Petrochemical Studies of the Rock Sample From *Dakshin Gangotri,* Antarctica

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ABSTRACT

Petrography, major, minor and trace element studies (including REE) have been carried out on the rock sample obtained from *Dakshin Gangotri* Antarctica. The study reveals that:

1. the rock is composed dominantly of plagioclase, quartz, garnet and biotite with minor amounts of microcline (with perthetic intergrowths), hypersthene, magnetite and accessory apatite and zircon grains,
2. the initial hypidiomorphic granular texture of the rock is affected by subsequent dynamic metamorphism, and
3. it has high SiO_2 (65.38%) and high CaO/K_2O(3.6) and Th/U (~30) ratios with enriched REE contents (La = 200X; $(La/Lu)_N$ = 7) and negative europium (Eu/Eu* = 0.5) anomaly.

Based on petrographic and chemical data the rock is identified as felsic charnockite (enderbite) with superimposed effects of later dynamic metamorphism which is discussed in detail.

INTRODUCTION

Antarctica has long been recognised as an important component of Gondwanaland forming the central locking piece in the natural reconstruction of the sourthern continents. Its geology has many points in common with that of peninsular India (Pichamuthu, 1966).

The first Indian Antarctica Expedition Team landed on the Antarctic continent on January 9, 1982 and collected rock samples from *Dakshin Gangotri* (Lat. 70°45' 12.96"S; Long 11°38' 13.62"E). The purpose of the present paper is to report the petrographic data and chemical characteristics of the rock sample from *Dakshin Gangotri* and evaluate its geochemical significance.

SAMPLE AND ANALYTICAL METHODS

About 150 g of the sample (with biotite showing distinct foliation) was supplied by the National Institute of Oceanography, Goa, for the present study. Two thin sections cut parallel and perpendicular to the foliation plane, were prepared for petrographic study of the sample. About 70 g of the sample, was crushed to —200 mesh (ASTM) for major, minor and trace element determinations.

Silica, ferrous iron and calcium were determined by classical methods (Jeffery, 1975) and aluminium, titanium and total iron following Shapiro and Brannock's (1962) procedure. Na, K, Mn, Mg, Co and Zn contents were determined by Atomic Absorption Spectrophotometry (AAS) and Vanadium (Sarkar and Rao, 1982) and phosphorus (Riley, 1958) by colorimetry. Instrumental Neutron Activation Analysis (INAA) procedure (Murali *et al.,* 1979) has been adopted for the determination of Na, Mn, Co, Sc, La, Ce, Sm, Eu, Tb, Yb, Lu and Th contents and uranium has been determined by DNAA technique (Reddy and Sankar Das, 1974). The INAA values of Na, Mn and Co agree well (within 2-4%) with the AAS values.

Both the sample from Antarctica (ANT-82) as well as the reference samples were analysed in duplicate or triplicate. The data presented in Tables I and II indicate the precision and accuracy of the results.

PETROGRAPHY

The rock is composed dominantly of plagioclase, quartz, garnet, biotite and minor amounts of microcline, hypersthene and magnetite. Apatite and zircon are found as accessories. A brief description of the important minerals is given below:

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The rock appeared to be originally hypidiomorphic granular but is now inequigranular due to dynamic effects. The effects of dynamic metamorphism manifest as follows:

1. broken grains of garnet and quartz.
2. plagioclases show bent twin lamellae.
3. flakes of biotite are twisted and bent.
4. quartz, feldspar and even biotite grains show strain shadows.
5. a retrograde breakdown of garnet and hypersthene to biotite.

Plagioclase: Plagioclase is bimodal in habit and grain size. The larger grains are usually characterised by bent twin lamellae. The smaller grains are fresh and twinned and do not show evidences of strain after crystallization.

Quartz: As in the case of plagioclase, some quartz grains show strain shadows and some are free from strain.

Garnet: Garnet is pale pinkish brown and fractured and has inclusions of quartz and magnetite but does not generally show sieve texture. Along the fracture plane and borders, garnet is found to be breaking down to biotite.

Biotite: Biotite is dark brown or reddish brown in colour. Some grains show well developed prismatic cleavage. It is generally found as alteration product of either garnet or hypersthene.

Microcline: Microcline shows typical cross-hatched twinning and perthitic intergrowths.

Hypersthene: The hypersthene is dark green or colourless with feeble pleochroism. Some of the grains are elongated and others are granular with irregular outlines. The grains are highly altered to an indistinguishable mass of biotite and chlorite (?). Relict pyroxenic cleavage is noticed in the altered portion.

Epidote: The rare grains of epidote are included within magnetite.

DISCUSSION

On the basis of petrographic and mineralogical criteria (Pichamuthu, 1969) the granulite gneiss sample from *Dakshin Gangotri* (ANT-82) is a felsic charnockite which is reflected in the chemical data as well (Table 1 and Fig. 1).

Tilley (1936) gave the name 'enderbite' for certain varieties of acid charnockites found in Enderby land, Antarctica, in which plagioclase is an essential feldspar (as against microcline perthite in typical charnockite) which are chemically characterised by low K_2O, high CaO (leading to high CaO/K_2O ratios) and high SiO_2 contents. The sample from *Dakshin Gangotri* with plagioclase as predominant feldspar with high CaO (4.25%) and low K_2O (1.17%) contents resulting in high CaO/K_2O (3.6) ratio (acid charnockites $CaO/K_2O= < 1$) and high SiO_2 (65.38%) content satisfied the criteria for enderbite. Enderbites are also reported from peninsular India (Tilley, 1936; Pichamuthu, 1953). Subrahmanyam (1959) reported both garnetifcrous and nongarnetiferous enderbites from Madras and ANT-82 major element data is comparable to the enderbite reported by him.

The Sc, V, Co and Cr contents of ANT-82 are within the range of values of various charnockite of peninsular India (Murali, unpublished data).

TABLE 1

Analyses of major element

Oxides (%)	ANT —82			TKT —1		
	1	2	3	Mean ±S	Ours	Reported*
$Si0_2$	65.24	65.52	—	65.38 ±0.20	65.28	67 1'?
TiOa	1.04	1.02	—	1.03 ±0.01	0.61	0.56
$AI2O_3$	15.96	15.96	15.69	15.87 ±0.16	15.40	15.28
$Fe20_3$	0.70	0.82	0.70	0.74 ± 0.07	4.08 +	4.24 +
FeO	5.48	5.00	—	5.24 ±0.34		1.88
MnO	0.09	0.08	0.08	0.08 ± 0.01	0.18	0.11
MgO	0.90	1.01	0.92	0.94 ±0.06	0.47	0.40
CaO	4.17	4.46	4.11	4.25 ±0.19	1.80	1.62
$Na2^o$	3.38	3.28	3.42	3.36 ±0.07	4.53	4.31
$K2^O$	1.15	1.16	1.19	1.17 ±0.02	4.91	4.86
PaOs	0.18	0.19	0.23	0.20 ± 0.03	0.13	0.12
HzO+	0.09	0.10	0.08	0.09 ±0.01		1.71
H2O-	0.96	1.00		0.98 ± 0.03		0.24
				99.33		

TKT — 1 Trachyte, Inhouse standard, Analytical Chemistry Division, BARC.
* Ali, 1979.
— Not determined.
\+ Total Fe as Fe_2O_3

Thorium and Uranium: The thorium and uranium values of ANT-82 are 27.3 ppm and 0.91 ppm respectively. Granites usually have 10 to 15 ppm thorium and 3 to 4 ppm uranium with a Th/U ratio 4 (Bayer *et al.,* 1978). The Th/U ratio increases with differentiation and/or due to uranium loss during magmatic activity (in oxidising conditions) or due to addition of secondary (hydrothermal or deuteric) thorium (Whitfield *et al.* 1959). The Th/U ratios reported from thoriferous provinces are generally < 8 (Divakara Rao *et al.*, 1972; Bayer *et al,* 1978). However, recent work on various granitic rocks of Dharwar craton (Reddy *et al.,* 1982) and on charnockites from Trivandrum (Parthasarathy, personal communication) indicate Th/U ratios as high as 15 to 30, comparable to our ANT-82 value. Since the typical mantle derived rock has Th/U ratio of 1 to 2, the higher Th/U ratios of ANT-82 and other Precambrian granites need a closer look to understand their petrogenetic evolution.

Rare earth elements: The high REE content of ANT-82 compares well with felsic charnockite in general. Its chondritic REE pattern (Fig. 2) indicates steep LREE slope {$(La/Lu)_N$ = 4} and a flat HREE trend (~50X) with $(La/Lu)_N$ ratio of 7 and negative europium (Eu/Eu* = 0.5) anomaly. The overall REE trend of the sample reflects low pressure fractionation of pyroxene-plagioclase assemblage from the system under low fo_2 conditions.

Quantitatively different REE abundances with positive, negative and no europium anomaly patterns are reported for various charnockites from different continents (Hubbard and Whitley, 1979; Peterson, 1980; Weaver, 1980; Pride and Mucke, 1981; Murali, unpublished data). Plotting the available REE data of felsic chamockites characterised by negative europium anomalies exclusively, reveals a broad overall similarity between them (i.e. comparable La/Sm and La/Lu ratios and europium anomalies) which includes our ANT-82 pattern as well (Fig.2) suggesting similar petrogenetic model for the whole group of rocks.

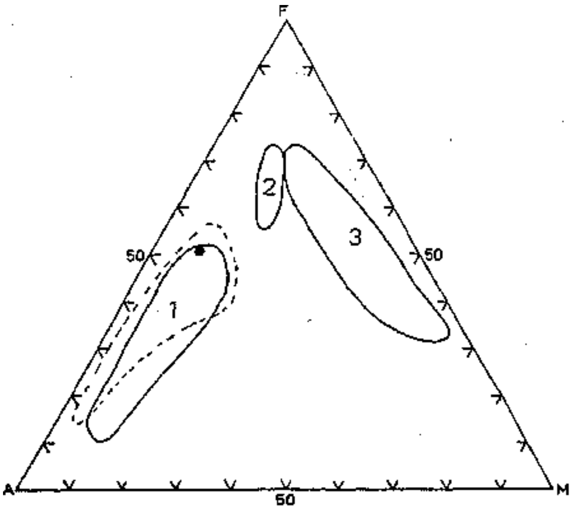

Fig. 1 :

A(Na_2O + K_2CO) - F(FeO)*-M(MgO) diagram.
1_Felsic, 2-Intermediate and 3 Basic granite regions of Pallavaram (after Weaver, 1980), FeO* total iron as FeO.
Sample from *Dakshin Gangotri* Antarctica Enderbite field (data from Subrahmanyan, 1959)

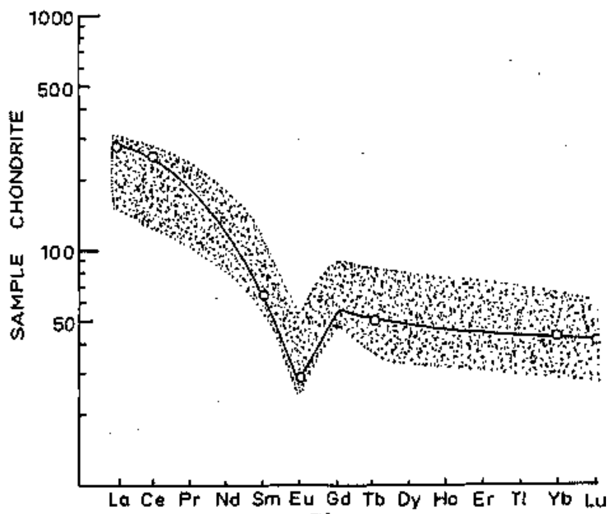

Fig. 2 :

REE pattern of ANT-82 (-O-).
(Dotted area represents the REE patterns of different charnockites with similar trends.)

TABLE 2

Analyses of trace element

Element(pp m)	ANT—82			Mean ± s	CRB —1	
	1	2	3		Ours	Reported**
Sc	22	23	—	22.5 ± 0.71	32	30
V	30	29.6	—	29.8 ±0.28	—	410
Cr	22	24	21	22.3 ± 1.53	18+	16
Co	8	10	8	8.7 ±1.15	36	34
Zn	100	84	80	88 ± 10.6	—	—
La	85.4	84.4	89.5	86.4 ±2.7	26	25.4
Ce	212	214	200	209 ± 7.6	55	51
Sm	12.0	11.8	12.4	12.1 ± 0.31	7	6.6
Eu	1.98	1.97	2.04	2.00 ± 0.04	1.95	1.90
Tb	2.35	2.12	2.58	2.35 ± 0.23	1.04	1.0
Yb	9.1	8.9	9.0	9.0 ±0.1	3.62	3.3
Lu	1.16	1.24	1.39	1.26 ±0.12	0.5	0.55
Th	25	27	30	27.3 ± 2.5	5.5	5.7
U	0.93	0.89	—	0.91 ± 0.03	3.9*	4.1*

CRB —1 Basalt, Inhouse standard,Radiation Center, Oregon State University, Corvallis,USA. Courtesy: R. A. Schmitt

* Reference sample is TKT— 1 (Inhouse standard, Analytical Chemistry Division, BARC).

** Laul and Rancitelli (19771)

\+ Poor signal-to-noise ratio.

— Not determined.

Plate 1 : Biotite with garnet showing faint degree of foliation and gneissic character (ord. light, x 60))

Plate 2 • Rounded grains of zircon (centre of the photograph) associated with garnet, biotite and quartz, (ord. light, X 60)

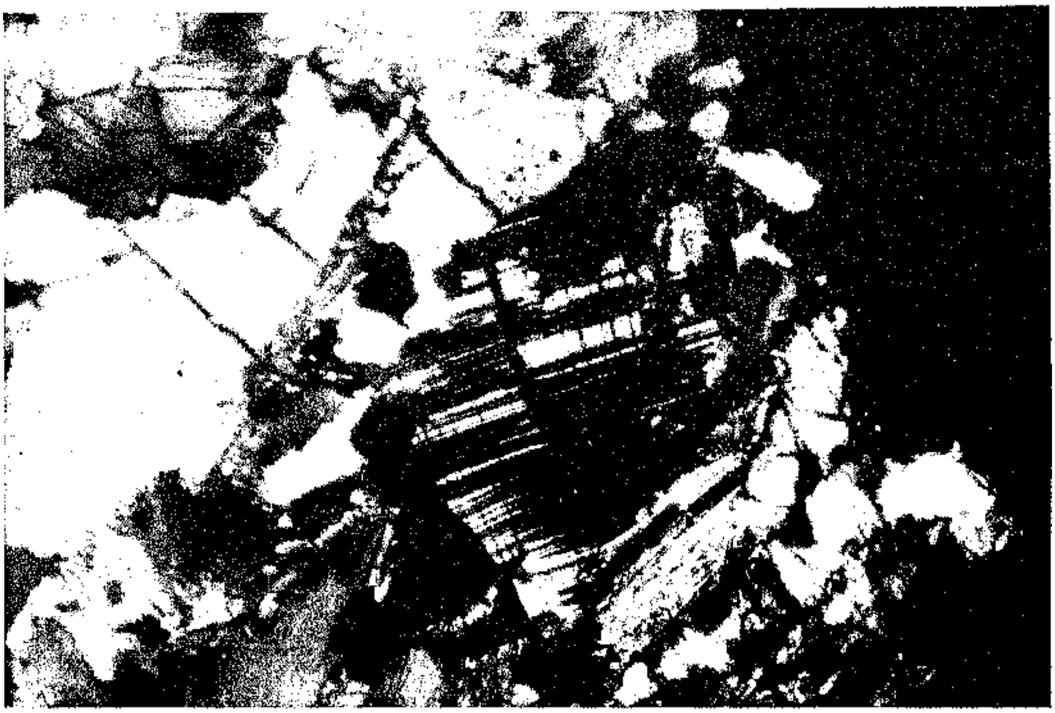

Plate. 3 : Albitic plagioclase showing very fine twin lamallae associated with quartz and biotite (Ord. light, x 60)

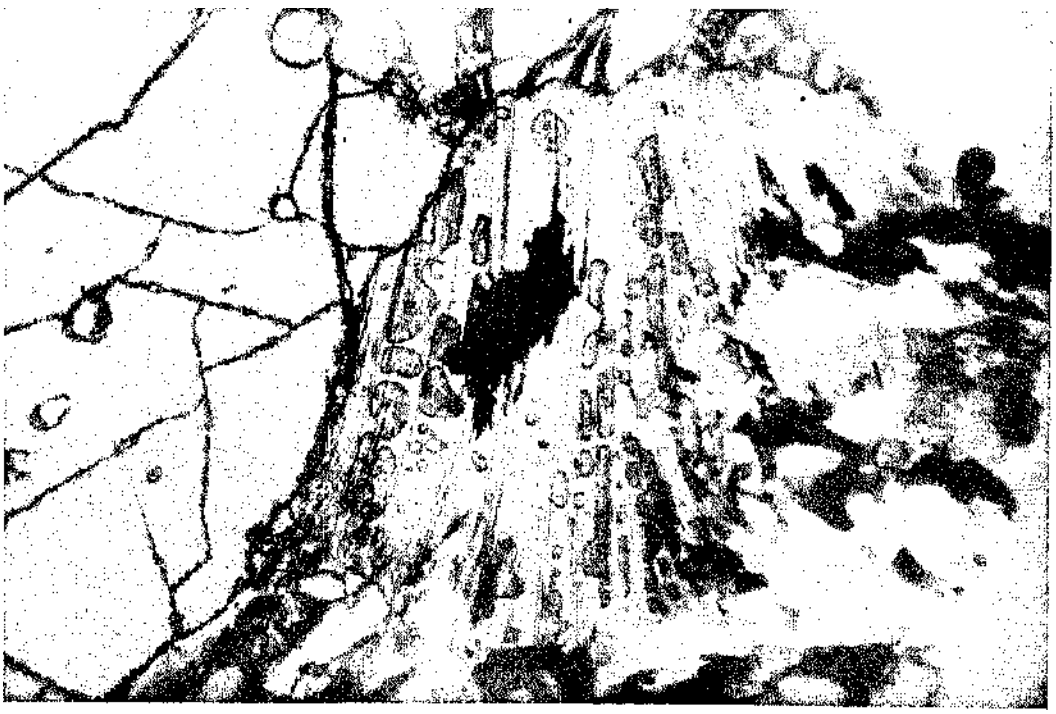

Plate. 4 : Biotite showing strain effects (fanned out cleavage planes) associated with garnet and apatite (?), (Ord. light, X 60).

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