INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN: 2278 – 0211

Mineral Chemistry And Geothermobarometry Of Ore-Host Minerals In The Sulphide Mineralization In A Part Of Subansiri District, Arunachal Pradesh

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Abstract:
Sulphide mineralization in a thin shear of about 25 mts wide locating in the Potin - Yazali road section of Subansiri district, Arunachal Pradesh has been reappraised. The mineralization is structurally controlled. Structural elements include shear fractures and shear foliations; lithological variant is confined to garnetiferous quartz-biotite-schist. A comprehensive EPMA analysis of host minerals viz., garnet and biotite has been evaluated and P&T condition for the host rock has also been determined by garnet-biotite geothermometry. Ore mineralogical study revealed dominance of chalcopyrite and pyrrhotite with minor quantities of sphalerite, occasional patches of arsenopyrite and isolated finely disseminated bodies of pyrite. From the EPMA analysis of sphalerite, sphalerite geobarometry has been evaluated. The equilibrium temperature estimated for the peak metamorphic assemblages are 480^0c $\pm$ 24^0c while the pressure value might be higher than estimated value of 2.5 Kbar

Keywords: Sulphide mineralization, Potin –Yazali area, Shear zone, structural

Introduction:

Reports on sulphide mineralization in Potin –Yazali area has been found in literature since 1959. The Geological Survey of India (GSI) subsequently carried out exploratory works in phases including drilling in order to probe mineralization potential in the area till 1974-75. Exposures of mineralized zone are seen along Kimin-Ziro road section at the northern bank of Ranga river (Lat:27°19′N; Long: 93°48′E) and continue across the river bed to the Southern bank for a distance of about 300mts along its strike. The continuation of mineralized zone however, could not be traced further due to the construction of a dam there.

Mineralization in the area is both structurally controlled. Structural elements include schistosity plane striking NE-SW dipping about 35^0 towards SE direction and shear planes developed often making low angle with the schistosity.(Fig.3) Lithological variants appears to strictly confined to the pelitic schists or garnetiferrous chlorite-sericite-quartz schist belonging to the Palaeoproterozoic Potin Formation of Bomdila Group. Mineralization in the area is dominated by chalcopyrite, pyrite, pyrhotite, sphalerite with occasional occurrence of magnetite and arsenopyrite.

The present paper deals with the mineral chemistry and geothermobarometry of the host rock of the study area.

Geological Setting:

The exposed lithology of the area belongs to the crystallines of the lesser Himalaya and mainly consists of quartz mica schist and biotite gneiss resting over a narrow patch of Gondwana on a hidden thrust. The general foliation trend is ENE-WSW with moderate dip of 35^0 towards the SE direction. The tight isoclinal F1 folds have highly appressed limbs and thick hinges with axial plane dipping to the north-west. These folds are recline type. The second generation F_2 folds have a coaxial relationship with the F1 folds and could be seen on cross section with fold axis plunging to NNW direction. The axial plane of F2 folds maintain near orthogonal relationship with F_1 folds. The thrust parallel drag and thrust imbrication are also observed at places facilitating avenues for upward movement of mineralizing solutions. Cross fractures indicate a north-south trend and are indicative of southward movement of sequence and accommodation of stress.

The general trend of schistose rocks is NNE-SSW dipping 40^0 -70^0 towards SE. Westerly dips are well defined and are more consistent towards the contact of the quartzite and mica schist, both on the hanging wall and footwall sides. Tentatively, it may be inferred that the quartzite and mica schist are younger and occur as alternating synclinal remnants on the two sides of semi-pelitic and more or less garnetiferrous schist. It appears that although the whole schistose zone forms a synclinal part between the granitic mass, the schistose zone itself is internally folded.

Metamorphism:

Megascopic study reveals that the garnetiferous quartz-biotite schist is medium-to coarse-grained well foliated rock consisting quartz, biotite and garnet.

Microscopic study shows the following general assemblages of the rock as follows:

Garnet-quartz-biotite-chlorite $\pm$ plagioclase $\pm$ zircon $\pm$ apatite (retrogressed assemblage: secondary-chlorite-muscovite-clinozoisite-epidote-sericite)

A critical examination shows that garnetiferous quartz-biotite schist indicate a polymetamorphic history. On the basis of mineralogical and textural features an attempt has been made to correlate growth of mineral with respect to metamorphic event/deformational episodes as shown in table1

M_1 assemblage	Pre- S_1	Quartz, Muscovite
M_2 assemblage	Syn-S_1	Biotite, Quartz, Chlorite, Garnet, Plagioclasae
M_3 assemblage	Post-S_1	Idioblastic Garnet, Biotite
M_4 assemblage	Post-S_1 post shearing	Ore minerals, sec. Chlorite, Clinozoisite-Epidote, Sericite, Muscovite

Table:1 Tentative correlation of the timing of growth of metamorphic minerals and deformational episodes

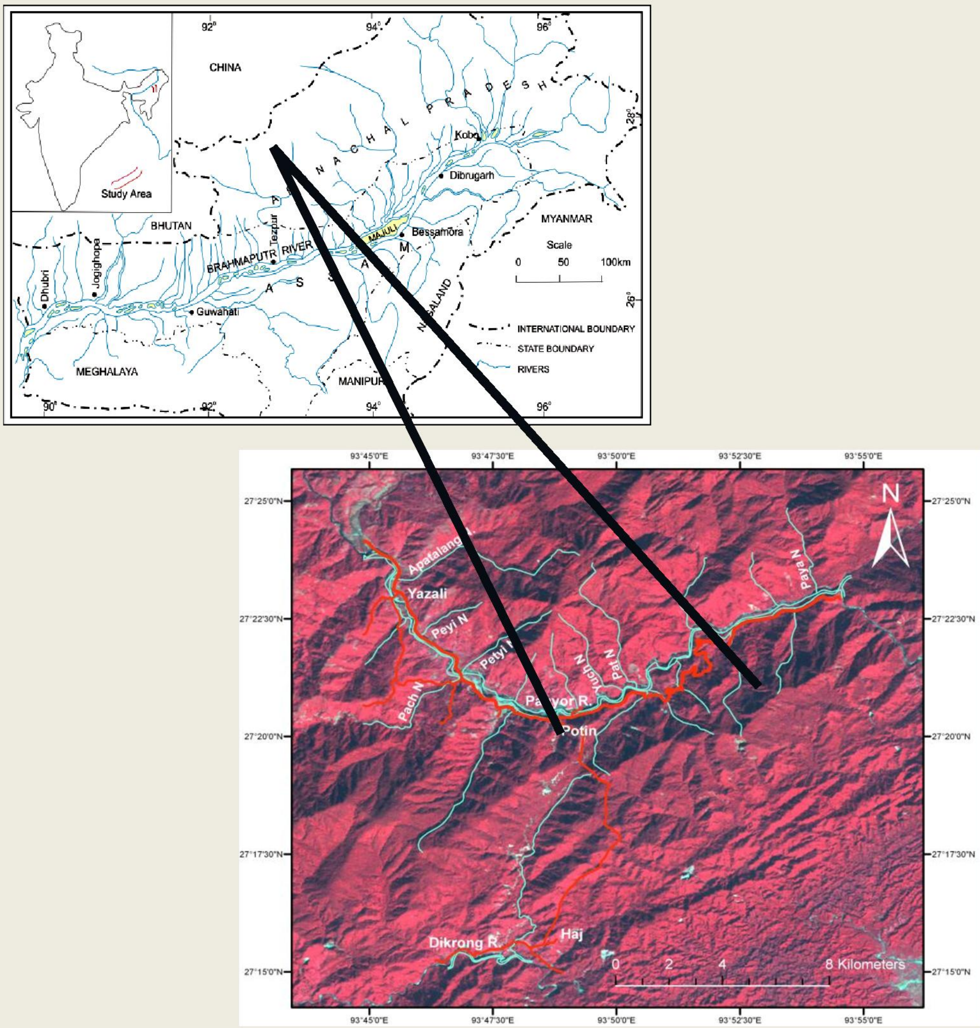

Figure: 1 Location map of the study area

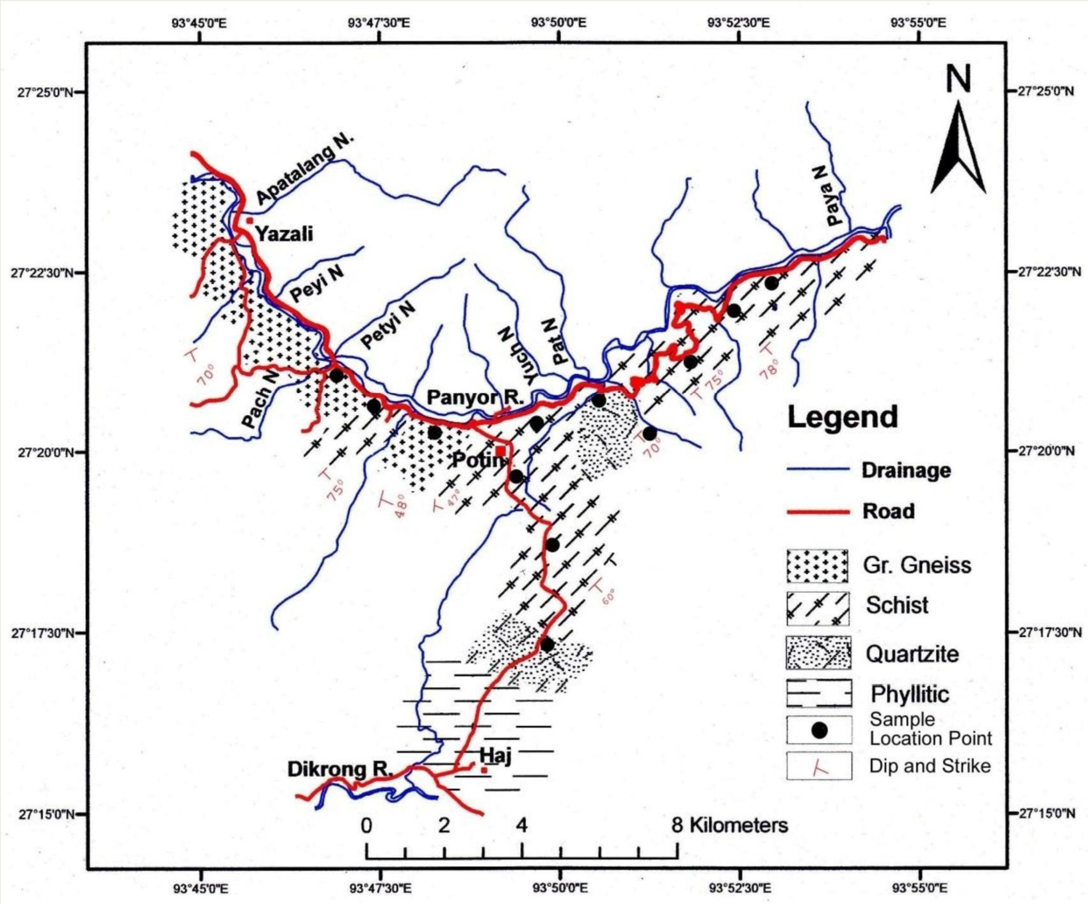

Figure: 2 Geological Map of the Study Area

Figure: 3 Shear zone featuring mineralization. Note that schistosity (S_2) strikes N-S to NE-SW dipping SE. (Location near 53 km post)

Analytical Methods:

Five nos. of host and ore sections were analysed for EPMA at GSI, Kolkata in a CAMECA Sx 100 machine at a voltage: 20Kv. Doubly polished thin sections of rock samples and ore were prepared and carbon coating was applied before EPMA analysis (Fig.4).

Mineral Chemistry:

For the study of mineral chemistry, total 16 minerals (garnet and biotite) have been analyzed by electron microprobe method. The results of which are presented in Table 2 and 3

Garnet:

Microprobe analyses of 8 garnets from metapellites are presented in Table No. 2 In calculating the structural formulae, amounts of Fe^{+3} in Y position have been computed as 2-(Al^{iv} + Cr^{+3} + Ti^{+4}); it must be recognized, however, that such assignments are sensitive to analytical error. There is no exceptional compositional heterogeneity in garnet grains have been observed under the probe. The relative concentrations of four end members of garnet do not show sharp variation. The grossular contents vary from 18.8% to 21/8%, spessartines from 2.0% to 2.8%, pyropes from 2.7% to 3.4% and almandines contents from 72.7% to 75.8% (Table No.4). These garnets are characterized by very high almandine contents and very low grossular contents with little zonation. The almandine contents show an increasing order from core to rim in the analyzed samples. Mn contents of the garnets are relatively low (upto 1.45 mole %) see in Table No. 2).

Biotite:

Analytical data on 8 biotites are presented in Table no. 3. The Mg/(Mg+Fe) ratios of the biotite vary from 0.22% to 0.96%. On the basis of Mg/(Mg/Fe) ratios biotites in the present rocks cannot be distinguished. An examination of analyzed biotites with respect to their occurrence shows that the biotites within or at the contact of garnet reflect a high

Mg value (0.16% to 1.09%), but within the lamination of few biotite analyzed in the present work, this cannot be generated.

Pressure and Temperature condition of the metamorphic host rock:

The mineral assemblage biotite-muscovite-chlorite–almandine-quartz of the host rock indicating the garnet zone of barrovaian metamorphism of pelitic rocks. In terms of facies concept of Eskola (1915) the assemblage represents greenschist amphibolites transition and the almandine rich garnet identify almandine amphibloite facies. In the present study an attempt have been made to quantify the pressure and temperature condition of the host rock. The pressure and temperature condition of metamorphism may be estimated: (a) by comparing the natural mineral assemblages with the experimentally determine mineral equilibria and (b) through the models of geothermobarometry. The mineral reaction in the petrographic section and such similar reaction belong to greenschist and amphibolites facies investigated epxperimentally are mostly dehydration end member's reaction which would be shifted in the pressure and temperature space due to complex solid solution in reaction and variation in the activity of the water. Thus these reactions can be used to infer broad range of metamorphic condition. In the last to decade considerable progress has been made to quantitatively estimate the pressure and temperature condition of metamorphism through the different models of geothermobarometry calibrated for anhydrous reaction that are not affected by variation in the activity of water, this has been possible by recent advance in mineral analysis by the electron probe micro technique geothermomertic measurement in phase equilibria study in the simple and complex solution.

Geothermobarometry:

Geothermometry and geobarometry are the calculation of metamorphic temperature and pressure and of equilibration where the temperature and pressure dependence of the equilibrium constant is used as the basic yardstick. Geothermometers are those reactions that show considerable temperature sensitivity (large ΔS, ΔH) and small pressure sensitivity (small ΔV) and geobarometers are reactions that show significant pressure sensitivity (large ΔV) and small temperature sensitivity (small ΔS, ΔH). Traditionally, the term geothermobarometry has been used only to describe solid-solid reactions so that the results are independent of partial pressure of fluid species.

Temperature estimation:

The temperature of equilibrium has been estimated from well known geothermometric models by various authors (Ferry and Spear; 1978; Ganguly and Saxena, 1984, Hackler and Wood 1989 and Perchuk and Lavrent, 1983 etc.) and a brief summary of different thermometric models are as follows:

Biotite-garnet geothermometry:

The Fe-Mg partitioning between coexisting biotite-garnet is a potential geothermometer of metamorphic rock and has been extensively studied by many workers (Ferry and Spear; 1978; Ganguly and Saxena, 1984, Hackler and Wood 1989 and Perchuk and Lavrent, 1983 etc.)

The basic assumption of ideal exchange underlying the two thermometric formulations of Ganguly and Saxena (1984), and Hackler and wood (1989), is that the almandine-pyrope binary is non ideal. Bhattacharya et al. (1992) reformulated garnet-biotite geothermometer by theoretical analysis of experimentally observed P-T-X (Mg-Fe) relationship in the biotite-garnet system on the basis of thermochemical data on mixing in pyrope-almandine binary. In the present context, the temperatures have been estimated considering geothermometric formulations of Bhattacharya et al., (1992) based on thermochemical data of Hackler and Wood, (1989) and Ganguly and Saxena (1984). Their geothermometric expressions are given below:

$T(HW)=[20286+0.0193P-\{2080(XMg^{Gt})^2-6350(XFe^{Gt})^2-13807(XCa^{Gt})(1-XMg^{Gt})+8540(XFe^{Gt})(1-XMn^{Gt})+4215(XCa^{Gt})(XMg^{Gt}-XFe^{Gt})\}+4441(2XMg^{Bt}-1)]/[13.138+8.3143\ln kp+6.276(XCa^{Gt})(1-XMn^{Gt})]$

$T(GS)=[13538+0.0193P-\{837(XMg^{Gt})^2-10460(XFe^{Gt})^2-13807(xCa^{Gt})(1-XMn^{Gt})+19246(XFe^{Gt})(XMg^{Gt})(1-XMn^{Gt})+5649(XCa^{Gt})(XMg^{Gt}-XFe^{Gt})\}+7972(2XMg^{Bt}-1)]/6.778+8.3143X\ln kp+6.276(XCa^{Gt})(1-XMn^{Gt})]$

Where T in K([Bhattacharya et al., 1992, (HW-Hackler and Wood; GS-Ganguly and Saxena),] In the present study geothermometric estimation was made on the refine garnet-biotite geothermometers (Bhattacharya, 1992 based on solution model of GS-Ganguly and Saxena , HW-Hackler and Wood;). In addition to this thermometric formulation those of popularly known model of Ferry and Spear; 1978 and Perchuk and Lavrent, 1983. The results of garnet-biotite geothermometry are shown below in Table no. 5.

Sphalerite Geobarometry:

The sphalerite geobarometric study was based on procedure after Scott (1976). The plots of the composition of the closely intergrown sphalerite are in the field of S.D. Scott (1976). At the temperature 480^0C based on garnet-biotite geothermometer (Average) yield a pressure about 2.5 Kbar which is realistic for the garnet zone of barrovaian metamorphic area shown in Fig. 5

Sl. No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Sample	Gr1(Core)	Gr2(rim)	Gr3(rim)	Gr 4	Gr5(Core)	Gr 6	Gr 7	Gr 8
SiO_2	37.64	37.06	37.1	36.94	36.62	37.2	36.58	37.86
TiO_2	0.03	0	0.13	0.01	0	0.05	0.04	0.06
Al_2O_3	21.31	21.1	20.8	20.87	20.29	21.1	20.98	21.14
Cr_2O_3	0.04	0.04	0.12	0.03	0.12	0.54	0.64	0.78
FeO	33.61	34.73	27.66	31.42	34.3	30.12	31.24	30.98
MnO	1.27	1.09	10.63	5.92	0.98	1.21	1.25	0.95
MgO	0.69	0.77	0.4	0.59	0.7	0.56	0.64	0.78
CaO	7.87	6.74	5.08	5.5	7.03	8.5	7.98	6.68
Na_2O	0.08	0.1	0.01	0	0.06	0.06	0.08	0.09
K_2O	0.01	0.05	0.03	0.01	0.02	0.81	0.95	0.85
Total	102.55	101.68	101.96	101.29	100.12	100.15	100.38	100.17

Table No: 2

Electron Probe Micro Analyses of garnet

IONS on the Basis of 24 Oxygen

Si	5.952	5.932	5.955	5.954	5.962	5.856	5.931	5.861
Ti	0.003	0	0.015	0.001	0	0	0	0.012
Al	3.972	3.98	3.936	3.964	3.893	3.123	3.147	3.487
Cr	0.006	0.006	0.015	0.004	0.016	0.017	0.012	0.013
Fe	4.445	4.469	3.714	4.235	4.67	4.121	4.581	5.241
Mn	0.17	0.148	1.445	0.808	0.135	0.124	0.136	0.139
Mg	0.163	0.183	0.095	0.142	0.17	0.18	0.19	0.2
Ca	1.333	1.156	0.874	0.95	1.226	1.364	1.452	1.354
Na	0.024	0.031	0.005	0	0.02	0.03	0.04	0.03
K	0.002	0.011	0.006	0.001	0.004	0.003	0.004	0.002
Cation	16.07	15.916	16.06	16.059	16.096	14.818	15.493	16.339
X Mg	0.035	0.035	0.024	0.003	0.032	0.031	0.032	0.031
X Fe	0.964	0.964	0.975	0.996	0.967	0.964	0.965	0.964

Table No: 3

Electron Probe Micro Analyses of Biotite

Sl. No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Sample	Bt 1	Bt 2(core)	Bt 3	Bt 4	Bt 5	Bt 6	Bt 7	Bt 8
SiO_2	33.37	34.89	35.11	45.31	33.63	36.32	37.24	38.25
TiO_2	1.75	0.09	1.99	0.28	1.92	2.11	2.14	1.98
Al_2O_3	17.64	18.2	18.35	34.6	17.59	18.65	19.24	20.24
Cr_2O_3	0.24	0.09	0.14	0.14	0.26	0.23	0.34	0.54
FeO	28.16	35.11	26.94	3.2	28.76	23.21	25.21	23.21
MnO	0.12	1.31	0.06	0.02	0.11	0.23	0.24	0.27
MgO	4.54	0.74	4.42	0.48	4.53	5.34	4.24	5.24
CaO	0.08	6.63	0.02	0.05	0.03	0.04	0.05	0.08
Na_2O	0.22	0.01	0.19	0.64	0.2	0.4	0.54	0.74

K_2O	9	0.04	9.38	10.51	9.18	10.65	9.54	10.24
Total	95.12	97.11	96.6	95.23	96.21	97.18	98.78	100.79

IONS on the Basis of 22 Oxygen

Si	5.346	5.476	5.476	5.471	6.109	5.34	6.12	5.21
Ti	0.211	0.01	0.01	0.234	0.029	0.229	0.241	0.261
Al	3.331	3.612	3.612	3.37	5.498	3.292	4.521	3.571
Cr	0.03	0.01	0.01	0.017	0.015	0.033	0.211	0.021
Fe	3.773	4.243	4.243	3.51	0.36	3.819	2.54	2.24
Mn	0.016	0.161	0.161	0.008	0.002	0.015	0.016	0.034
Mg	1.085	0.159	0.159	1.026	0.097	1.074	1.064	1.032
Ca	0.014	1.026	1.024	0.004	0.002	0.005	0.007	1.023
Na	0.068	0.004	0.004	0.058	0.168	0.061	0.072	0.054
K	1.84	0.007	0.007	1.865	1.808	1.86	1.74	1.54
OH	4	4	4	4	4	4	4	4
Cation	19.714	18.708	18.706	19.563	18.088	19.728	20.532	18.986
X Fe	0.776	0.960	0.790	0.770	0.780	0.770	0.740	0.730
X Mg	0.223	0.030	0.220	0.220	0.210	0.220	0.210	0.210

Gross	21.8	18.8	19.8	20.9	19.6	20.3	20.1	19.8
Spss	2.8	2.4	2.2	2.0	2.3	2.4	2.1	2.3
Prp	2.7	3	2.7	2.3	3.1	3.2	2.7	3.4
Alm	72.7	75.8	75.3	74.8	75.1	74.1	75.1	74.5

Table No:4Concentration of Garnet End Members

Sample	**Ref. P. kbar**	**B92-HW**	**B92-GS**	**FS82**	**PL83**
P/ 1	2.5	503	441	537	510
P/2	2.5	523	468	560	529
P/3	2.5	501	445	528	508
P/4	2.5	474	414	493	485
Avg.	2.5	480	420	520	510

Table No: 5

Results of Garnet-Biotite Thermometer

B92-Bhattacharya et al., 1992

GS-Ganguly and Saxena

HW-Hackler and Wood

PL Perchuk and Lavrent, 1983

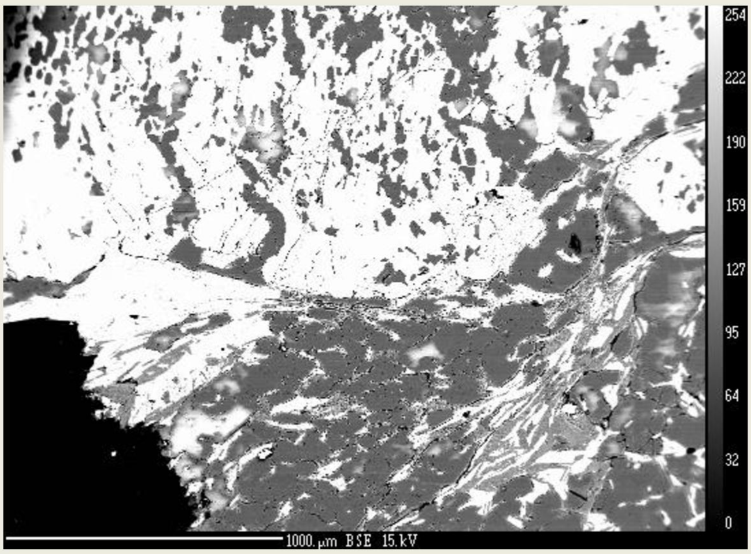

Figure: 4 Backscattered EPMA image of garnet and biotite

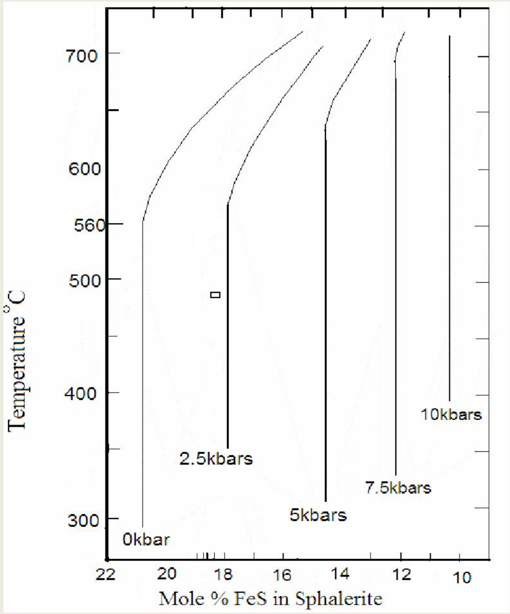

Figure: 5 Sphalerite Geobarometry in Potin Mineralization (Fields after Scott, 1976)

Discussion of Thermobarometric Results:

The main difficulty is to identify the adject pressure and temperature location of the present rock is related to two factors: firstly the complex solid solution in the low grade metamorphic rock offers anomalous results and secondly there is no tailor made assemblages available in the rock. The garnet-biotite geothermometers is the only accepted model for the computation of temperature of the rocks of the area. According to the most defined geothermometers after Bhattacharya et al., 1992 the estimated temperature is 480^{0}C (HW)and 420^{0}C(GS) respectively. On the other hand temperature for the rocks of the area is 520^{0}C and 510^{0}C according to Ferry and Spear, 1982 and Perchuuk and Lavrenteva, 1983 respectively. Thus overall average temperature for the present rock is 480^{0}C$\pm$24^{0}C. The estimated pressure at this temperature according to the method of Scott (1976) is 2.5 kb.This pressure –temperature condition is realistic for garnet zone in different terrains (Lal et al., 1987). In absence of tailor made assemblage suitable for geobarometry, pressure has been estimated on the basis of sphalerite geobarometry. But sphalerite being M_4 assemblage the estimated pressure may not consistent with the peak metamorphic, M_2 assemblage. Hence the pressure condition for the metamorphism for the rocks of the area is still cloudy. Since M_4 assemblage was formed during the retrograde phases the probable pressure for the peak metamorphic condition might be higher than 2.5 kbar.

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