaridrug. The Sankaridrug series has been mapped by Balasubrahmanyam, and the Sittampundi series by Nehru. The combined map is presented in Fig. 1. The whole region consists of metasediments and earlier intrusives which have been domed up by an alaskite that extends in all directions beyond the confines of the area mapped. Thus all the rocks of the area are xenoliths within alaskite. These xenoliths are of limestones (now converted to marbles), calc-silicate rocks (having the minerals, wollastonite, tremolite, grossularite, diopside, sphene etc.), biotite (dark brown)-gneisses, hornblende gneisses, hornblende-biotite gneisses, garnetiferous-biotite (dark brown) gneisses, two-pyroxene-garnetiferous rocks and two-pyroxene pyroxenites (both of the charnockite series), sillimanite gneisses, biotite (reddish brown)-pyroxene (ortho- and clino-) gneisses, garnetiferous quartzites, hematite quartzites, quartz-hematite-emery rocks, anorthite amphibole gneisses (with the combinations of one or more of the minerals: grossularite, epidote, zoisite, clinozoisite, corundum, chromite, fassaite and highly aluminous calciferous amphiboles etc.), amphibolites and peridotites. The name anorthite-amphibole gneiss here used is the equivalent of anorthosite of Subrahmanyam (1956) and will be so referred to in this paper.

These rocks by analogy with similar rocks occurring elsewhere in India, are assigned in the following Indian stratigraphical scale given by Pascoe (1950).

ARCHAEAN	Post-charnockite	Alaskite granite
	Charnockite series	Two-pyroxene-garnetiferous rocks (eclogitic) and two-pyroxene pyroxenites (noritic). Biotite (reddish brown)—pyroxene gneisses.
	Peninsular Gneisses	Biotite-hornblende gneisses, hornblende-biotite gneisses, garnetiferous biotite gneisses.
	Dharwars	Sillimanite gneisses, hematite-quartzites, quartz-hematite-emery rock, garnetiferous quartzites.
		Limestones, amphibolites, anorthite gneisses, calc-silicate rocks and peridotites.

All these rock types are present in both the areas of Sankaridrug and Sittampundi, but the marbles dominate in the northern region and the anorthite gneisses in the southern. Peridotites are absent in the north, and the sillimanite-gneisses do not occur in the south.

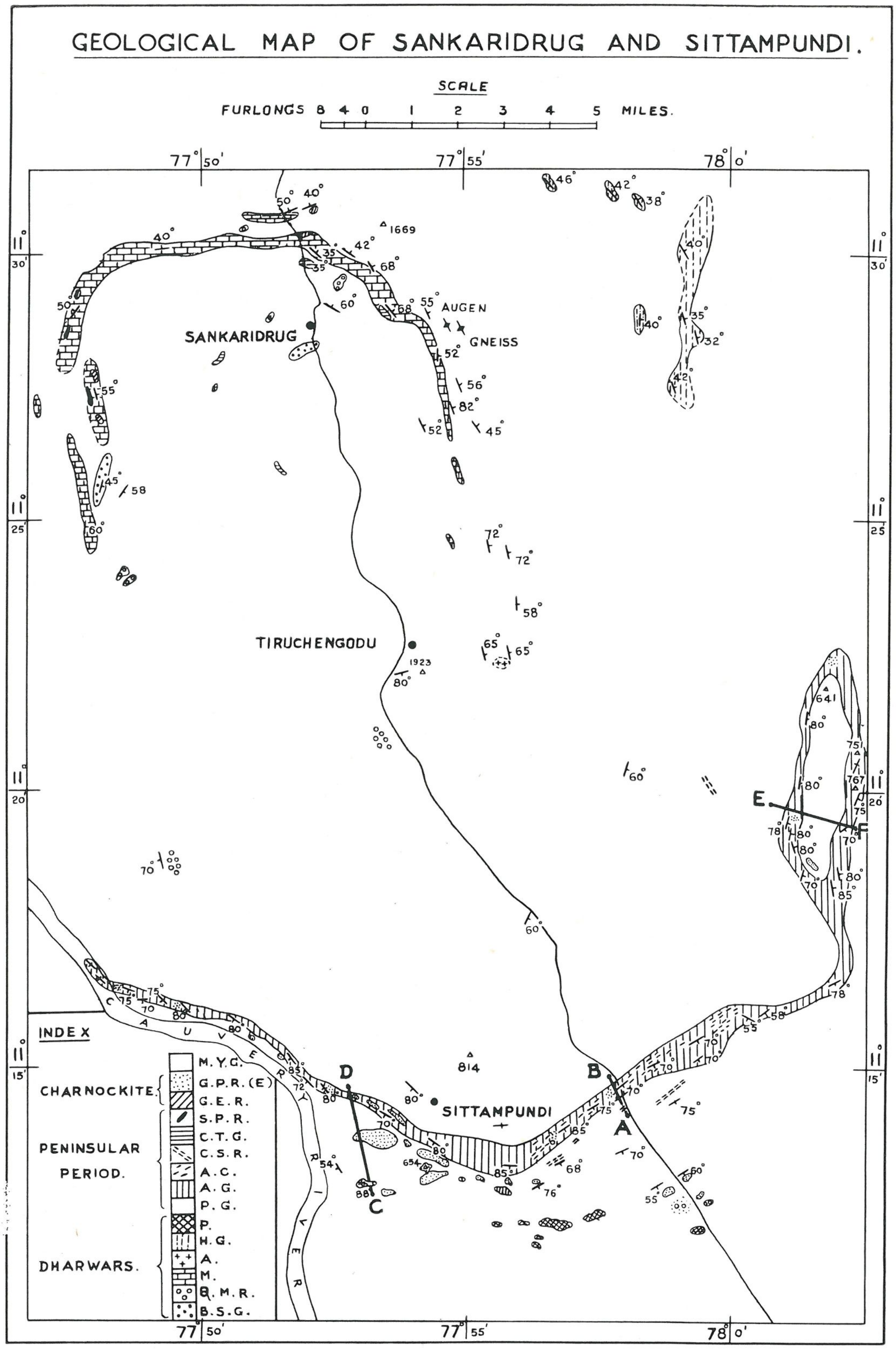

FIG. 1. Geological map of Sankaridrug and Sittampundi. In the index, M.Y.G.—Migmatite and younger granite. G.P.R.(E)—Garnet-pyroxene rock (eclogite). G.E.R.—Garnet-epidote rock. S.P.R.—Scapolite-pyroxene rock. C.T.G.—Calc-tremolite gneiss. C.S.R.—Calc-silicate rock. A.C.—Amphibolite with chromite. A.G.—Anorthite gneiss. P.G.—Peninsular gneiss (not mapped separately from younger granite). P—Peridotite. H.G.—Hornblende gneiss. A—Amphibolite. M—Marble. Q.M.R.—Quartz-magnetite rock. B.S.G.—Biotite-sillimanite gneiss. AB, CD and EF are sections along the anorthite gneiss band.

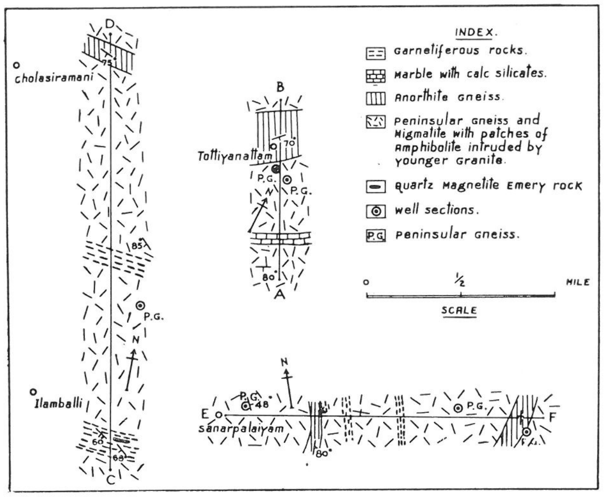

FIG. 2. Enlarged section along AB, CD and EF of Fig. 1.

DESCRIPTION

Henceforth rock types of Sittampundi alone concern us. In order to elucidate the mutual field relationships of the various rock units, sections along lines AB, CD and EF (centre/ west and east of the anorthite-gneisse band) of Fig. 1, will be described. Enlarged diagrammatic sketches to scale are given in Fig. 2.

Section along AB. The succession from A to B is migmatite (hybrids between peninsular gneisses and alaskite), marble (with calc-silicates), migmatites again with xenoliths of peninsular gneisses, anorthite gneiss and alaskite.

The calc-silicate band consists of the minerals, calcite, epidote, hedenbergite (deeply pleochroic from green to blue), reddish-yellow grains of spongy andradite, pale green diopside, scapolite and sphene. These alternate with bands of quartz and plagioclase (An_{30}). The calc-silicate bands are cut by alaskite veins and pegmatites.

In the well section (50 feet deep), near the southern border of the anorthite gneiss, the Peninsular gneiss is in contact with it. The Peninsular gneiss has the minerals, greenish-blue amphibole, pale green relic diopside, reddish-brown sphene, plagioclase (An_{30}), quartz and iron ore. The anorthite gneiss has a granulitic texture with the minerals, anorthite, pale blue amphibole, grossularite, calcite and chlorite. There are also pools of calcite, and sillimanite threading through the anorthite grains. Corundum may also be present. There are several druses. Two of these are figured (Fig. 3). These consist of five zones. The first zone is composed of anorthite gneiss having anorthite, pale-blue amphibole, calcite and chlorite. The second consists of chlorite and sericite with relics of plagioclase. The third is composed of muscovite and talc (Fig. 4). The fourth consists of pools of talc amidst irregular aggregates of calcite and chalcedony. In the fifth, there are well-developed crystals of calcite and quartz. The second to the fifth zone are considered to be the sedimentary material from which the anorthite-gneiss was constituted.

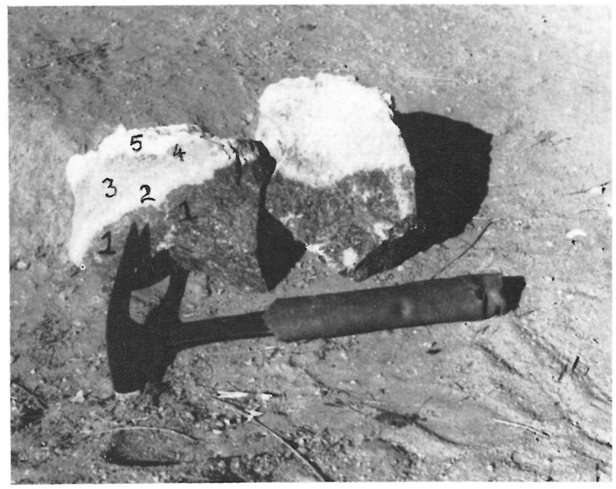

FIG. 3. Specimens from druses in a well along section AB. 1 to 5 zones in the specimen.

The next band of anorthite gneiss consists of anorthite and greenish-blue amphibole of the type found in the Peninsular gneiss which is different from the pale-blue amphibole, found elsewhere in the anorthite gneisses.

The section AB ends in the north in alaskite, a potash-rich pegmatitic granite.

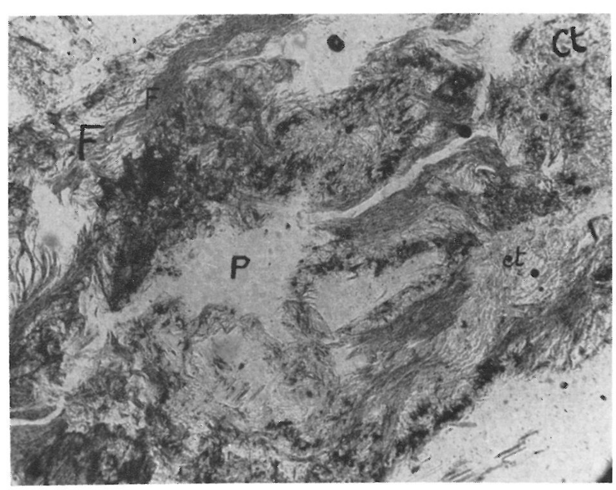

FIG. 4. Zone 3 of Fig. 3. Nicols not crossed. ×70. P—Relics of plagioclase, F—muscovite, ct—chlorite and talc.

Fig. 5. Quartz-hematite-emery rock (Q.H.E.) flanked by garnetiferous quartzites (G.Q.).

Section along CD: It starts with migmatite again. Then comes a band of quartz-hematite-emery rock (Fig. 5), which is flanked on either side by a garnetiferous quartzose gneiss (consisting of spongy garnets (Fig. 6)), plagioclase and quartz grains enclosed in a matrix of minutely granulitic plagioclase, quartz and microcline. The matrix also in places, consists of amorphous matter which alters to sericite. The

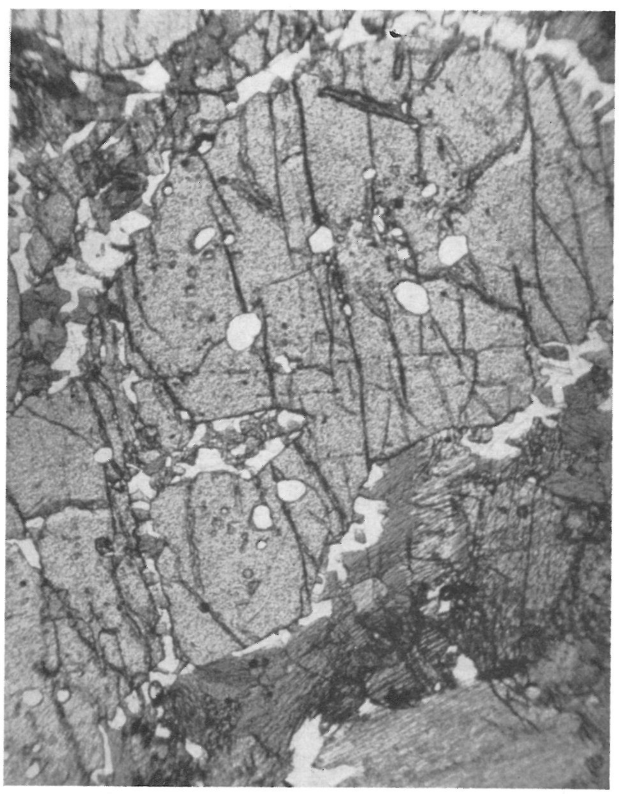

Fig. 6. Spongy sieved garnet in garnetiferous quartzite (G.Q. of Fig. 5). Nicols not crossed. ×70.

Fig. 7. Well-foliated hornblende-biotite gneiss (Peninsular gneiss).

quartz which is of various sizes is far in excess of plagioclase and forms distinct bands. The garnet is converted to reddish-brown mica, and has inclusions of plagioclase, quartz, biotite, limonite and hematite. This band is followed by a micaceous gneiss that stands out as high inclined tables. This consists of distinctly gneissose bands of reddish-brown mica, quartz and feldspar (plagioclase and microcline). Among the biotite folia, hypersthene granules are also present. Other foliae consist of pyroxenes alone, both orthorhombic and monoclinic. Biotite develops at the expense of both. There are local pools of calcite. The plagioclases are all antiperthites with distinct rods of orthoclase (rod-perthites). The next band consists of alaskites and migmatites. A section in a well in this band discloses the presence of biotite-rich gneiss (Peninsular gneiss). Again there is a band of garnetiferous gneiss. This consists of granules of garnet, brownish-green amphibole, quartz and plagioclase with a granulitic texture. Coarse gneissosity is present. The garnet is spongy and has inclusions of quartz, plagioclase and some indeterminate granules. Massive iron ore is abundant. The brownish-green amphibole is typical of the charnockite series. This rock is invaded by quartz veins and pegmatites from the neighbouring alaskite. At contact with the quartz vein, the garnet develops a corona of plagioclase (An_{95}) and blue amphibole. The garnets are spongy and are sieved with quartz, plagioclase and iron ore. Hairlike inclusions cross each other at rhombohedral angles. The rest of the rock consists of lamellar pyroxenes, with interrupted lamellae, and plagioclase (An_{40}). (This is the average content of anorthite found in plagioclases of basic charnockites.)

The above band is bordered by biotite-hornblende

FIG. 8. Garnet with corona of anorthite and pale-blue amphibole. Nicols not crossed. ×26.

gneiss (Peninsular) with biotite in excess of hornblende (Fig. 7). The rest of the rock consists of abundant quartz and subordinate plagioclase. Biotite is pleochroic from yellow to dark-brown, and the hornblende is pleochroic from yellow to blue. These are biotites and hornblendes characteristic of Peninsular gneisses.

Then comes the band of alaskite and migmatite, followed by anorthite gneiss, which is again bordered by the former. A section in a well at the northern edge of the anorthite-gneiss reveals only the presence of migmatites.

The quartz-hematite-emery rock, the two garnetiferous rocks one associated with quartz-emery rock, and the other with charnockites, and the reddish brown biotite gneiss have been analysed and the results are presented in Table 2. Quartz in the quartz hematite-emery rock has been introduced from the quartz veins of the alaskite granite.

Section along EF. This section starts with a zone of alaskites and migmatites, but half a mile west of this occurs a calc-silicate band (not included in the section). The calc-silicate band contains the minerals, calcite, diopside, greenish-blue amphibole, epidote, sphene and apatite in decreasing abundance.

In the zone of alaskite-migmatites is a well which discloses a Peninsular gneiss having distinct pencilled banding. This consists of greenish-blue amphibole, quartz and plagioclase with apatite as accessory.

This is followed by a first band of anorthite gneiss having the characteristic pale-blue amphibole. Long epidote needles are abundant. This is the bluish anorthite-gneiss. The white and pale-pink varieties occur in the western section of the anorthite-gneiss band. The blue anorthite gneiss here shows diffuse and sinuous lamination such as is found in marbles.

East of this band is a xenolith of charnockite. This consists of pools of brownish-green hornblende developing around iron ores. Elsewhere the pools have relics of ortho and clinopyroxenes. The rest of the rock consists of plagioclase with well-twinned but disturbed lamellae. This rock has a few boulders of 2-pyroxene pyroxenites of the charnockite series. The hypersthene is deeply pleochroic, X = pink, Y = yellow, Z = green. The brownish-green amphibole, as usual, develops around iron ore.

Then comes a long stretch of migmatites intersected by two bands of quartzose-garnetiferous rocks similar to those described along section CD. A well among the migmatites revealed a Peninsular gneiss with its characteristic biotite (dark brown) and hornblende (greenish-blue). Quartz and plagioclase in various proportions, discrete grains of calcite and abundant apatite are present.

Then comes the second anorthite-gneiss band with a temple at the top. This is the highest point (767 feet) of the whole anorthite-gneiss band, whose general level is 600 ft. above M.S.L. A well immediately at the eastern end of it revealed the presence of a rock with anorthite, greenish-blue amphibole (characteristic of Peninsular gneisses), abundant sphene and apatite. A neighboring well 50 ft. eastwards disclosed only migmatites.

From the above description it is obvious that there is no amphibolite bordering the anorthite-gneiss on either side, much less, surrounding all the rock types of the area as has been mapped by Subrahmanyam (1956).

Corundum and chromite mines: Corundum and chromite mines occur in the middle of the anorthite-gneiss band. While chromite occurs on either side of section AB, corundum is confined to the nose. The chromite is confined to the amphibolite lenses. The amphibole is a pale-blue amphibole (characteristic of the major part of the anorthite-gneiss). Chromite is segregated from the walls to the center, and the amphibolite lenses do not extend downwards. There are druses in the chromite mines, showing layers of chromite, calcite and muscovite mica. Probably chromite was introduced metasomatically from the dunites and periodotites occurring immediately to the south of the nose of the anorthite-gneiss band.

The corundum mines are traversed by pegmatites. Corundum occurs in well-formed crystals, and also as disseminated grains in the anorthite-gneiss. A specimen of anorthite-gneiss from the mines consisted of abundant epidote, anorthite, stray diopside, greenish-blue amphibole and pools of calcite. The pools of calcite are sometimes bordered by epidote and diopside.

Isolated patches of garnetiferous rocks and calcite in the anorthite-gneiss. There are isolated patches of garnetiferous rocks throughout the anorthite-gneiss. One of these occurs to the west of section AB. It consists of pyrope, lamellar pyroxene and pale-blue amphibole. The pyrope has a corona of anorthite and bluish amphibole (Fig. 8). The analysis of this rock is given in table 2. There are also stray calcite masses along the length of the anorthite-gneiss.

Chemical Data

It has been held by the author that the Sittampundi area consists of rock units separated vastly in geological timescale; namely, the Dharwars, peninsular gneisses, charnockites, and post-charnockitic granite, formed during about a thousand million years. Their mutual relationships are brilliantly stated by Pascoe (1950, p. 35). The units can be recognized not only petrographically, but also mineralogically. Analyses of garnets and amphiboles can be used to this end.

Analyses of garnets and amphiboles, three of each, are presented in Table 1.

The garnets are almandinic in rocks associated with iron ores, pyropic in basic charnockites, and grossularitic in anorthite-gneisses. The amphiboles are common hornblendes in peninsular gneisses, hastingsitic in basic charnockites, and a highly aluminous calciferous amphibole in anorthite gneisses. The optical characters of the last amphibole correspond neither to pargasite nor to edenite. But, in the banded anorthite-gneisses at the nose of the band, the greenish-blue amphibole, characteristic of the Peninsular gneisses, is present.

From the above account of petrography and mineralogy, it is obvious that rocks of three different geological periods, namely, the Dharwars, the Charnockite series and the Peninsular gneisses, cannot be

Table 1. Analyses of Garnets and Amphiboles

	Garnets			Amphiboles		
	1	2	3	4	5	6
SiO_2	37.50	36.34	37.59	43.91	45.91	41.21
TiO_2	1.03	0.15	0.21	0.89	0.05	2.04
Al_2O_3	21.57	24.52	17.14	19.04	18.35	16.78
Fe_2O_3	0.34	0.11	11.04	nil	nil	4.83
FeO	23.61	14.51	0.39	8.65	6.07	6.15
MnO	n.d.	1.35	n.d.	Tr.	0.08	0.14
MgO	7.38	14.61	0.63	12.96	12.10	11.22
CaO	7.73	6.35	32.91	12.13	15.92	15.32
Na_2O	0.22	0.26	n.d.	1.29	0.32	1.56
K_2O	0.13	0.81	n.d.	0.17	0.05	0.25
H_2O^+	0.21	0.32	0.13	0.60	0.54	0.98
H_2O^-	0.09	0.26	0.05	0.11	0.15	0.16
Total	99.81	99.59	100.09	99.75	99.54	100.64

Garnets in Standard Molecules

	1	2	3
Almandine	51.35	28.87	1.00
Pyrope	27.93	51.88	2.50
Grossularite	19.82	16.32	62.50
Andradite	0.90	—	34.00
Spessartite	—	2.93	—

Optical characters of the Amphiboles

		4	5	6
	2Vx=	72°–78°	85°–95°	68°–72°
	Z∧c=	18°–20°	16°–18°	15°–17°
Pleochroism	X=	Yellow	Colourless	Yellow
	Y=	Brownish-green	Pale-green	Brown
	Z=	Greenish-blue	pale-blue	Greenish-brown

1. Garnet associated with iron ores of Salem, Madras State Analyst: S. Saravanan, Analytical Chemist, Department of Geology & Geophysics, University of Madras.
2. Garnet associated with basic charnockites of Salem, Madras State. Analyst: S. Ramanathan, Oil & Natural Gas Commission, Government of India.
3. Garnet associated with calc-silicate rock, Kadavur, Tiruchirapalli, Madras State. Analyst: S. Saravanan.
4. Greenish-blue amphibole from Peninsular gneiss, Sittampundi, Salem. Analyst: C. E. Nehru.
5. Pale-blue amphibole from anorthite gneiss, Sittampundi, Salem. Analyst: C. E. Nehru.
6. Brownish-green amphibole from basic charnockites, Kadavur, Tiruchirapalli. Analyst: S. Saravanan.

TABLE 2. ANALYSIS OF GARNETIFEROUS ROCKS AND THE QUARTZ-HEMATITIC-EMERY ROCK OF SITTAMPUNDI, SALEM, MADRAS STATE

	1	2	3	4	5	6
SiO_2	48.39	62.08	73.55	50.44	47.00	49.68
TiO_2	Tr.	0.50	0.21	1.12	1.00	Nil
Al_2O_3	10.48	19.28	12.15	12.70	17.61	36.13
Fe_2O_3	0.23	0.98	1.64	1.06	2.25	2.49
FeO	6.89	3.62	3.15	9.55	6.78	8.88
MnO	Tr.	—	0.12	—	—	0.05
MgO	15.79	5.92	2.58	8.19	8.78	1.13
CaO	16.58	0.89	0.77	13.99	14.99	0.79
Na_2O	0.54	0.93	0.75	1.95	1.14	Tr.
K_2O	0.23	4.82	3.57	0.73	0.21	Tr.
H_2O^+	0.18	1.01	0.85	0.15	{ —	0.57
H_2O^-	0.12	0.12	0.12	0.03	{0.40	0.05
P_2O_5	—	—	—	—	0.40	—
Total	99.43	100.15	99.46	99.91	100.56	99.77

CIPW norms for the Analysed Rocks

	1	2	3	4
Quartz	—	24.90	48.12	—
Orthoclase	1.11	28.36	21.13	4.45
Albite	4.72	7.86	6.29	16.77
Anorthite	25.58	4.45	3.89	23.63
Corundum	—	10.91	5.71	—
Diopside	45.31	—	—	37.46
Hypersthene	1.36	20.61	10.59	5.55
Olivine	20.91	—	—	8.36
Magnetite	0.46	1.39	2.32	1.62
Illmenite	—	0.91	0.46	2.13
Total	99.45	99.39	98.51	99.97

The percentages of Or, Ab, An, +fem, in Analyses 1, 2, 3, & 4

	1	2	3	4
Or	1.12	38.07	41.93	4.45
Ab	4.74	10.55	12.48	16.78
An+fem	94.14	51.38	45.59	78.77

1. Garnetiferous-brown-amphibole-pyroxene-plagioclase rock.
2. Garnetiferous-reddish-brown biotite-pyroxene-antiperthite rock.
3. Garnetiferous quartzite.
4. Garnetiferous-anorthite-pale-blue amphibole-pyroxene rock (Coronite).
   1, 2, 3 & 4—Analyst: S. Saràvanan.
5. Garnet amphibolite quoted from Subrahamnyam (1956) p. 372, Analysis 4.
6. Quartz hematite-emery rock, Analyst, C. E. Nehru.

connected together by crystallization-differentiation processes.

To ascertain the character of the garnet-bearing rocks (the so-called eclogites), four of them have been analysed and the results are presented in Table 2.

The four garnet-bearing rocks analysed show large variations in the chemical constituents. The fourth is similar to Biere's Garnet-amphibolite, but for the lower percentage of alumina. The other three do not agree with this eclogite in 2 or 3 constituents. The Or, Ab and (An+fem) constituents were plotted in Brammall's diagram (1933). Garnetiferous reddish-brown biotite-pyroxene-antiperthite rock (No. 2) and Garnetiferous-quartzite (No. 3) fall in the sedimentary field. Garnetiferous brown-amphibole-pyroxene-plagioclase rock (No. 1) falls in the metamorphic field. This is a variation of the charnockite series. Garnetiferous-anorthite-blue-amphibole pyroxene rock (Coronite) falls in the igneous field.

Garnets from Nos. 1, 3 and 4 were determined by x-ray. The molecules read from x-ray data and FeO content are as follows:

	1	3	4
Cell dimensions	11.58 Å	11.54 Å	11.54 Å
FeO content	14.19%	9.90%	6.15%
Standard molecules:			
Pyrope	48	66	71
Almandine	32	22	15
Grossularite	16	10	12
Spessartite	2	1	1
Andradite	2	1	1

They are all pyropic, and are related to the Charnockite series. The relative abundance of pyrope and almandine is dependent on the original composition of the orthopyroxenes from which these garnets are constituted.

DISCUSSION

The anorthite-gneiss consists of the following mineral assemblages:

(1) Anorthite-anthophyllite-amphibole (pale-blue, highly aluminous and calciferous) . . . Hornblende hornfels facies.
(2) Anorthite-greenish-blue-amphibole (of the type of the peninsular gneiss)-biotite . . . Hornblende hornfels facies.
(3) Anorthite-grossularite-fassaite . . . Hornblende hornfels facies.
(4) Anorthite-corundum-spinel . . . Sanidinite facies without sanidine (Turner and Verhoogen, 1960).
(5) Anorthite-corundum-calcite . . . Pyroxene hornfels facies.
(6) Anorthite-epidote-diopside-calcite . . . Almandine amphibolite facies.
(7) Anorthite-epidote-hornblende(pale-blue) . . . Almandine amphibolite facies.

These mineral assemblages are certainly those formed from marly and pelitic sediments, and can be inserted into the appropriate triangles of Goldschmidt (Turner and Verhoogen 1960).

The Charnockite series, including the garnet-bearing varieties, belong to the granulite facies (Turner and Verhoogen, 1960).

The Peninsular gneisses (with biotite, hornblende and plagioclase) belong to the almandine-amphibolite facies.

There are thus, in Sittampundi, rocks of the Dharwarian, Charnockitic and Peninsular gneissic periods, belonging to the sanidinite, pyroxene-hornfels and granulite facies, on which has been imposed an almandine-amphibolite facies metamorphism by the intrusion of an alaskite-granite. These certainly are not "a layered igneous anorthosite-gabbro series of the type of Bushveld Complex and Bay of Islands, highly metamorphosed."

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