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Charnockites of Visakhapatnam, Andhra Pradesh

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Abstract

The tonalitic charnockites from Visakhapatnam, Andhra Pradesh, belong to 2,600 m y. age. They were structurally emplaced along the axes of NE and E plunging overturned isoclinal synclines exhibited by khondalites. The palingenetic charnockites of granodioritic composition have indicated an age of 2,000 m.y., which corresponds to the age of NW-SE cross-folds in the Eastern Ghats of Andhra Pradesh.

Introduction

The Eastern Ghats extend along the east coast from Ongole in Andhra to Sambalpur in Orissa. The Eastern Ghats consist largely of khondalites and charnockites belonging to high grade granulitic facies and maintain general NE-SW trend with local irregularities. The khondalite group comprises garnet-biotite-graphite-sillimanite (±)-quartz-feldspar gneisses, quartzites, limestones, calc-granulites, hypersthene-cordierite-biotite-garnet-sillimanite gneisses, whereas the charnockites include hypersthene-garnet (±) granitic-granodioritic rocks. The pyroxene granulites occur as sills and dykes. The charnockites are mostly confined to the axes of overturned isoclinal synclines exhibited by khondalites. The charnockites occasionally show stock like intrusive relationship with the garnet-biotite granites. Migmatitic impress is common in khondalites, granites and charnockites.

Structures around Visakhapatnam

The pattern of hill ranges around Visakhapatnam portrays the general structural features. The hill ranges northwest of Elamanchili and Kasimkota trend NE–SW and further east of Chodavaram up to Visakhapatnam and Bhimunipatnam trend E–W with occasional swerving to N70°W-S70°E at places like Kommadi.

Elamanchili and Kasimkota hill ranges are made up of khondalites and have the general strike of foliation N45°E and dip S55°E. The folds exhibited by khondalites are overturned isoclinal synclines plunging NE. Garnetiferous granites and charnockites are confined to the axes of major folds. The paragneisses in Sabbavaram, Kottavalasa and Visakhapatnam ranges east of Chodavaram have E–W foliation with steep southerly dips and indicate a major overturned syncline plunging E to ESE. The major fold axis swerves from NE to E (Fig. 1) and this is due to superimposed folding along the NW–SE axis. The domal upwarps near Kommadi in Visakhapatnam are related to refolding. Similar upwarps in Kondapalli in Krishna district, Kasipatnam in Visakhapatnam district (Rao, 1977), and Phulbani and Baliguda in Orissa (Narayanaswami, 1975) are evidently related to refolding. The gravity anomaly pattern (M. N. Qureshy's Bouguer anomaly map of Peninsular India – Fig. 10; in Pichamuthu, 1967), in the Eastern Ghats of Andhra Pradesh and Orissa confirms the regional cross fold structures in NW–SE direction mainly at Visakhapatnam, Kondapalli and Phulbani, and Baliguda regions.

The Sarada river follows along the cross fold axis in Visakhapatnam district. The change of river course from Anakapalle to Elamanchili is possibly due to faulting in NE–SW direction (Fig. 1). NE–SW trending faults and shear zones parallel to the Sarada river course are more prominent along the coast of Pudimadaka.

Mineralogy and Petrology of charnockites

The charnockites are dark in colour and show vitreous to almost greasy lustre. They show medium grained granular textures and are characterised by the presence of generally highly pleochroic orthopyroxene. The charnockites are essentially made up of plagioclase and hypersthene and the latter has a definite tendency to occur in clusters. Quartz, orthoclase and augite occur as coarser grained aggregates between other minerals. Accessories include magnetite, ilmenite, apatite, zircon and monazite. The plagioclase has well developed twins both on the albite and on more complex twin laws. Optics and X-ray determinations indicate the composition An_{38-42} per cent representing sodic andesine range. The hypersthene occurs in completely anhedral irregular grains and shows moderate to strong pleochroism (α-pink, β-greenish yellow, γ-green). Its composition from optics and X-ray determination is En_{40}.

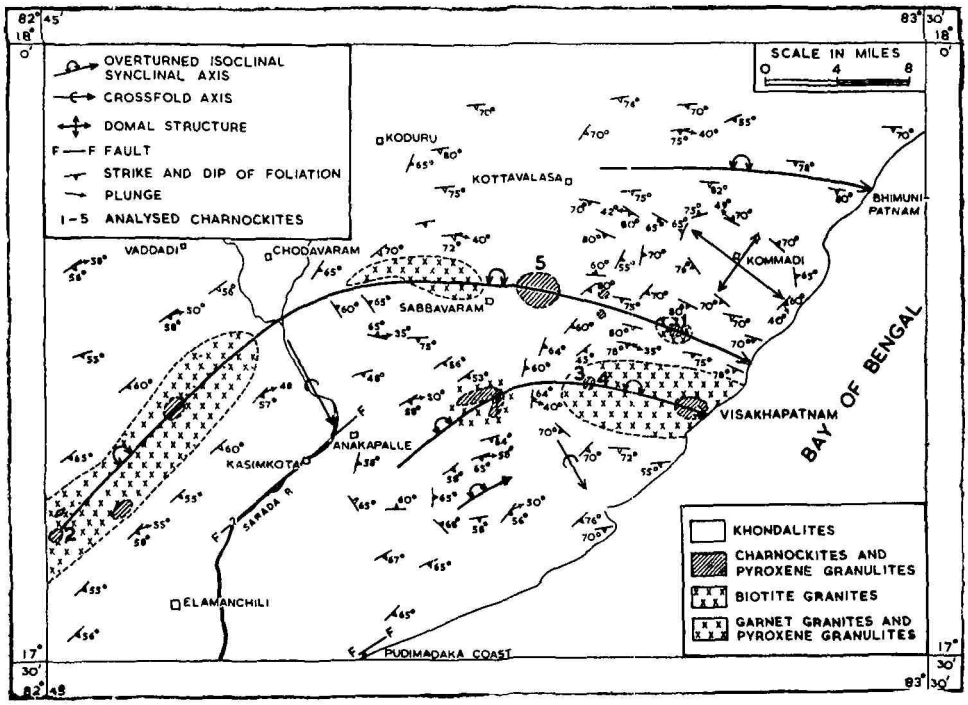

Figure 1. Structural trends in Visakhapatnam.

Biotite and garnet rich coarser grained charnockitic layers (Fig. 2), lenses and patches in granulitic charnockites are well foliated and occasionally characterised by feldspar porphyroblasts (Fig. 3). Hypersthene (En_{44}) and pink garnets (Alm_{66}, Py_{25}, Gr_7, Sp_2) concentrate around the grain margins and also occupy the interspaces of feldspars. Strongly pleochroic (α bright yellow, $\beta = \gamma$ brown) iron rich biotite laths wrap round garnets and are strewn throughout with a tendency to cut through the pyroxenes. The potash feldspar, having oligoclase (An_{30}) lamellae, is an orthoclase perthite (Or_{80}, Ab_{15}, An_5) and has occasional development of myrmekite nearby. The plagioclase (An_{40}) is clear and fresh with abundant fine twinning. In addition to hypersthene, clinopyroxene with a composition of Ca_{44}, Mg_{25}, Fe_{31} also occur in small amounts.

Figure 2 Layer of granodioritic charnockite (central part of the photo) in tonalitic charnockite.

Figure 3. Porphyritic texture in granodioritic charnockite.

The chemical and spectrographic analyses of both medium and coarse grained charnockites together with the C.I.P.W. norms and modes are given in Tables I and II.

TABLE I. Chemical analyses of charnockites around Visakhapatnam, Andhra Pradesh

	1	2	3	4	5
SiO_2	55.74	58.75	56.44	58.87	60.76
Al_2O_3	16.96	15.84	16.36	17.56	15.68
TiO_2	1.08	0.97	0.85	1.52	1.91
Fe_2O_3	1.67	2.18	1.90	1.38	3.04
FeO	10.34	7.91	10.44	7.28	6.02
MgO	3.60	4.52	3.50	2.80	2.26
MnO	0.31	0.14	0.22	0.28	0.20
CaO	5.50	4.28	5.61	4.00	3.43
Na_2O	3.50	3.79	3.14	2.10	2.42
K_2O	1.34	1.20	1.15	3.60	3.89
P_2O_5	0.30	0 24	0.28	0.36	0.41
H_2O^+	0.10	0 17	0.15	0.35	0.30
H_2O^-	0.05	0.04	0.10	0.12	0.11
Total	100.49	100.03	100.14	100.22	100.43
Trace elements as p.p.m.					
Ga	25	20	30	35	15
Cr	75	50	80	40	30
Li	10	12	10	15	10
Ni	25	50	40	75	83
Co	3	2	5	20	25
V	200	175	225	100	150
Zr	100	150	200	250	300
Sc	10	10	15	20	15
Y	20	15	10	30	40
Sr	1100	900	1000	350	400
Ce	20	20	25	60	100
Pb	10	15	15	20	25
Ba	700	500	550	2000	2500
Rb	20	10	30	100	150
Th	10	13	10	30	40
U	3	4	3	8	10

1—Hypersthene tonalite, Mudasarlova, Visakhapatnam.

2—Hypersthene tonalite, 8 miles NW of Elamanchili.

3—Hypersthene tonalite from Air Port Hill, Visakhapatnam.

4—Biotite-hypersthene granodiorite, Air Port Hill, Visakhapatnam.

5—Biotite-hypersthene granodiorite, Rampuram near Pendurti.

The dark looking even grained granular charnockites are tonalitic in composition. The apparent constancy in composition (major and trace) of the medium grained charnockites, occupying the axes of synclines, suggests original igneous parentage and subsequent recrystallisation under granulite facies in the solid state. The coarser foliated biotite (± amphibole and allanite)-garnet bearing charnockites confined to the shear zones and axes of cross folds indicate that they were subjected to metamorphism under high P_{H_2O} and attained palingenesis. This led to the remarkable concentration of K and associated elements Ba, Rb, Zr, Ce, Th, U, P and enrichment of radioactivity. The radioactivity, 2.3 ± 0.1 c.g.m. in the igneous charnockites has increased to 8.9 ± 0.1 c.g.m. in the palingenetic charnockites and supports the evolution of two types of charnockites belonging to two different metamorphic episodes. These two types are separated by basic activity in the form of younger sills and dykes of pyroxene granulites.

Age of Charnockites

The overall structures exhibited by khondalites in Visakhapatnam district are overturned isoclinal folds plunging NE, which are emplaced by charnockites along the cores and axes. Refolding along NW-SE axes has resulted in simple SE plunging synclines, anticlines—often doubly plunging—and occasionally overturned folds, isoclinal in nature. Charnockite bands have attained double thickness along cross fold axes wherever involved and are well exposed at

TABLE II. C.I.P.W. Norms and Modes of charnockites around Visakhapatnam

	1	2	3	4	5
		Norms			
Q	6.4	11.7	9.6	16.4	19.5
Or	7.9	7.1	6.8	21.3	23.0
Ab	29.5	32.0	26.5	17.8	20.5
An	25.5	19.8	26.4	17.8	14.6
C	0.3	1.0	0.3	3.7	2.1
Hy	25.3	22.7	25.4	17.2	11.4
Mt	2.4	3.2	2.8	2.0	4.4
Il	2.0	1.9	1.6	2.9	3.6
Ap	0.7	0.6	0.6	0.9	0.9
		Modes			
Quartz	8	12	11	22	23
Orthoclase	8	7	7	29	31
Plagioclase	50	49	47	28	26
Orthopyroxene	29	26	30	7	5
Garnet	—	—	—	7	8
Biotite	—	—	—	2	3
Ores	4	5	4	3	3
Zircon	1	1	1	2	1

1-5: Same description as in Table I.

Kasipatnam, Kondapalli region in Andhra Pradesh and Baliguda in Orissa. The widespread shear zones and fractures running in NW-SE directions are parellel to the cross fold axial plane traces. The allanite-bearing palingenetic charnockites and pegmatites and apatite-magnetite deposits following the NW-SE trends are coeval and belong to 2,000 m.y. (Rao and Babu, 1978) and hence the age of refolding is related to the same period. K-Ar age of biotite, 2085±43 m.y., from the type area charnockite (Balasubrahmanyam, 1975) is sympathetic to the refolding age. The structurally emplaced monazite bearing charnockites into the earlier fold system are thus much older. The monazite from beach sands of Visakhapatnam gave an age of 2,600 m.y. (Vinogradov *et al.*, 1964) and relates to the older charnockites. The Rb-Sr isochron age of 2,615 m.y. and 2,580 m.y. for Nilgiri and Madras charnockites (Crawford, 1969), and the zircon age of Madras acid charnockite, 2,600 m.y. (Vinogradov *et al.*, 1964) are concordant with the monazite age from Visakhapatnam. The Rb-Sr whole rock ages of charnockites from Kasipatnam, Visakhapatnam district have also indicated ages of 2,695 m.y. and 2,129 m.y. (Perraju, 1977 – personal communication) supporting observations of two ages for the charnockites.

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Rare earth element geochemistry of basalt-spilite association of Bombay and Carlsberg Ridge—a preliminary study

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Introduction

Sukheswala (1974) reported the occurrence of spilite with pillow characters from Bhoiwada, on the eastern ridge of Bombay island, in the Deccan traps of India for the first time. The Bhoiwada section exhibits the gradation of fresh black tholeiite into altered green spilite; perhaps this is the only known occurrence in the world showing complete gradation within one section. Therefore, this section provides a unique opportunity to trace the possible ancestry of the spilite. Similarly, Hekinian (1968) reported the presence of tholeiite and spilite from the Carlsberg Ridge, Arabian Sea, from two nearby dredge hauls.

In this short note, an attempt has been made using rare earth element (REE) geochemistry to see whether or not any genetic relation exists betwen the basalt (tholeiite) and spilite.

Results and Discussion

REE analyses of a tholeiite and spilite from Bambay and Carlsberg Ridge were made using Neutron Activation Analysis involving radiochemical group separations (Reddy *et al.*, 1976). The results are presented in Table I, while the chondrite-normalized REE patterns are shown in Fig. 1.

While both the rocks from the Bombay area display LREE enriched patterns, the absolute abundance of spilite is at least 3 times higher than that of the basalt. Similarly the $(La/Sm)_{e.f.}$ also shows an increase from 1.85 to 2.45 for tholeiite and spilite respectively.

Thus the contrasting REE geochemistry for these two rock types from the Bombay area opens up at least three alternatives:

1) That the increase in concentration of REE and $(La/Sm)_{e.f.}$ ratio may perhaps be related to spilitization, suggesting that the REE are not immobile at least under some secondary processes.
2) It is likely that the relative fractionation of LREE in spilite may be similar to that of the basalt, suggesting possible genetic relationship between these two rock types.