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Geothermometric and Geobarometric Studies on the Precambrian Granulites Occurring Near Patharkhang Village, West Khasi Hills Distirict, Meghalaya

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Summary

The present work is a geothermometric and geobarometric study on the Precambrian Granulites occurring near Patharkhang (Lat.25°36' - 25°40' & Long 91°7' - 91° 12') village, 20 Km southeast of Sonapahar, West Khasi District in Meghalaya. Geologically, the area represents a part of the " Gneissic Complex" of Shillong Plateau.

Sonapahar in the Western Khasi Hills district in Meghalaya not only represents an amphibolite-granulite transition in the North East India (Lal et.al.,1978) but also straddles amphibolite facies gneisses on the north and a variety of granulite to the south. The area is particularly known for the Sapphirine bearing metapelitic assemblages and the works carried out by Lal et.al (1978) showed the chemographic relation of the metapelitic assemblages. However, precise quantitative temperature and pressure regarding peak metamorphic assemblages in the light of modern petrology is yet to be known. Within the jurisdiction of time and facilities available in the department, the author has attempted to calibrate the peak metamorphic P-T using EPMA analysis of coexisting phases for the variety of rocks and has evaluated the metamorphic P-T path traversed by the ancient rocks in the crustal sector. As per as the mineral chemistry data is concerned the present work is also said to be an attempt towards building up a database of the subject where adequate knowledge is rare.

Introduction

The study area around Patharkhang situated southeast of Sonapahar in the Weat Khasi Hills District of Meghalaya. The area is included in the toposheet number 78 $O/_2$ of Survey of India 1971, in the scale 1: 50,000. The area can be approached from either Guwahati through Highway No.37 via Boko and Hahim or through Shillong via Nongstoin. Another alternate route is through Williamnagar via Ronjeng of East Garo Hills District. Bus sevices operated by the Meghalaya State Transport Corporation as well as a few private buses forms the basic means of communication network of the area.

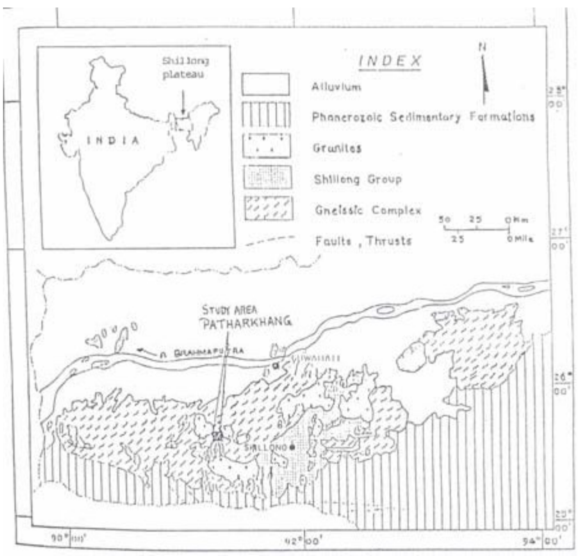
The area around Patharkhang constitute a part of the Shillong plateau which represents the north eastern wedge of the Peninsular shield of India, uplifted and moved to the east over a distance of about 250 Km along E-W trending transcurrent Dauki fault during the Himalayan Orogeny (Evans, 1964). The Precambrian rocks of the plateau have been variously interpreted as part of the Eastern Ghats charnokitic terrain (Crawford, 1974) or a continuation of the Satpura belt of Bihar prior to the eastward movement. The plateau consist essentially of rocks of upper amphibolite to granulite facies, flanked on the east by greenschist facies rocks belonging to the Shillong series of Precambrian age and to the south by sedimentary rocks and basic volcanics of Cretaceous age. The area received several attention from the geologist since world's richest deposits of sillimanite-corundum rocks located in the neighbouring Sonapahar area . *Dunn* (1929) was the first geologist who mapped the area in details. *Ghosh* and *Saha* (1954) reported sapphirine bearing rocks elsewhere around Sonapahar. A petrological note on the metamorphites around Sonapahar area was published by *Banerjee* (1955). The latest petrological report on Sapphirine bearing silica undersaturated rocks in the area by *Lal et.al.*, (1978) are worth mentioning. However, a detailed study on the rocks in the area concern, particularly Patharkhang is lacking before this investigation. Refer geological maps 1&2

Theory and/or Method

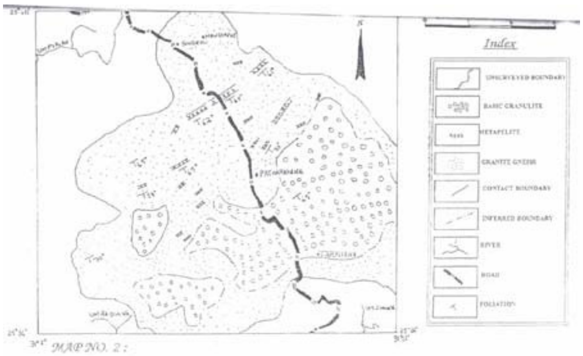
Method of study include field techniques (including collection of samples), sample preparation for analysis and method of analysis.

An area of about 32sq.Km around Patharkhang was surveyed and more than fifty (50) samples collected during seven days of field work .The field investigation was carried following the methodology of Lahee 1961. Only the fresh samples, free from weathering and alteration of relatively larger dimension were collected and the sample locations were plotted in the map by the procedure of front and back bearing measurements using a "Brunton Compass". Twenty five (25) rocks were subjected to detailed petrographic studies. Finally some selective mineral phase from fifteen (15) thin sections were analysed by Electron Probe Micro Analyser (EPMA) at the University Scientific Instrumentation Center (USIC), IIT Roorkee, Roorkee, Uttranchal, India. The minerals were analysed in an automatic 3- Channel wavelength dispersive JEOL JXA 8600M Superprobe at USIC, IIT Roorkee. The operating conditions were: 15 KV accelerating voltage, 1μ m beam diameter and 30 ηλ beam current. ZAF correction is applied to get the data and the accuracy is estimated to be of the order of 2 % error. Refer tables 1, 2 &3 and also graph 1.

Figures and Tables



Map-1- Geological map of the Shillong plateau (simplified from GSI map, 1973).



Map-2: Geological map of Patharkhang, West Khasi Hills district, Meghalaya (in part of toposheet) no. 78 O/2.

Sample No. / Mineral constituent	NS-33	NS-37	NS-40	NS-31	NS-42	NS-48	NS-41	NS-50
Plagioclase	40.13	42.51	44.96	36.74	38.00	34.21	12.18	38.62
Hornblende	32.54	25.83	15.12	35.81	26.95	30.52	44.97	28.91
Ortnopyroxene	10.52	12.21	16.97	11.95	13.51	13.00	17.94	14.13
Clinopyroxene	13.76	17.64	18.91	13.26	16.94	19.96	19.76	15.76
Biotite	1.51	...	1.72	0.71	2.67	0.63	2.66	1.34
K-feldspar	...	...	...	...	...	...	0.23	...
Opaque Oxide	1.21	1.81	1.76	1.12	1.18	1.21	1.91	1.12
Accessories	0.33	...	0.55	0.41	0.75	0.47	0.35	0.12
TOTAL	**100**	**100**	**99.99**	**100**	**100**	**100**	**100**	**100**

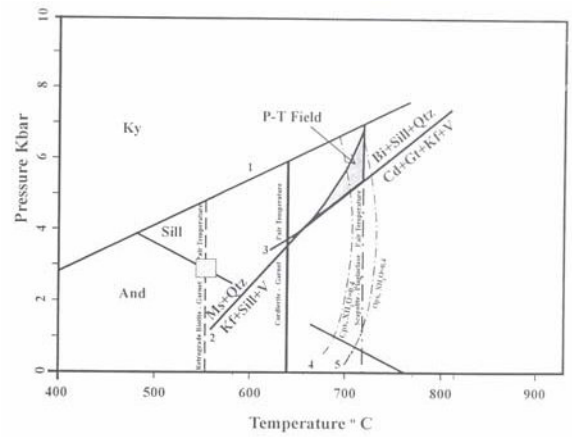
Table-1: Modal composition of hornblende pyroxene granulite.

Sample No / Mineral Constituent	NS-34	NS-51	NS-36	NS-53	NS-43	NS-49
Plagioclase	38.54	42.13	25.17	54.92	43.29	44.46
Orthopyroxene	33.81	33.21	45.72	25.26	33.23	33.21
Clinopyroxene	15.93	11.64	19.31	11.00	11.92	14.37
OpaqueOxide	6.53	7.52	5.14	3.25	6.26	3.12
Quartz	2.31	2.91	3.11	2.18	3.29	2.12
K-feldspar	0.32	0.62	...	0.84	...	0.42
Hornblende	2.11	1.65	1.13	2.21	1.18	1.85
Accessories	0.45	0.32	0.42	0.34	0.83	0.44
TOTAL	**100**	**100**	**100**	**100**	**99.99**	**100**

Table-2: Modal composition of pyroxene granulite

Sample No / Mineral Constituent	NS – 47	NS – 54	NS – 45	NS – 32	NS – 52	NS – 55
Quartz	30.65	22.12	33.52	34.56	21.45	36.45
K-fledspar	32.50	28.94	42.12	16.21	26.52	28.76
Plagioclase	34.48	33.40	20.50	40.69	33.48	27.52
Biotite	1.11	5.12	3.12	5.25	7.21	6.12
Hornblende	1.12	8.56	...	2.12	9.52	...
Others	0.13	1.85	0.74	1.17	1.81	1.15
TOTAL	**99.99**	**99.99**	**100**	**100**	**99.99**	**100**

Table-3: Modal composition of granite gneiss



Graph-1: P-T conditions of the area based on different geothermometres and geobarrometers and relevant experimentally determined reaction curves Aluminum- silicate phase diagram is taken from Holdaway (1971), clino pyroxene- ortho pyroxene break down reaction curves at xH2O = 0.4 is taken from Spear (1981). The curve 2 represents

Muscovite + Quartz = K- feldspar + Sillimanite + Vapour

From Chatterjee and Johannes, 1974. The curve 3 represents :

Biotite + Sillimanite + Quartz = Cordierite + Garnet + K- Feldspar + H_2O

From Holdaway and Lee (1977). The shaded area represents near peak conditions and post peak retrogression condition is represented by the dotted area.

Conclusions

Temperature estimated from the core composition of garnet and cordierite according to Bhattacharya, Majumdar and Sen (1988) are ranging from 620^0C to 670^0C with the mean temperature 640^0C . This temperature indicate the lower temperature limit of the metamorphic conditions of the area (Graph -1). The pertinent evidence is the absence of primary muscovite in the metapelites and quartzo-feldpathic gneisses in the area. Further, the presence of sillimanite and potash feldspars in the metapelites indicate the muscovite breakdown reactions which is consistent with the temperature estimated from the cordierite-garnet geothermometer.

Temperature estimated from scapolite-plagiclase pairs according to Goldsmith and Newton (1977) ranges between 670^0C and 800^0C with an average temperature of 730ºC. This temperature indicate the high temperature side of the P-T field of the rocks underwent metamorphism (graph 1). The experimental curve of hornblende breakdown reaction at low PH_2O (Spear, 1981as shown in Graph 1) is consistent with the temperature estimated from scapolite-plagioclase geothermometer. However, the higher temperature of the metamorphic conditions of the rocks in the area is inferred from the textural features such as calcite plagioclase symplectite at the contact of scapolite. This textural feature indicate that the temperature estimated from the scapolite- plagioclas pair truly represents post-peak temperatures; the peak temperature could be higher.

The post-peak cooling temperature is estimated from the biotite-garnet pairs where biotite is texturally secondary mineral probably formed during the post – peak cooling period. The estimated temperature for the biotite –garnet pairs according to Bhattacharya et al (1991), Ferry and Spear (1978) and Perchuk and Lavrent'eva (1983) are 560^0C(mean), 540^0C(mean) and 560^0C(mean) respectively.

Considering the geothermometric estimate and the different experimental curves the peak metamorphic conditions is considered for the rocks of the area is 700^0C or higher. The retrograde temperature for the biotite forming reactions presumably during cooling is considered as 560^0C.

The intersection of kyanite-sillimanite equilibrium curve of the Al_2SiO_5 phase diagram according to Holdaway (1971) throw light on the pressure of the area in the peak and retrograde metamorphic temperature. Thus at peak metamorphic temperature i.e. at 700^0C the pressure is 7kb. Presence of sillimanite and an universal absence of kyanite not only in the area but also in the entire Precambrian rocks of the Shilong plateau indicate that the metamorphic pressure can not exceed 7kb. The presence of cordierite, garnet, K- feldspar also indicate that an important reaction such as:

Biotite + Sillimanite + Quartz = Cordierite + Garnet + K- Feldspar + H_2O

The intersection of this equilibrium reaction at the peak metamorphic temperature indicate the lower pressure limit 5kb. From this it is considered that metamorphic pressure ranges between 5-7kb while metamorphic temperature attains upto 700^0C or more.

Finally on the basis of the findings of this project work, the following conclusions can be taken (Refer Graph 1):

(1) The interbanded and cofolded bands of basic granulites, metapelites and granite gneisses were metamorphosed and peak metamorphic condition attained a granulite facies equilibration. This was followed by thorough annealing recrystallisation and subsequent cooling and rehydration which were responsible for the retrogressed assemblage in different rock units.

(2) The basic granulites were derived from an igneous parentage while the other rocks particularly metapelites were definitely of sedimentary origin and hence represents a volcano-sedimentary terrain prior metamorphism.

(3) One of the important aspects of the present work is quantitative estimation of P-T condition of the area. As evident from the graph 1, the peak metamorphic condition of the area is at temperature 700°C or more and pressure 5 to 7 Kbar. This P-T condition is consistent with the granulite formation in the other Precambrian terrain of the world. The post-peak cooling retrograde temperature which is estimated as 560°C and pressure 5 Kbar. This indicate the cooling takes through a temperature interval of 140°C through a minimal pressure of 2 Kbar. This feature indicate an isobaric cooling condition (Harley 1983,1985 a; Ellis and Green 1985). This isobaric cooling clearly indicate that the metamorphism took place due to magmatic emplacement in the area.

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