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Geochemistry of Precambrian metapelites from Patharkhang, West Khasi Hills district, Meghalaya, India

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Abstract

Cordierite bearing and cordierite free garnet sillimanite gneisses constitute granulite facies metapelitic assemblages in the Gneissic Complex rocks of the Shillong Plateau in Patharkhang, West Khasi Hills district in Meghalaya. The petrographic study shows that the mineralogical developments of the metapelites are related to different metamorphic events. However, geochemical affinity of these rocks is totally unknown till date and this study reveals the results of geochemical study of the rocks. The precursors of cordierite bearing metapelites were shales with some volcanic intercalations whose compositions have been possibly modified by partial melting and metamorphic differentiation. The high average K/Rb ratios of the rocks also suggest their restitic origin after the removal of partial melts.

Keywords: Metapelites, Cordierite, Granulite, Shillong Plateau.

Introduction

Precambrian granulite facies metapelites from many parts of the world have received much attention during the past few decades. The Gneissic Complex of the Shillong Plateau in the Patherkhang area (Lat. 26º38' and Long. 91º9' 50") in West Khasi Hills district exposes large expanses of garnet-cordierite bearing metapelites. However, geochemical affinity of these rocks which is a major consideration for the evolution of these rocks is remained cloudy in the area and therefore it is highly essential to fill up the gap of our understanding on the basis of detailed geochemical study. For this purpose, major and minor element oxides of the representative eight samples were analysed at the Department of USIC, Gauhati University by WDXRES PAN analytical AXIOS XRF spectrometer method.

Materials and methods

The Patharkhang area is northwestern extension of the Precambrian Gneissic Complex of the Shillong Plateau (Figure-1) which not only exposes a variety of granulites and granite-gneisses but also represents a transitional granulite terrain[1]. The plateau is believed to be the northeastern wedge of the Precambrian shield of India and forms a composite tectonogeomorphic entity comprising the Meghalaya plateau together with the monadnocks in the Brahmaputra plains and the adjoining uplands of Karbi-Anglong district (Mikir Hills) of Assam. The Precambrian rocks of the plateau are subdivided into the Gneissic Complex, nonporphyritic granites, the Shillong Group of supracrustal rocks, the Khasi greenstone and porphyritic plutons[2-5]. The Gneissic Complex and the nonporphyritic granites form the basement for the Shillong Group. The rock types in the area are characterized by intercalated and co-folded bands of metapelites, basic granulites within milieu of quartzofeldspathic gneisses and blastoporphyritic granite. Recent study shows that the dominant granulite facies condition (M_1) prevailed before the regionally pervasive tectonic fabric-forming episode (S_2). Thus, the peak metamorphic event followed by annealing recrystallisation, which gave rise granoblastic polygonal texture in associated basic granulites and mosaic of equant, polygonal, grains of cordierite and rare garnet partly wrapped by sillimanite-biotite layers in metapelites[6]. The gneissic layering is isoclinally folded leading to the development of the biotite + sillimanite (M_2) defined S_2 foliation, parallel to the axial planes of the D_1 folds. In the area, the D_1 folds are relatively rare, small, and observed only as rootless, intrafolial, tight to isoclinal folds. The S_2 foliation is refolded into the D_2 folds while D_3 represents the last folding episode. The S_2 foliation strikes NE–SW with dip amounts varying between 65º and 75º in the SE direction. Phase equilibria study indicate that peak metamorphic granulite facies condition took place at a temperature range between 730°C and 780°C (average=750°C) and at the pressure of ~4.5 kbar[6]. Information on radiometric ages of rocks of all the regions of the Shillong Plateau is scanty. The limited isotopic data so far known for the rocks of the region are restricted to late-kinematic granitic plutons of the Shillong Plateau. The Rb/Sr whole rock isochron ages of granitic plutons as obtained by various workers are 647 ± 10 Ma from Mylliem Granite; 647 ± 122 Ma from the granites and pegmatites in Pancharatna, Goalpara district[7,8]. The emplacement of granitic plutons in the region took place between 885 Ma and 480 Ma[9]. The monazite yield a well-constrained age of 500 ± 14Ma from Sonapahar situated immediately north of the present area[10].

Results and discussion

Petrography: The metapelites from Patharkhang is medium- to coarse- grained rocks characterized by the general assemblage, Garnet ± cordierite + biotite + sillimanite + quartz + k- feldspar ± plagioclase ± spinel ± monazite ± rutile ± ilmenite ± magnetite ± zircon ± apatite. On the basis of presence or absence of cordierite metapelites of the area are classified into (1) cordierite bearing and (2) cordierite free garnet –sillimanite gneiss. Texturally the metapelites of the area are relatively coarse-grained, polygonized aggregates of xenoblastic grains of cordierite (X_{Mg}= 0.81 to 0.78), garnet ($Alm_{76–79}$ $Prp_{10–21}$ $Grs_{2–3}$ $Sps_{9–14}$), mesoperthite (Or_{85-92} Ab_{8-15}) are intrafolially surrounded by anisotropic minerals such as biotite (X_{Mg} 0.45 to 0.54) and sillimanite, which show strong shape and lattice preferred orientations (Figure-2A and B). This sillimanite + biotite fabric in a recrystallized poly mineral aggregates of K-feldspar, quartz, plagioclase (An_{18} to An_{37}) (M_2) define the prominent foliation which warp around the polygonized aggregates of cordierite and rare garnet, mesoperthite that texturally pre- dated M_2 assemblage and we designate this assemblage as M_1. The common inclusions within cordierite and rare garnet are sillimanite, biotite, spinel, which are not continuous with the external fabric defined by biotite + sillimanite (Figure-2A and B). These mineral inclusions are considered as earliest minerals so far identified in the Patharkhang metapelites. These are considered as pre-M_1 assemblage representing a prograde evolutionary P-T path of the Patherkhang metapelites.

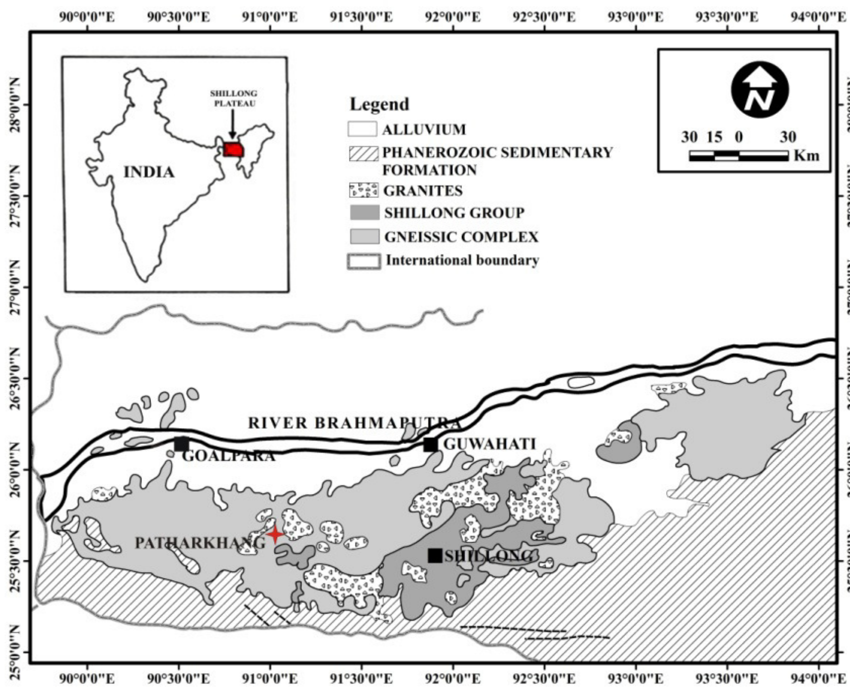

Figure-1: Generalized geological map of Shillong Plateau showing location of study area (modified after Mazumdar, 1976).

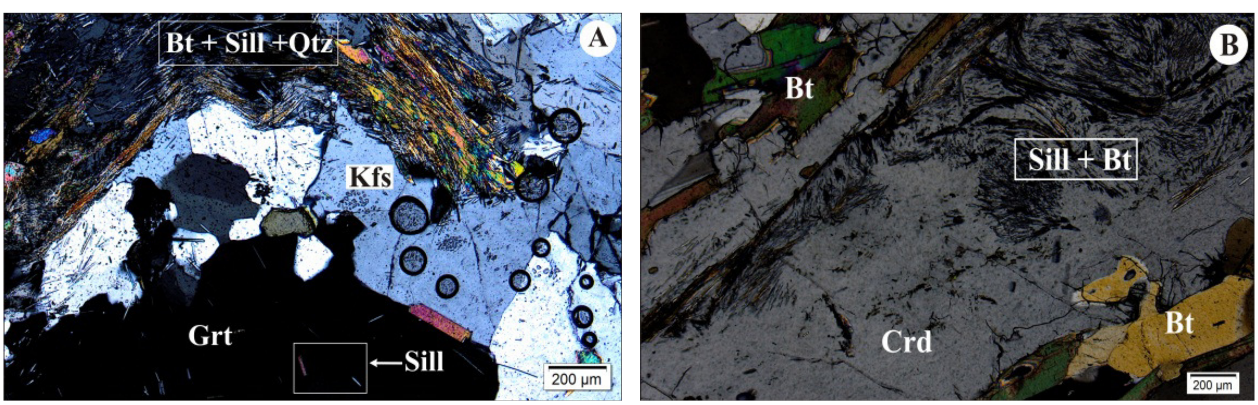

Figure-2: Polygonized aggregate of garnet, k-feldspar and cordierite (M_1) wrapped around by biotite + sillimanite defined penetrative foliation; (A) garnet and (B) cordierite. Note that the inclusions (Si) within garnet and cordierite orthogonal to matrix biotite + sillimanite (Se) (Under Cross Polar).

Geochemistry: The main point of interest in the chemistry of metapelites of this area relates to the characteristics of the cordierite-bearing metapelites. Similar cordierite bearing metapelites are found in many high-grade metamorphic areas as intercalated patches within sillimanite-garnet gneisses, or at places as independent bands. In the present area, the metapelites occur in three metasedimentary bands, the smallest one displaying a cordierite- free assemblage. The analytical data on five cordierite bearing metapelites and three on cordierite free variety are presented in Table-1 and Table-2 shows the average chemical composition of cordierite bearing and cordierite free metapelites of the Patharkhang area along with those of other high grade terrains and some relevant average compositions of pelitic rocks and greywakes[11-13].

Table-1: Major and trace element analytical data on Metapelites from Patherkhang West khasi Hills district, Meghalaya.

	NS-55	NS-56	NS-234	NS-241	NS-141	NS153*	NS-54*	NS-55*
SiO_2	58.42	55.17	58.54	59.7	57.81	56.58	53.15	54.14
Al_2O_3	21.9	22.87	21.48	21.26	22.17	19.12	21.92	22.81
$Fe_2O_3^{(t)}$	8.13	8.34	8.09	7.62	8.36	12.65	12.95	12.73
MgO	5.74	5.13	5.62	6.02	5.16	3.63	3.95	3.43
CaO	0.44	1.38	0.79	0.31	0.81	0.59	1.28	0.51
Na_2O	0.4	3.09	1.27	0.38	0.68	2.63	2.13	2.2
K_2O	2.53	1.14	1.46	1.56	2.31	3.82	1.2	0.9
TiO_2	0.84	0.97	0.95	1.04	0.7	0.67	1.53	1.56
P_2O_5	0.02	0.00	0.00	0.01	0.01	0.00	0.34	0.29
MnO	0.08	0.03	0.09	0.04	0.09	0.08	0.19	0.18
Total	98.5	98.12	98.29	98.01	98.1	99.77	98.64	98.75
Ba	311	357	178	231	291	673	563	691
Cr	705	667	685	719	670	514	456	543
Zr	169	254	261	249	231	194	218	171
Ni	331	308	315	346	302	161	193	194
Sr	58	136	71	52	72	73	112	81
Rb	29	31	32	28	34	115	69	56
Y	29	45	18	35	47	31	23	29
Nb	9	16	14	7	9	5	7	6
Zn	52	26	41	56	47	112	99	71
Ni	331	308	315	346	302	83	104	129
V	225	205	201	253	168	181	172	183
K/Rb	734	305	378	463	563	275	120	101

Note: *cordierite free metapelite.

Table-2: Compositional comparison between Patharkhang metapelites and other metapelites, average pelites, shales and greywacks

	Patharkhang cordierite bearing metapelites (Average)	Patharkhang cordierite free metapelites (Average)	Patharkhang metapelites (Grand average)	Cordierite bearing metapelites, Lambodenmais area, Bavaria[19]	Cordierite bearing metapelite, Inari complex[18]	Cordierite free metapelite, Inari complex[18]	Average pelites[11]	Average Shales [12]	Average gray wackes [13]
SiO_2	57.928	53.290	56.189	65.07	66.68	65.11	61.54	58.10	64.43
TiO_2	0.900	1.253	1.033	0.47	0.35	0.73	0.82	0.00	0.62
Al_2O_3	21.936	21.283	21.691	18.15	17.46	17.13	16.95	15.40	15.48
$Fe_2O_3^t$	8.108	12.160	9.628	6.98	6.22	7.04	5.86	6.74	6.54
MgO	5.534	5.597	5.558	2.32	3.15	2.81	2.52	2.44	3.12
CaO	0.746	0.793	0.764	0.32	0.97	2.07	1.76	3.11	2.22
Na_2O	1.164	2.320	1.598	1.74	1.36	2.03	1.84	1.30	3.74
K_2O	1.800	1.973	1.865	3.34	3.08	2.48	3.45	3.24	2.44
MnO	0.066	0.150	0.098	0.32	0.06	0.06	0.00	0.00	0.07
P_2O_5	0.013	0.315	0.134	0.12	0.06	0.09	0.00	0.00	0.00
Total	98.204	99.030	98.514	98.83	99.39	99.55	94.74	90.33	98.66

Major element geochemistry: The status of all these rocks have been tested by calculating their values according to discriminate function (DF) derived and they are found to be purely of sedimentary origin[14]. These rocks have SiO_2 from 53.15 wt% to 59.70 wt%, high Al_2O_3 contents (19.12 wt% – 22.87 wt.%) and relatively low FeO contents and low values of K_2O. The MgO / (FeO+ MgO) ratios range between 0.32 and 0.46. A comparison with other metapelites (Figure-4) shows that, though the present rocks are broadly similar, they are relatively lower in F/M (FeO/MgO) and higher in A' (Al_2O_3-CaO-K_2O-Na_2O) than those in similar rocks (Table-2).

In relation to average greywackes and pelites, the present rocks possess higher Al_2O_3, MgO and lower K_2O, CaO, and F/M ratios. The chemical distinction between cordierite bearing and cordierite free variety in terms of major oxide as reflected from Figure-2 that the cordierite free variety relatively possesses a higher F/M ratio as compared to cordierite bearing variety. The assemblages with cordierite, garnet and (cordierite + garnet) can be distinguished on the basis of relative molecular proportions of CaO, MgO and FeO[15]. Figure-4 shows that the line of separation between garnet and (garnet + cordierite) assemblage holds for the present samples[15].

Trace element geochemistry: Based on the limited information available on trace element contents, it appears that the present metapelites are higher in Cr (456 – 719 ppm), Zr (169 – 261ppm), V (168 – 253 ppm) and lower in Sr (52 – 136 ppm). The chemical separation between cordierite bearing and cordierite free metapelites in respect of trace elements is not well understood because of limited data. Examination of literature shows that only from the Napier complex, Antarctica is there a sufficient amount of trace element data on this issue available[16].

In terms of trace elements, the present cordierite-bearing metapelites appear to have high Cr, Zr, Ni and low Ba, Rb; however, the volume of data is rather small. The cordierite bearing metapelites have higher Cr, Ni, Zr and low Ba, Rb as compared to metapelites without cordierite. One interesting feature of the present metapelites is a fairly well developed positive correlation of MgO/MgO+FeO and Cr as well as with Ni (Figure-5).

This might indicate the presence of volcanic intercalations in the precursors. In this exercise, one must remember that the precursor compositions are subject to modification by differentiation processes during metamorphism.

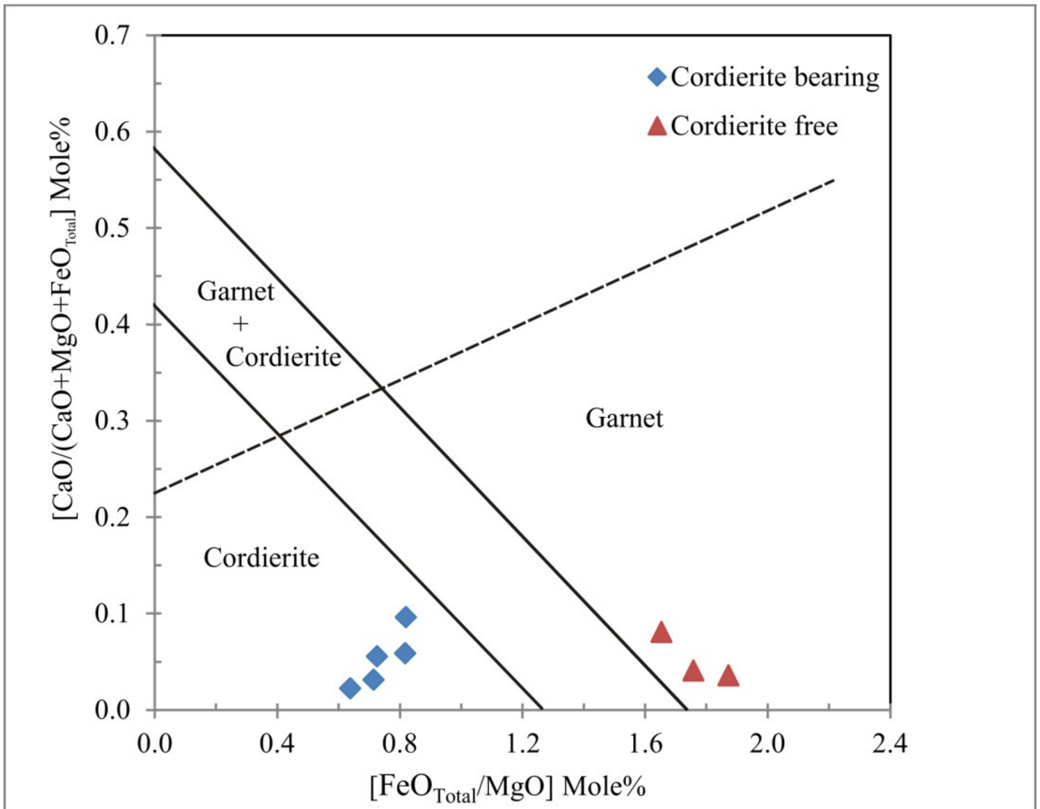

Figure-3: The mole% $CaO/(CaO+MgO+FeO^{total})$ Vs. mole% FeO^{total}/MgO Plots of metapelite[15].

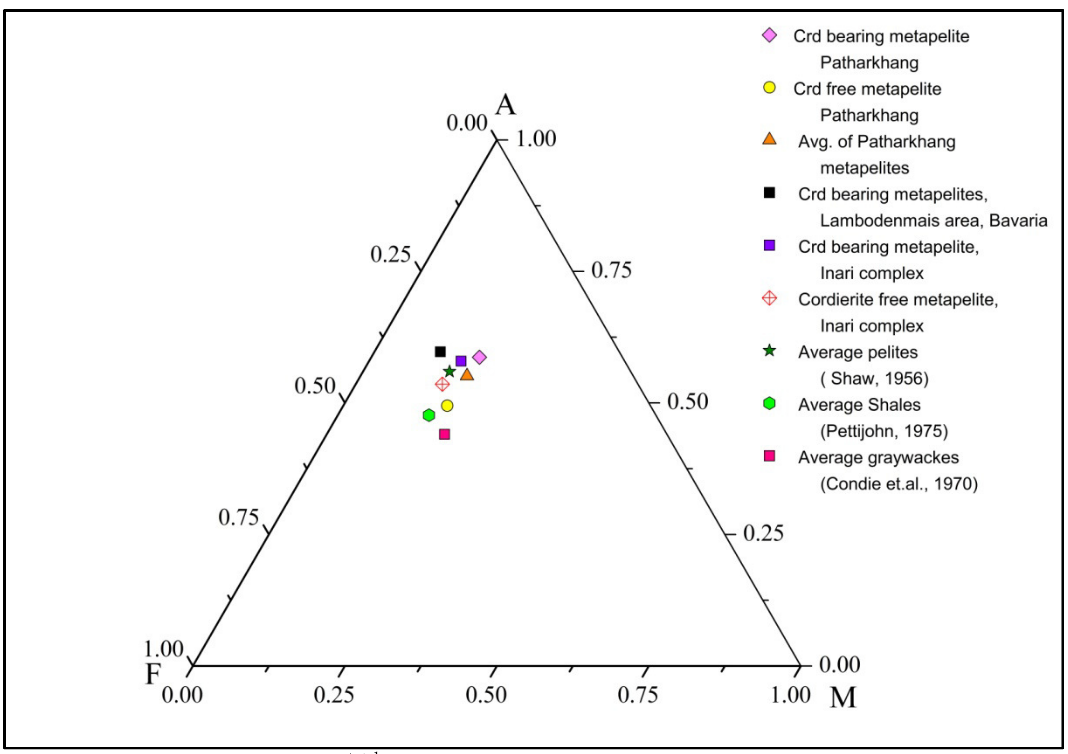

Figure-4: A' (Al_2O_3-CaO-K_2O-Na_2O) – F(FeO^{total})-M(MgO) diagram for metapelites of the Patharkhang and other comparable areas.

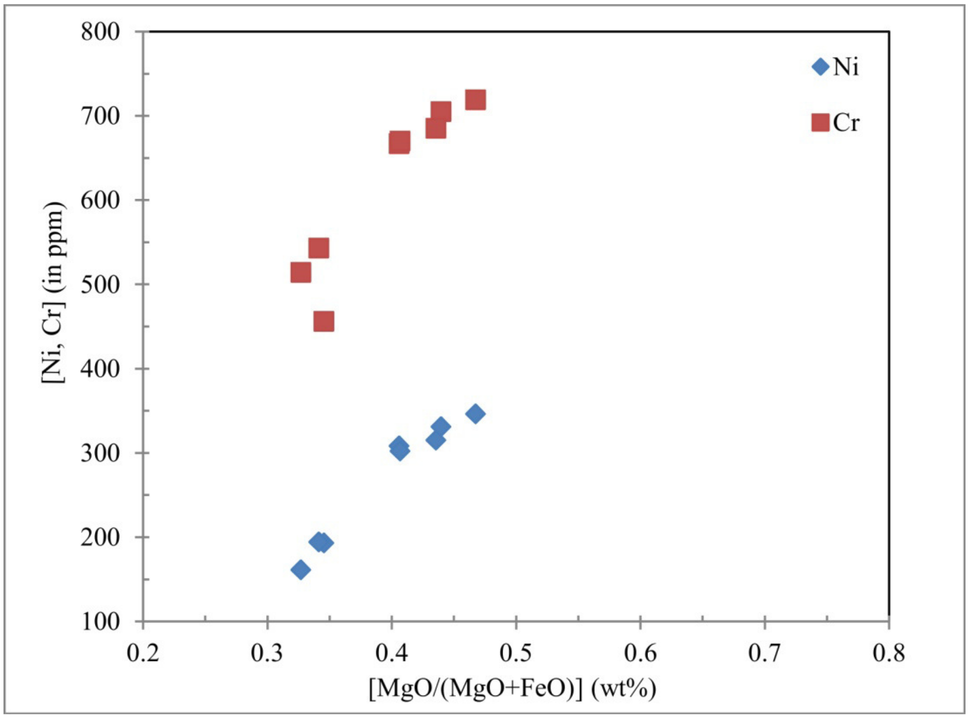

Figure-5: Ni, Cr Vs. MgO/(MgO+FeO) binary plot.

Conclusion

The compositional feature of the present metapelites are interesting in the fact that these rocks contain high values of MgO as compared to the cordierite bearing metapelites of other localities (Table-2). Also they have a higher Cr, Ni and V contents. It is agreed that cordierite bearing metapelites are often interpreted as restites of partial melting[17]. In view of the susceptibility of rocks of pelitic compositions to melting and chemical signatures like high MgO/(MgO+ FeO), a restite type of origin is possible. It is pertinent to mention that the average K/Rb ratios of the cordierite bearing variety are in the range of 300-734 ppm and such a high value indicates that the cordierite bearing metapelites may be of restitic origin after the partial melting event during regional metamorphism. It should also be pointed out that stabilization of cordierite during metamorphism is capable of generating further chemical differentiation such as higher concentration of magnesium. In view of these, Patherkhang metapelites can hardly be expected to be analogues of any type of pelites. The processes mentioned above might have caused the differences in K and Mg with average pelites. Lower Ca-contents of the present rocks are not, however, easily explained in terms of similar mechanisms, and might have been original compositional features. It is also important to note that the compositional match with graywacke is poor even allowing for the expected changes caused by metamorphic differentiation. It is inferred that the precursors of the Patherkhang metapelites could be shales with some volcanic intercalations (as indicated by MgO/(MgO+FeO) Vs. Cr, Ni correlation) (Figure-5) of whose composition have been possibly modified by partial melting and metamorphic differentiation.

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