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Note on the P-T Conditions of Metamorphism of Schirmacher Range, East Antarctica

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ABSTRACT

Mineral chemical data of selected rock types of Schirmacher range East Antarctica are presented. Some of these rocks have strong petrological comparisons to south Indian leptynites and Khondalites. Temperature estimate based on the Fe-Mg calibrations of co existing garnet biotite mineral pairs suggested that metamorphic temperatures varied from 550 750°C. Geo barometer calibration of gar-sil-plag-qtz yielded an estimate of 5 31k bar at 600 °C for khondalites.

INTRODUCTION

Recent third Indian expedition to Antarctica carried out mapping of 35 sq km of Schirmacher Range of East Antarctica (Sengupta 1985). The rock types recorded were calc silicates pelitic gneisses charnockites metabasics and migmatitic variants of gneisses. Several late granites and basic dykes were also noted. Detailed field and petrographical account of the rock types are given in Sengupta(1986). In this paper some preliminary work carried out on the mineral chemistry and metamorphism of selected rocks of Shirmacher Range is presented.

ROCK TYPES, MINERAL CHEMISTRY AND METAMORPHISM

Following a detailed petrographic study of selected rock types mineral chemical analysis of four samples were carried out. An ARL electron microprobe at the University of Chicago was used. The samples selected were garnet biotite gneisses two samples leptynite (garnetiferous quartzofeld spathic gneiss) and khondalite (garnet + sillmanite + plagioclase + graphite gneiss) one sample each. The microprobe was operated at 15 kV using an energy dispersive analysis system (Reid and Ware 1975) with natural garnets (Gore mts New York) and plagioclase-composition glasses as standards.

ROCK TYPES

Garnet-biotite gneiss These are coarse to medium grained units with a mineralogy of plagioclase + K-feldspar + quartz + garnet + biotite. They have undergone extensive migmatisation. In coarser grained varieties garnet with flakes of biotite are seen randomly distributed in a quartzofeldspathic matrix. They define a crude foliation in hand specimen. Medium grained garnet biotite gneissic varieties have good foliation and planer fabric defined by biotite flakes. In thin section, an alternating quartzofeldspathic and garnet-biotite layers are noticed. In highly deformed varieties, ribbons of elongated quartz are present. Such varieties show recrystallisation of quartz and bent and broken.

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twin lamellae of plagioclase. Modaiy garnet and biotite vary from 5% to 25%. Rounded zircons sphene and apatite are noticed in few varieties as accessories.

Leptynite The leptynite studied in this work (HG 6) is a medium grained variety showing an elongated fabric defined by quartz and feldspar. The mineral assemblage is K-Feldspar + plagioclase + quartz+garnet. Biotite is extremely rare and noticed only in one of the three sections prepared.

Khondalite This rock is characterised by an assemblage of plagioclase + K-feldspar + quartz + sil limanite Fibrolitic sillimanites and flakes of biotite mark the foliation of the rock. Large garnets are seen breaking down along their grain boundaries to secondary biotites. Rutile and graphite are significant accessories.

MINERAL CHEMISTRY

Analyses of minerals of selected four rock types from above three groups have been carried out with a primary aim to assess the conditions of metamorphism. Hence mineral analyses that were essential for P-T calculations have only been analysed. The mineral chemical data of garnet biotite and plagioclase are presented in tables 1 2 and 3.

TABLE 1

Average Mineral chemistry of garnet

	HG 1		*HG 2*		*HG 6*		*HG 10*	
	Core	*Rim*	*Core*	*Rim*	*Core*	*Rim*	*Core*	*Rim*
No of analyses	*3*	*3*	*2*	*2*	*3*	*3*	*3*	*3*
SiO_2	39 31	37 71	38 67	38 16	37 55	38 05	38 60	38 60
Al_2O_3	21 40	20 96	20 76	21 29	20 42	20 65	21 54	21 32
FeO	29 19	32 14	30 05	29 44	34 19	33 80	31 79	31 45
MgO	8 86	5 66	2 79	1 78	2 14	2 02	5 51	7 00
CaO	0 88	1 99	4 52	5 33	4 32	4 84	1 89	1 05
MnO	0 00	0 63	2 26	2 41	0 00	0 42	0 42	0 00
Structural Formulae based on 24 (O)								
Si	3 044	3 006	3 092	3 073	3 053	3 055	3 039	3 032
Al	1 952	1 969	1 956	2 021	1 956	1 954	1 998	1 973
Fe	1 889	2 143	2 009	1 983	2 324	2 269	2 092	2 068
Mg	1 022	0 673	0 332	0 214	0 259	0 243	0 646	0 817
Ca	0 073	0 171	0 387	0 460	0 376	0 416	0 159	0 089
Mn	0 00	0 094	0 153	0 164	0 00	0 029	0 028	–
X_{fe}	0 64	0 76	0 85	0 90	0 89	0 90	0 76	0 71

TABLE 2

Mineral chemistry of biotite Structural formulae based on 22 oxygen atoms in brackets

Sample No.	HG 1	HG 2	HG 6	HG 10
No. of Analysis	3	3	1	2
SO_2	35 90 (5 3682)	36 50 (5 634)	35 78 (5 637)	37 48 (5 466)
Al_2O_3	18 55 (3 263)	15 32 (2 782)	14 43 (2 674)	19 33 (3 316)
TiO_2	1 65 (3 185)	3 88 (0 449)	4 29 (0 507)	2 19 (0 239)
FeO	18 96 (2 3626)	22 89 (2 944)	22 74 (2 985)	13 27 (1 613)
CaO	0 12 (0 192)	– –	–	
MgO	12 89 (2 8912)	7 92 (1 834)	7 66 (1 810)	14 31 (3 131)
K_2O	7 60 (1 4506)	8 95 (1 763)	9 00 (1 810)	9 34 (1 739)
X_{fe}	0 45	0 62	0 62	0 34

TABLE 3

Average composition of plagioclase, structural formulae based on 8 oxygen atoms in brackets

Sample No.	HG 1	HG 2	HG 6	HG 10
No. of Analysis	3	2	3	4
SiO_2	61 31 (2 730)	60.48 (2.736)	60.10 (2.701)	61.56 (2.741)
Al_2O_3	24 14 (1 276)	23.36 (1.745)	26.82 (1.289)	26.19 (1.248)
CaO	6 75 (0 322)	6.06 (0.294)	6.84 (0.329)	6.19 (0.295)
Na_2O	7 21 (0 622)	8.12 (0.711)	7.47 (0.651)	7.98 (0.689)
K_2O	0 20 (0 012)	-- --	0.17 (0.010)	0.16 (0.009)

Garnets The analyses and formulae are given in table 1. This mineral is commonly present in all the rocks and in most cases are seen devoid of any inclusions. They are rich in almandine component with a general high Fe ratio (X_{Fe} 0 90-0 64). They belong to the end members of the solid solution series of almandine pyrope and grossularite. Spessartine component is generally low but in one sample appreciable content of MnO is noticed (HG 2 MnO = 2 26-2 41). This might be due to the original composition of the host rock. Micro probe analyses carried out at several points from core to rim of garnets did not indicate zoning.

Biotite The chemical composition of biotite is presented in table 2. A general high X_{Fe} (0 62-0 34) is characteristic of the biotites. Biotites of khondalite (HG 10) have slightly higher alumina. Ti is generally low.

Plagioclase The average composition of plagioclase from each rock type is listed in table 3. A fairly similar composition of plagioclase in all the rock types and almost pure nature of the plagioclase is noticed. Anorthite content averages around 32. Micro probing from core to rim of the plagioclase did not show any zoning.

CONDITIONS OF METAMORPHISM

The conditions of metamorphism of rocks have been assessed based on different geothermometers applicable to garnet-biotite mineral assemblages and geobarometer of garnet plagioclase-sillimanite-quartz assemblage. Inconsistency of temperatures from garnet-biotite geothermometer calibration is well known. However in this work compositions of garnet cores and analyses of biotite as much as possible from the matrix of the rock are used in calculations. These estimates are considered to give reliable peak metamorphic estimates as the Fe-Mg re equilibration during cooling is considered low between such pairs (Indares and Matignole 1985).

In table 4 the temperature and pressure of metamorphism estimated for different rock types are presented. Some variation in the estimates for single pairs is noticed between different methods of gar-bio thermometer due to differences in calibration and thermodynamic function of the thermometer. Holdway and Lee (1977) estimate suggest 556 to 861°C and of Ferry and Spear (1978) 545-1073°C. Considering the large area and wide separation of rock types and a minimum variation of at least 300°C temperature from a single method large variation in temperature conditions of metamorphism in the terrain can be inferred. The possibilities for slight changes of compositions of co-existing minerals of leptynite and khondalite assemblages due to further re-equilibration following peak metamorphic conditions cannot be ruled out. The highest average for a single pair from different methods obtained for HG 2 suggest 956° C (935°C-861°C-1073°C). This is outside the calibration range of thermometres. Bearing in mind the probable large errors at high temperatures from these calibrations the realistic palaeotemperatures in the area may have varied between 550-750°C.

TABLE 4

Temperature and Pressure of metamorphism

Sample No.	*Temperatures (°C)*			*Pressure (kb)*
	Thompson 1976	*Holdway and Lee 1977*	*Ferry and Spear 1978*	*Newton and Haselton 1981*
HG 1	935 ± 50°C	861 ± 50°C	1073 ± 50°C	
HG 2	720 ± 50°C	685 ± 50°C	745 ± 50°C	
HG 6	608 ± 50°C	589 ± 50°C	594 ± 50°C	
HG 10	570 ± 50°C	556 ± 50°C	545 ± 50°C	5 16

The geobarometer data obtained by the application of gar—plag-silli—qtz barometer of Newton and Haselton (1981) to the khondalite (HG 10) gave 5 16 k bar pressure at 600°C.

INDO-ANTARCTIC TERRAINS

A summary of metamorphic and plutonic activities in East Antarctic region is compared with that of southern India in table 6. It appears that East Antarctican terrain had a more or less similar geological history to southern India.

TABLE 5

Comparison of metamorphic and plutonic activities in the Indo Antarctic terrains (Antarctican events after Yoshida and Kizhaki (1983) and Sengupta (1986)

	ANTARCTICA (Queen Maud Land and LutzowHolm bay in East Antarctica)	*S INDIA (Kerala and Tamil Nadu)*
1st Event Late Archaean	High grade metamorphism/Emplacement of original igneous rocks of charnockites	High grade metamorphism of pelitic gneisses and conversion of ortho-amphibole gneisses to charnockites.
2nd Event Mid Proterozoic	Intermediate pressure granulite facies metamorphism and formation of charnockites	Granulite facies metamorphism and incipient charnockite development in metapelites
3rd Event Late Proterozoic	High amphibolite facies metamorphism	Amphibolite facies metamorphism
4th Event Early Phanerozoic	Intrusion of granite pegmatite and associated low amphibolite facies metamorphism	Emplacement of granite and pegmatite and marginal retrogression of granulite facies rocks

The development of early metasedimentary sequences granulite facies metamorphism plutonic activity late stage retrogression are all analogous to both the belts. Before the breakup from Gondwanaland similar metamorphic and plutonic activity may have operated in Indo-Antarctican terrains particularly in producing siilimanite-orthopyroxene bearing gneisses and granulites. The striking similarities between the sillimamte-gamet-graphite gneiss and garnetiferous quartzofeldspathic gneiss with those of khondalites and leptynites of southern India imply a strong petrological correlation and probable space and time relation for a continuous granulite facies terrain in pre-Proterozoic times. Recent geochronological data suggesting major Proterozoic granulite facies event and emplacement of pegmatite and granites of 400-600 m a in southern India (Crawford 1969 Soman *et al* 1982 Nair *et al* 1985 Srikantappa *et al* 1985 Parthasarathy *et al* 1986 and Per communication R C Newton 1985) are comparable with the ages reported for similar rock types and event from East Antarctica (Yoshida and Kizhaki 1983 and Grew 1984). Extensive geochronological data from both the terrains may prove as infallible guide to strengthen the correlation.

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REFERENCES

Crawford AR (1969). Reconnaissance Rb S dating of the Precambian rocks of southern Peninsular India *Jour Geol Soc India* v 10 pp 117 166.

Ferry J M and Spear F S (1978). Experimental calibration of the partitioning of Fe and Mg between biotite and garnet *Con trib Mineral Petrol* v 66 pp 113 117.

Grew E S (1984). A review of Antarctic garnulite facies rooks *Tectonopbysics* v 105 pp 177-192.

Holdway M J and Lee S M (1977). Fe-Mg cordierites Stability in high grade pelitic rocks based on experimental theoretical and material observations *cont Mineral Petrol* v 63 pp 175-198.

Indares A and Martignole J (1985). Biotite-garnet geo-thermometry in granulite facies rocks evaluation of equilibrium criteria *Canad Mineral* v 23 pp 187-193.

Nair N G K Soman K Santosh M Arakelyan M M and Golubyev VN (1985) K-Ar ages of three granite plutons from North Kerala *Jour Geol Soc India* v 26 pp 674-677.

Newton R C and Haselton H T (1981). Thermodynamics of the garnet-plagiaclase-$A1_2$ S_1 O_5-quartz barometer In R C Newton A Navrotsky and B J Wood (Eds). *Thermo dynamics of minerals and melts Advances in Physical geochemistry* Springer - Verlag Berlin pp 131-148.

Parthasarathy R Palrecha M M and Sankar Das M (1986). Chemical ages of zircons. New results *Jour Geol Soc India* v 27, pp 110-113.

Reed,S J B and Ware NG (1975). Quantitative electron microprobe analysis of silicates using energy-dispersive X-ray spectro metry. *Jour Petrol* v 16 pp 449-519.

Sengupta Sudipta, (1985). Antarctic geology *Every man's Science* v XX No 5 pp 121-127.

Sengupta Sudipta (1986). Geology of Schirmacher Range (Dakshin gangotri) East Antarctica. Scientific Report of third Indian Expedition to Antarctica. *Technical Report No 3* (This volume).

Soman, K Nair N G K Golubyev V N and Arakelyan M M (1982). Age data on pegmatites of South Kerala and their tectonic significance. *Jour Geol Soc India* v 23 pp 458-462.

Srikantappa C Raith M and Spiering B (1985). Progressive charnockitisation of a leptynite-khondahte suite in Southern Kerala - India - Evidence for formation of charnockites through decrease in fluid pressure? *Jour Geol Soc Indila* v 26 pp 849-872.

Yoshida M and Kizaki K (1983). Tectonic situation of Lutzow - Holm Bay in East Antarctica and its significance in Gondwana land. In R L Oliver P R James and J B Jago, Earth Sciences pp 36 - 39.