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Instrumental Neutron Activation Analysis of Rock Samples from Schirmacher Range, Central Dronning Maud Land, East Antarctica

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Abstract

Non-destructive Instrumental Neutron Activation Analysis (INAA) of rare earth elements, some trace and major-elements of the representative rock samples from Schirmacher Range, Dronning Maud Land, East Antarctica comprising five gneiss samples (quartz-biotite gneiss, garnet-biotite gneiss, sheared banded gneiss, leucocratic gneiss, banded gneiss) have been carried out. The samples were irradiated for 8 hours along with standard reference rock samples of suitable weights in a thermal neutron flux of -10^{13} ncm^{-2} sec^{-1} .

The elemental concentrations are estimated by studying the induced activity produced in samples using high resolution gamma ray spectrometry. The results of elemental characterisation of five different rock types are compared with normal magmatic rock and discussed,

Introduction

Instrumental Neutron Activation Analysis is an established, high sensitive and non-destructive nuclear technique used to find quantitative elemental concentrations of rare earth elements and other trace elements ranging from percentage to the trace level with very good precision (Gibson and Jagam,1980 and Gurna *et al,* 1988). The quantitative determination of several trace elements in the different international standard reference materials (SRM) are often analysed by this technique (Gurna *et al,* 1988 and Potts and Rogers, 1991). Since the abundances of REE in rocks are being used for petrogenetic studies for their geochemical significance, the accurate data is essential before doing any quantitative modelling. Petrological and mineralogical studies of these rocks have been done extensively. Geochemical studies including.major and trace elements have been carried out and attempts to explain the genesis of the gneisses were made (Chakraborty et al.,1985; Kaul *et al.,* 1985 and 1988). These rocks were compared with well known shield areas of South India, Africa and Australia (Craddock, 1982; Fedorov *et al.,* 1982; Murali *et al,* 1983; Pichamuthu, 1966 and Ravich, 1982). However, REE data of the gneisses and other rock types have not been used to explain their petrogenesis.

This work is an attempt to present the analytical results of some of the major, trace and REE elements of the gneisses from Schirmacher Range,Dronning Maud Land, East Antarctica.

Schirmacher range of Dronning Maud Land, East Antarctica, is about 16km long and lies between latitudes 70°44'30"S and 70°46'30"S and longitudes 11°22'40"E to 11°54'00"E. It is an E-W to WNW-ESE trending low lying range with a maximum width of 2.7kms in the central part.

The stable craton of East Antarctica comprises Precambrian high-grade gneisses and crystalline schists with granite intrusives (Singh, 1986).

The gneisses consist of microcline(and/or) orthoclase, plagioclase,quartz,biotite, hornblende and opaque ore as the essential mineral constituents (Chakraborty *et al.,* 1985).

Experimental Technique

The rock samples weighing about one kilogram were washed and crushed to -200 mesh. The crushed powder of each sample was homogenized and sampling was done by coning and quartering. Powdered rock samples weighing ~ 180mg each with comparators/standards such as SY-3,Inhouse standard ARD-22 and synthetic of suitable concentrations were taken alongwith silicate rock samples weighing 100-150mg. About 40 nos. of samples were wrapped in high purity aluminium foil and they were properly interposed by comparator stacked in one or two rows in a big aluminium foil forming a target of size 1.6cm in diamater and 3.7cm in height.This target was irradiated in a thermal neutron flux ~ 10^{13} ncm^{-2} s^{-1} from CIRUS reactor at BARC, Bombay.

The gamma emissions of induced activities were measured after allowing cooling time of 4 to 5 days from the end of irradiation. The determination of all possible REEs namely La, Ce, Nd, Sm, Eu, Tb, Tm, Yb, Lu, trace elements Sc, Cr, Co, Rb, Hf, Ta and major elements Na, Ca and Fe were made under varying conditions of cooling and counting intervals. The different factors, viz. cooling.and counting intervals, possible interferences, details of radioisotopes and their gamma emission energies, accuracy and sensitivity have been described by Brunfelt and Steinnes, 1966; Gordon *et al.,* 1968; and Murali *et al.* ,1979. Over the past nine years, parameters required for the above elements have been standardised (Gurna *et al.,* 1988 and 1990).

The measurements of desired gamma emissions were carried out by gamma ray spectrometry using ORTEC HPGe coaxial detector (relative efficiency 10%)-Type 10175, which has 2kev resolution at 1332kev of ^{60}Co and ORTEC HPGe planar detector-Type GLP 36385 with 0.8kev resolution at 122kev of ^{57}Co. ORTEC spectroscopy amplifier and ECIL PC based multichannel analyser with 8k Silena

ADC were employed in counting.The counting errors due to statistics at one sigma level were within ±10% for La, Ce, Nd, Sm, Yb and Th and within ± *5%* to ± 20% for Eu, Tb, Tra, Lu and U for all the samples except where indicated in the tables. The counting errors due to statistics at one sigma level for Sc, Cr, Co, Na and Fe were within ±5% and for Hf, Ta, Rb, Ca and K were within ± *5%* to + 15%.

Results and Discussion

The results of 9 REE, Th and U as obtained by INAA of the five gneissic samples from Antarctica have been given in the Table 1, which are generally used for Atomic Mineral Exploration Programme.

The gneisses have low to moderate REE contents ($\sum$ REE =19-218 ppm). The Chondritic normalised REE pattern of the samples is shown in Fig. 1, which reveals an enriched LREE and flat HREE pattern showing a wide variation in their abundances.

The LREE/HREEN values for these gneiss samples increases as CaO content decreases, except in sheared banded gneiss. In all these gneisses the La/YbN ratio

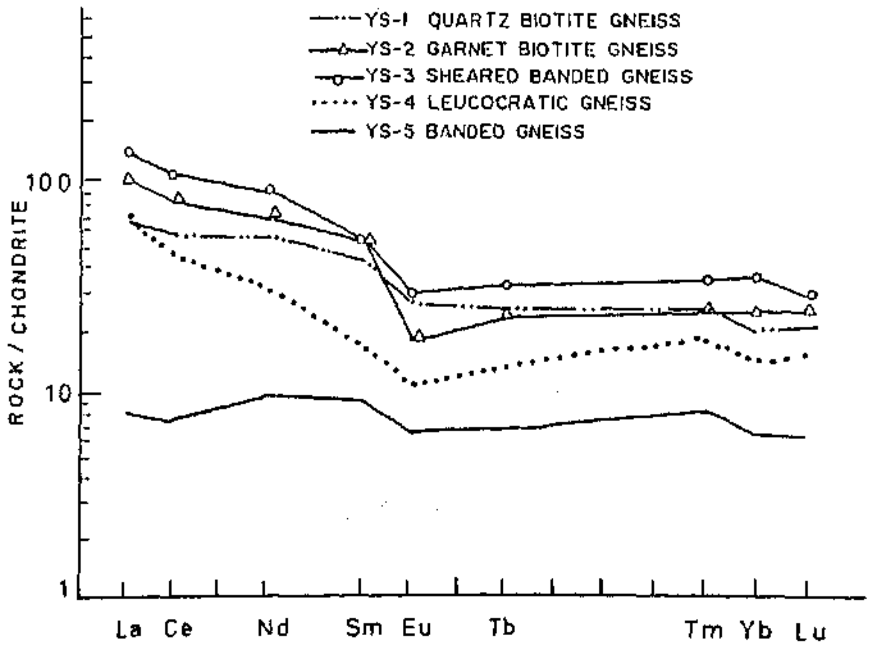

Fig. *1. REE pattern of five gneiss samples from Schirmacher range, east Antarctica.*

Table 1: Concentrations of La, Ce, Nd, Sm, Eu, Tb, Tm, Yb, Lu, Th and U in ppm

S.No.	Rock type	Reference number	La	Ce	Nd	Sm	Eu	Tb	Tm	Yb	Lu	Th	Li
1	Quartz biotite gneiss	YS-1	21.5	48.0	34.0	7.8	1.80	1.1	0.75	4.1	0.65	1.7	1.6+0.6
2	Garnet biotite gneiss	YS-2	33.0	71.0	42.0	9.6	1.20	1.0	0.70	5.0	0.75	9.2	3.0
3	Sheared banded gneiss	YS-3	45.0	95.0	56.0	9.6	2.00	1.4	1.00	7.2	0.90	5.1	<1.0
4	Leucocratic gneiss	YS-4	22.0	40.0	19.0	3.0	0.75	0.6	0.55	2.9	0.50	7.7	3.4
5	Banded gneiss	YS-5	2.7	6.5	6.0	1.7	0.44	0.3	0.25+0.07	13	0.20	<1.0	1.7

Table 2: The Relative Concentrations of the Radio Elements

S.No.	Rock Type	Reference number	Th/U	K/Na	$K/U*10^{-4}$	$K/Th*10^{-4}$	Relative concentations in relation to K
1	Quartz biotite gneiss	YS-1	1.06	0.59	0.625	0.59	U normal Th depleted
2	Garnet biotite gneiss	YS-2	3.06	1.89	1.160	0.38	U normal Th depleted
3	Sheared banded gneiss	YS-3	5.10	0.51	0.800	0.16	U normal Th enriched
4	Leucocratic gneiss	YS-4	2.26	2.41	1.260	0.55	U depleted Th depleted
5	Banded gneiss	YS-5	0.58	0.94	0.410	0.70	U enriched Th depleted
6	Normal magmatic rock		3.50		1.000	0.25	

* Data from Atal(1978).

Table 3: Concentrations of Sc, Cr, Co, Rb, Hf, Ta, Na, Ca, K and Fe in ppm (except Where Indicated)

S.No.	Rock Type	Reference number	Sc	Cr	Co	Rb	Hf	Ta	Na_2O %	CaO %	K2O %	Fe_2O_3(T) %
1	Quartz biotite gneiss	YS-1	27.5	138	30.5	N.D.	5.5	0.55	2.3	7.27	1.20	6.6
2	Garnet biotite gneiss	YS-2	13.5	97	9.0	122	7.5	0.80	2.5	<1.4	4.21	3.5
3.	Sheared banded gneiss	YS-3	18.0	144	10.5	N.D.	9.0	0.90	2.1	2.94	0.96	4.5
4	Leucocratic gneiss	YS-4	3.5	99	2.0	162	3.5	0.40	2.4	<1.4	5.18	1.0
5	Banded gneiss	YS-5	29.5	535	35.0	N.D.	0.9	<0.1	1.0	10.20	0.84	4.9

Note: (i) N.D.- Not detectable.
(ii) The data on K_2O was obtained by gamma ray spectrometry using 5" x 4" Nal (Tl) assembly.
(iii) The oxide concentrations of CaO and K_2O are calculated from the elemental values.

is greater than one. Therefore, an inverse relation between CaO content and La/Yb_N ratio exists in these samples.

The LaN values for the gneisses range from 63 to 132 and YbNvalues range from 13 to 33 except in banded gneiss whose LaN value is 7.9 and YbN is 5.9. The enrichment of LREE over HREE is characterised by high La/YbN values ranging from 3.4 to 4.9 except in the case of banded gneiss having a ratio of 1.3. This shows a medium to high fractionation in these samples.

All the samples show medium negative Europium anomalies Eu/Eu*, ranging from 0.41 to 0.76. Thus, the data indicate that these rocks have LREE enriched crustal origin and undergone high degree of differentiation (Henderson, 1984).

The relative concentrations of radio elements U, Th and K of these gneiss samples are given in Table 2. The radio elemental distribution in these rocks is characterised by low U, Th and Th/U ratios. The K/U and K/Th ratios of these rock samples show little scatter around normal values. The normal values for magmatic rocks are taken as $K/U \times 10^{-4} = 1$, and $K/Th \times 10^{-4} = 0.25$ (Atal *et* al.,1978). The K/Na ratio and Th/U ratio of these gneiss samples are almost in good agreement

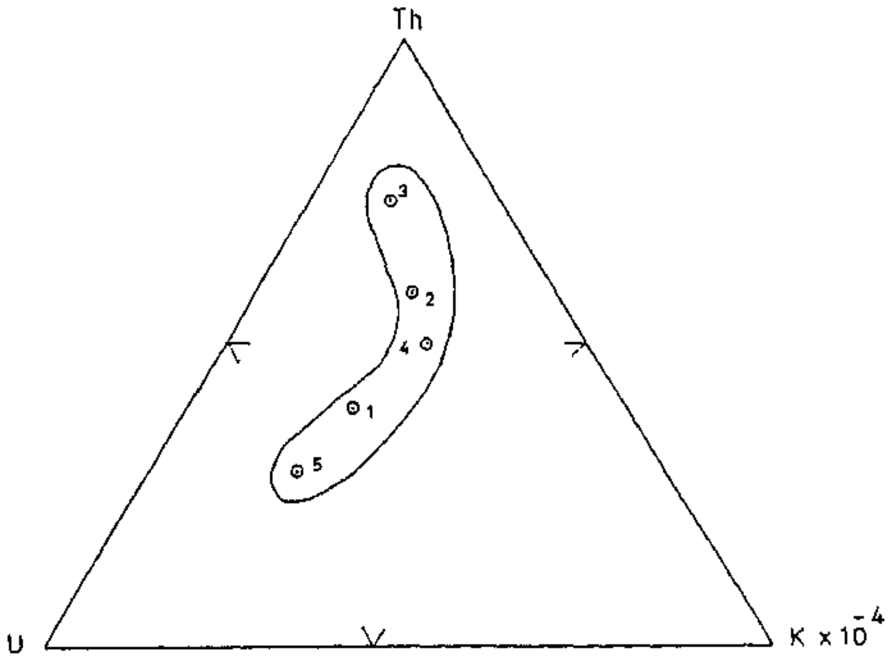

Fig. 2. Th U & K variations of gneisses from Schirmacher range, east Antarctica.

with each other except in the case of sheared banded gneiss, where the ratio difference is 10-fold.

The Th/U ratio in granites is about 4 with Th levels of 10-15 ppm (Bayer *et al.,* 1978). In these gneissic samples, the Th/U ratio ranges from 1 to 5.1 except in Banded gneiss sample where U is 1.7 ppm and Th is below detection limit of one ppm for this matrix. Fig.2 shows that banded gneiss and quartz-biotite gneiss samples have high U/Th ratios. The sheared banded gneiss sample which was collected near Russian station in Schirmacher hill range, contains 5ppm of Th and less than one ppm of U.

The results of trace elements such as Sc, Cr, Co, Rb, Hf, Ta and major elements Na_2O, K_2O, Fe_2O_3(T) are given in Table 3. It is seen that the quartz- biotite gneiss, sheared banded gneiss and banded gneiss show high CaO/K_2O ratios varying from 3 to 12. The garnet-biotite gneiss and leucocratic gneiss sample have CaO/K_2O ratio of less than one.

Similarly the quartz-biotite gneiss, sheared banded gneiss and banded gneiss have high Na_2O/K_2O ratios ranging from 1.1 to 2.1. The garnet- biotite gneiss and leucocratic gneiss show low Na_2O/K_2O ratio of less than one. Fig.3 shows that these samples fall in the classification of granite to tonalite.

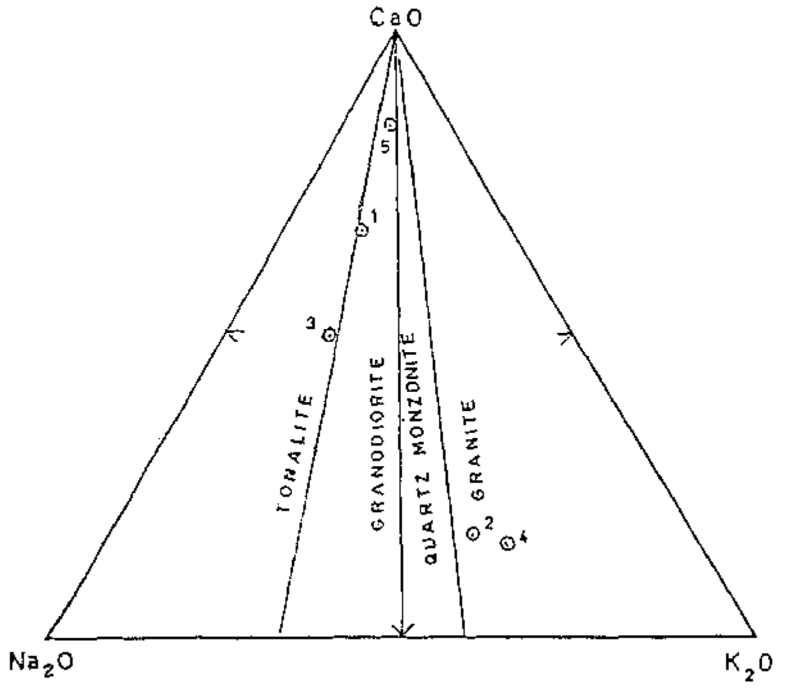

Fig. 3. CaO-Na_2O-K_2O diagram of gneisses from Schirmacher range, east Antarctica.

The Cr concentration in these gneisses varies from 97 to 144 ppm except in banded gneiss in which the concentration is 535 ppm, which may be due to the concentration of mafic minerals in the sample.

The K/Rb ratios in garnet-biotite gneiss and leucocratic gneiss are 287 and 265.

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