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RESEARCH ARTICLE

CERIUM, THORIUM AND ZIRCONIUM BEARING MINERALS FROM CHARNOCKITES OF THE EASTERN GHATS GRANULITES BELT, ANDHRAPRADESH SOUTHERN INDIA

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ABSTRACT

Radioactive minerals allanite, monazite and zircon are observed in the charnockites, from Eleswaram and Visakhapatnam in the Eastern Ghats Granulite Belt (EGGB). Intrusive charnockites (garnetiferrous hypersthene gneisses) in the host khondalites (garnetiferrous sillimanite gneisses) are occasionally allanite bearing and rich with ubiquitous accessory minerals, monazite and zircon. These radioactive minerals are found to be more Ce, Th, and Zr rich. It is observed that Ce is more than Y in allanite and monazite. Similarly Th and U are more significant in monazite than allanite. Zr is more in zircon, while REE, U and Th are less. Further allanite is highly altered and different stages of metamictisation characterized by loss of major elements, REE and enrichment of Th rendering the altered allanites to be highly radioactive. The wide spread charnockite occurrences in the EGGB are favorable for the mineralization of radioactive minerals and detailed investigation may through light in locating new findings. In addition to the allanite, monazite and zircon, an unknown Y rich mineral (Ca, Y, Ti silicate) was found with unusual composition in the REE (Predomination of HREE). A significant amount of Bao is also found in Ca, Y and Ti silicate mineral.

INTRODUCTION

Experimental Details

The EGGB is known for the occurrence of high grade metamorphic rocks formed in the deep crust belonging to P-T environment (7-10 Kbr / 750^0-950^0C) (Sudipta Neogi *et al.*, 1999; Grew *et al.*,1982; Kamineni *et al.*, 1991; Rao *et al.*, 1995) and represented by migmatitic garnetiferrous quartzo-feldspathic gneisses (referred in the literature as leptynites) and garnet-sillimanite gneisses (Khondalites). The migmatitic garnetiferrous quartzo-felspathic gneisses occur in the form of low lying mounds and sillimanite gneisses as major hill ranges. Basic and granitic intrusions of different dimensions are commonly observed in the migmatitic gneisses. These are also metamorphosed and characterized by granulite textures. Metamorphic basic igneous rocks are considered as basic pyroxene granulites and dark and greasy looking hypersthene bearing granitic intrusives are named as charnockites. The charnockites have counter parts in Srilanka, Madagascar, Australia and Antarctica in the Gondwanaland. Major occurrences of charnockites are observed in Aganampudi and Airport hills in Visakhapatnam and Eleswaram hill range in the EGGB. (Fig 1)

The charnockites are identified to be mostly enderbites, and charnoenderbites. The enderbites are medium grained dark grey in colour and have plagioclase, hypersthene with minor orthoclase, garnet, biotite as essential mineral assemblage and accessory opaques (magnetite/ilemanite), monazite and zircon as accessory minerals. The enderbites in the Airport hill and Aganampudi area in the Visakhapatnam are occasionally porphyritic, coarse grained with blue quartz and greasy appearance, and attain charnoenderbite to charnockitic composition. The charnockites in Eleswaram region in the EGGB are mostly biotite rich enderbites with minor charnoenderbites. In both the areas the charnockites are traversed by coarse charnockite (Fig 2) pegmatites

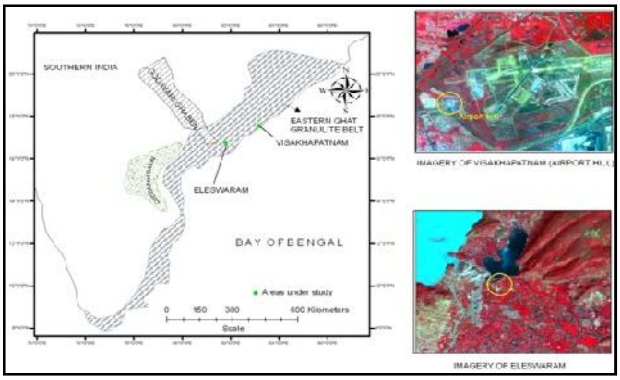

Fig .1 Location map of the study area

Fig .2 Pegmatite cutting across the charnockites

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Fig. 3 Allanite crystals in pegmatite

RESULTS AND DISCUSSION

The charnockite pegmatites have plagioclase (Ab_{59}, An_{40}, Or_1), orthoclase (Or_{88}, Ab_9, An_3), quartz, biotite ± hypersthene ± hornblende the as essential mineral assemblage, opaques (magnetite/ilemanite/pyrite, chalcopyrite) as accessory minerals and radioactive mineral assemblage of allanite, monazite and zircon. Biotite and hornblende are halogen rich (Table 1) and compare with halogen bearing minerals in charnockites in portions of the EGGB (Leelanandam, 1969a; Leelanandam, 1969b; Kamineni *et al.*, 1982)

Table 1 Electronprobe data * of hydrous mineral assemblage from Eleswaram

	BIOTITE	**BIOTITE**	**HORNBLENDE**
Samples	**95TX A3 Bi G1**	**95TX A3 Bi G2**	**95TX A3 HB**
SiO_2	35.51	35.51	36.77
AL_2O_3	14.09	13.83	13.01
TIO2	3.46	3.9	1.22
CR_2O_3	0.05	0.05	0
FE_2O_3	-	-	6.39
FEO	19.6	19.85	15.62
NIO	0	0	0
MNO	0.42	0.29	0.75
MGO	11.23	11.18	6.29
CAO	0.11	0.08	10.89
BAO	0.08	0.11	-
NA_2O	0.08	0.1	1.22
K_2O	9.72	9.19	2.53
F	0.53	0.6	0.28
CL	1.3	1.39	2.42
TOTAL	**96.18**	**96.08**	**97.39**

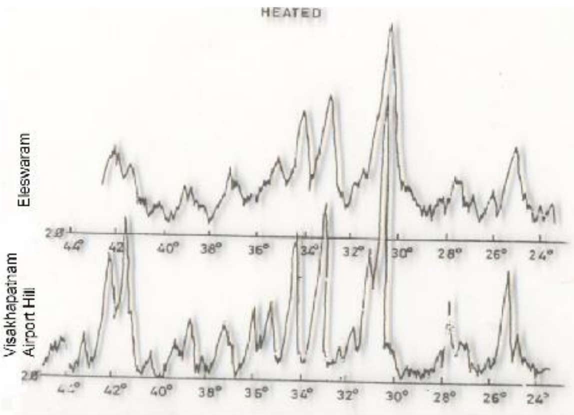

Fig .4 x-ray diffraction patterns of allanites

Allanite is prominent and show euhedral to rounded appearance with anastomizing cracks around the margins. At places the size of the allanite is 2 feet in diameter, exposed in the inner parts of charnockite bodies. The monazite and zircon are wide spread as minor phases and are of millimeter size. The allanites are mostly in metamict stage and gave no X-ray patterns. After reheating at 900^0 C the amorphous mineral, defined peaks (Fig 4) are obtained and match with the ASTM data on allanites. The X-ray and microprobe data is obtained from Geological Survey of Canada, Ottawa, Canada. The partial electron micro probe analyses of allanite (Fig 5) indicate the possibility of high REE enrichment (Table 2).

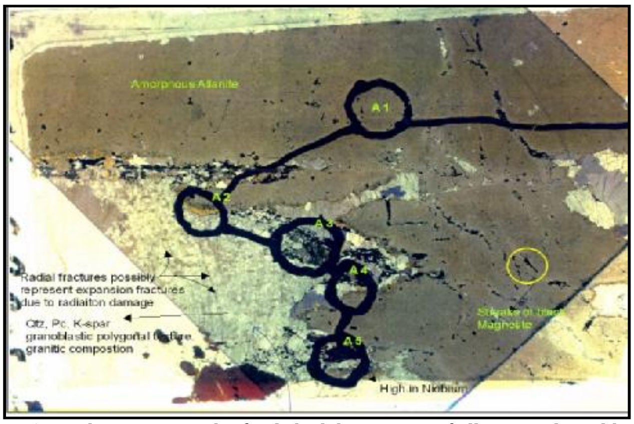

Fig .5 Photomicrograph of polished thin section of allanite scale width 2.5cm, Circles, A_1-A_5 Minerals probed

Table 2 Electronprobe data* of allanite from Eleswaram charnockites

	ALLANITE	**Allanite**
	Metamict	Yellow edge
Sample	95TX A1G1	95TX A2G2
SIO_2	30.03	45.78
AL_2O_3	14.52	17.57
TIO2	0.42	0.68
FE_2O_3	4.65	0
MGO	1.22	0.71
FEO	8.09	6.65
MNO	0.8	0.32
CAO	11.24	5.82
TOTAL	**70.97**	**77.53**

*Analyzed by Drs. S.Tella and A.R.Miller of the mineral resources division, Geological Survey of Canada with a MAC

electronprobe equipped with a KEVEX energy dispersive spectrometer. Acceleration voltage was 20 kV with a specimen current of a 10 nA measured on a kaersutite, chromite, biotite, halite and synthetic phlogophite standards. The precision ± 15% ranges from 0.1 to 0.3

Mineral analyses were performed by A.T.Rao, Co author, at the Institute of Experimental Mineralogy, Chernogolovka, Moscow District, Russia, using CAMEBAX-MBX with energy dispersive X-ray spectrometer line 860 / 500 and two wave dispersive spectrometers. Electron beam energy was set at 20 KV for both wave dispersive and energy dispersive with current beam, 30nA (under wave dispersive) and 1 nA (under energy dispersive). The ZAF correction was applied with CAMEBAX - MICROBEAM and line 860-500 software and oxide minerals and synthetic monazite were used as standards. The precision (± 20) ranges from 0.1 to 0.3 for the microprobe data.

Although the totals for allanite analyses (70%-77%) appear low, rare earths (La, Ce, Y, etc), and hydrous phases will make up most of the difference. However detailed electron microprobe analysis of allanites and associated monazite, zircon (Table 3) carried out at the Institute of Experimental Mineralogy, chernogolovka, Russia.

Monazite and Zircon from Visakhapatnam and Eleswaram are presented (Table 4) to know the individual concentrations of REE, U, Th and Zr. It is observed that Ce is more than Y in allanite and monazite. Similarly Th and U are more significant in monazite than allanite. Zr is more in zircon, while REE, U and Th are less. The metamict parts of allanite relative to the unaltered parts show loss of major elements and REE and enrichment of Th (Table 3, Fig 5). The petrographic study reveals that monazite and zircon, garnet and biotite occur as inclusions in allanites indicating allanite has crystallized late in the paragenetic sequence of charnockite pegmatites. The allanites from both the Visakhapatnam and Eleswaram have almost similar geochemistry supporting that the charnockites and pegmatites are evolved from a same or similar source region.

The intrusive charnockites and pegmatites are more allanite and monazite bearing when compared to the garnet ± sillimanite-quartz feldspar gneisses in the EGGB. The charnockites in the EGGB belong to 1000 ma (Grew and Manton, 1983) and correlated with the evolution of charnockites from Antarctica in the Gondwanaland.

Table 3 Electro micro probe data# of Allanites

	Allanite Eleswaram1	**Allanite Eleswaram 2**	**Allanite Eleswaram 5**	**Allanite Eleswaram10**	**Allanite Eleswaram12**	**Allanite Eleswaram13**	**Allanite Airport hill 1**	**Allanite Airport hill 2**
SiO_2	31.25	16.5	18.33	24.93	15.25	36.99	31.64	0.85
TiO_2	0.58	0.11	-	0.19	0.23	0.59		
Al_2O3	15.15	3.22	4.16	11.07	6.71	14.66	15.19	0.33
Fe_2O3	13.58	3.24	4.01	4.21	3.18	14.82	14.55	1.66
MnO	0.28	0.04	0.14	-	-	0.11		
MgO	1.68	0.13	0.26	0.49	0.26	0.72	2.05	0.13
CaO	10.15	2.32	1.75	5.56	5.74	2.92	10.24	2.65
K2O	0.05	0.01	0.09	0.23	0.16	0.34		
La_2O3	4.28	1.23	0.91	4.88	5.52	0.21	3.96	0.52
Ce_2O3	9.7	3.32	2.08	11.88	15.91	0.22	10.3	4.27
Pr_2O3	0.94	0.28	0.31	1.21	2.04	-	1.3	0.02
Nd_2O3	3.65	1.23	0.8	4.61	6.39	-	3.26	0.46
Sm_2O3	0.3	0.27	0.03	0.65	1.12	-	0.51	0
Y_2O3	0.96	2.27	1.37	0.71	0.8	0.68	0.47	0.1
ThO_2	1.56	41.39	47.46	3.6	3.08	2.56	1.88	5.26
UO_2	0.11	5.35	3.92	0.02	0.19	-	-	0.54
PbO	0.07	0.13	0.13	0.04	0.02	0	-	3.38
ZrO_2	0.06	0.86	0.44	-	-	0.13	-	-
BaO	-	0.13	0.37	0.16	-	0.09	-	-
Total	94.35	82.03	86.56	74.44	66.6	75.04	95.35	20.17

The host quartzo felspathic garnet sillimanite gneisses (Khondalites) for the charnockite intrusions show relatively low REE (Fig 6). The U concentration in charnockites is more (4 ppm), when compared to khondalites (0.5 to 1 ppm), while Th has similar abundance (14-30 ppm).

Table 4 Electron probe data of monazite and zircons

	Monazite Ellaswaram1	**Monazite Airport hill**	**Zircon (Ellaswaram)1**	**Zircon (Airport Hill)**
P_2O_5	29.30	29.63	0.41	-
SiO_2	1.50	1.39	32.09	31.88
CaO	0.70	0.76	-	-
FeO	-	0.04	-	-
La_2O_3	13.31	13.22	-	-
Ce_2O_3	26.38	26.29	-	-
Pr_2O_3	3.23	2.75	-	0.08
Nd_2O_3	10.21	9.67	-	0.16
Sm_2O_3	1.69	1.69	0.02	-
Gd_2O_3	1.24	1.56	0.05	-
Dy_2O_3	0.20	0.53	0.16	0.05
Y_2O_3	2.03	2.51	0.43	0.78
ThO_2	9.80	9.76	0.15	-
UO_2	0.36	0.04	-	0.09
PbO	0.04	0.15	-	-
ZrO_2	-	-	66.68	66.96
Total	**99.99**	**99.99**	**99.99**	**100.00**

The apatite -magnetite skarn veins in the charnockites and migmatitic quartz-feldspathic biotite ± hypersthene gneisses of Kasipatnam in Visakhapatnam region of EGGB are also allanite, zircon and monazite bearing and belong to 500 ma (Kovach *et al.,* 1997) Allanites, monazites and zircons thus belong to different stages of evolution of migmatitic and metamorphic stages and intrusions in the EGGB. The significant concentrations of monazite and zircon more with garnet and sillimanite in beach placers suggest that they are mostly derived from major exposure of migmatitic garnetiferrous ± quartzo-felspathic gneisses and garnet-sillimanite gneisses. Charnockites though wide spread, less weathered and have contributed monazite and zircon to a lesser extent than the quartzo-felspathic gneisses and sillimanite gneisses. Allanite being sporadic in occurrence and highly subjected to alteration in charnockites, it could not be traced in the beach placers.

The charnockites in the EGGB are more extensively quarried for building material. Detailed studies may throw light in locating radioactive minerals and to establish controls of mineralization particularly, allanite, monazite and zircons in the EGGB.

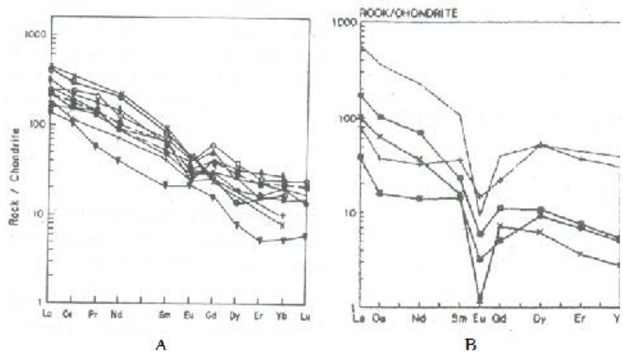

Fig .6 REE distribution patterns in charnockites (A) and Khondalites (B) (Mallikharjuna Rao *et al*., 1999)

In addition to the allanite, monazite and zircon, an unknown Y rich mineral (Ca, Y, Ti silicate) was found with unusual composition (Table 5) in the base elements (not corresponding to charnockite) and REE (Predomination of HREE). Significant amount of Bao is also found in Ca, Y and Ti silicate mineral.

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