Geochemistry of Mallampalli Group Phyllite from Pakhal Supergroup, Western Belt of Pakhal Basin in PG Valley, Telangana: Implications for Provenance & Source Area Weathering

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Abstract:
Phyllites from the Mallampalli group from the Pakhal Supergroup rocks of Pakhal Basin in PG Valley, Telangana,India was analyzed for their major and trace element geochemistry in order to constrain their provenance and source area weathering. The analyses of the phyllites generally define a single geochemical group by their major- and trace-element abundances. The metamorphosed sediments may be classified as immature by their high index of compositional variability values of mostly < 1. HREE are generally depleted whereas LREE are typically enriched relative to average Proterozoic upper crust. Such geochemical characteristics suggest that the source of the phyllites dominantly consisted of felsic rocks. Average Cr and Ni abundances and Cr/Ni ratios of average phyllites of the Mallampalli metasediments indicate that the source consisted of granitic material. Major element data, plotted in Al2O3 – (CaO+Na2O) – K2O ternary diagram indicate that the phyllites have not undergone significant post-depositional K metasomatism. Low to moderately high chemical weathering of the source terrane is indicated by pre metasomatized chemical index of alteration values of 60 – 86. The geochemical data further suggest that the sediments were deposited within a passive margin setting and mostly supplied by the adjacent basement granitoids.

Keyword: Pakhal Supergroup, Mallampalli Phyllite, provenance Study.

Introduction:
The Pakhal Supergroup of rocks of Mesoproterozoic age are exposed in and around Yellandu and west of Yellandu upto Bayyaram. Yellandu is present in the south-eastern part of the western arm of the Pakhal Supergroup (King, 1881). The Pakhal Supergroup of rocks unconformably overlie the Archaean granite basement in the western margin. In the eastern margin of Pakhal Supergroup, it is thrusted, over by granite gneiss and amphibolites of Khammam Schist Belt (KSB). Most of the earlier workers viz. Mahadevan (1949), Heron (1949), Appavadhanulu (1960), Roychowdhuri (1963), Sarma and Appavadhanulu (1963), Ramamohana Rao (1964), Nageswara Rao (1963) and Johnson (1969) worked on the stratigraphic correlation of the Pakhal Supergroup with the Cuddapah Supergroup of rocks. Basumallick (1967) suggested a detailed litho-stratigraphic sequence for the Pakhal of the Mallampalli-

Mulug area. The Pakhal Supergroup is represented by both the older Mallampalli and younger Mulug Group. The Mallampalli Group in this area is represented by Bolapalli quartzite, Gunjeda dolomite, Pandikuntaphyllite and Mulug Group is represented by Jakaram quartzite and phyllite, Polavaram phyllite, Enchencheruvu dolomite, Laknavaram phyllite (Rao, 1987).

The Bolapalli Formation is exposed in the western part of the study area (Fig:1). It is exposed in and around north of Nilavancha, east of Sitanagar, south of Gunjeda villages. It is the lowermost unit of Mallampalli Group of Pakhal Supergroup. It unconformably overlies the basement in the west and underlies dolomite of Gunjeda Formation in the east. It is represented dominantly by quartzite with bands of phyllite and shale. The phyllite is composed of fine grained quartz and feldspar. The shale is brown or yellow in colour while interbedded sandstone is brownish in appearance. In thin section, the phyllite is composed of silt to clay size feldspars, quartz, chlorite and muscovite. The chlorite and muscovite define the foliation. Stretched quartz crystals are also seen along the foliation plane. The Pandikunta Formation conformably overlies the Gunjeda Dolomite. This is the thickest unit of Mallampalli Group, exposed in the studied area with a thickness of around 4-6 km. Phyllite exposed are grey to brownish grey in colour, fine grained. Phyllite of Pandikunta Formation is composed of very fine-grained quartz and feldspar. All quartz and feldspar grains show the prominent foliation and along the foliation some stretched quartz grains, muscovite and chlorite is present. The cross cutting relation of chlorite band is also present in the rock and it may be formed during the time of metamorphism.

Structure

Bedding: The lower unit of the Pakhal basin (Bollapalli Formation), along the western margin, the beds are trending NNW-SSE with north easterly dip of 5°-40°. Proceeding easterly, there is a progressive increase in the variations in trend due to folding. In the East of Yellandu, southern part of the mapped area, Bollapalli Formation, Gunjeda Formation, Pandikunta Formation show the beds are trending in NNE-SSW direction. In the north of the Monditogu dip direction is northwesterly.

Foliation: Pakhal sediments show polyphase deformation in the study area. In this study area two sets of foliation are recorded during the field work. The foliations are well preserved in the different formations like shale/phyllite of Bollapalli, Pandikunta, Jakharam, Polavaram and Laknavaram Formation, dolomite of Enchencheruvu and Gunjeda Formations(Fig:2&3). In present study are early foliation (F_1) trend is NW-SE to NNW to SSE. This foliation is parallel to the bedding plane. Due to repeted folding of the Pakhal, the foliation trends are highly divergent from place to place. S_1 foliation of the Pakhal sediments are folded during second deformation (D_2). During the second deformation, foliation of second generation (S_2) is developed locally. The general trend of the S_2 is NE-SW to NNE-SSW. Second foliation is noticed in the base of the Bayyaram 578 hills, south of the Gandhinagaram area. In some area, early foliation (S_1) has been refolded due to the effect of the third deformation (D_3). But third deformation related foliation (S_3) is not properly present in the study area. In the east of the Yellandu area bedding and bedding parallel F_1 foliation is folded due to the effect of the third deformation. But the foliation related to third deformation is not well developed in this area.

The studied area has suffered polyphase deformation. Fold interference pattern is also present in the study area. The features of polyphase deformation are well preserved in the Bodu area in the eastern side and Bayyaram area in the western side of the study area.The deformational history of the area can be summarized as follows (Mitra and Adhikary, 2012).

The first deformation (D_1)

F_1 Foliation trends NW-SE to NNW to SSE in Pakhal sediments as well as in granitoids and formation of migmatite within the granitods is a local phenomena which are formed near the margin of the Pakhal sediment during the time of the D_1 deformation.

The second deformation (D2)

The general trend of the F_2second foliation (F_2) is NE-SW to NNE-SSW in Pakhal sediments as well as granitoids.But this foliation is not prominent in the granitoids.A brittle-ductile to ductile shear zone of regional scale with sinistral sense of movement, parallel to axial plane of second fold and trending NNW-SSE to N-S direction is related to D2 deformation.

Third deformation (D3)

The general trendof the third foliation (F_3) is E-W. But third deformation related foliation (F3) is not properly present in the study area. In the east of the yellandu area effect of the third deformation was observed.

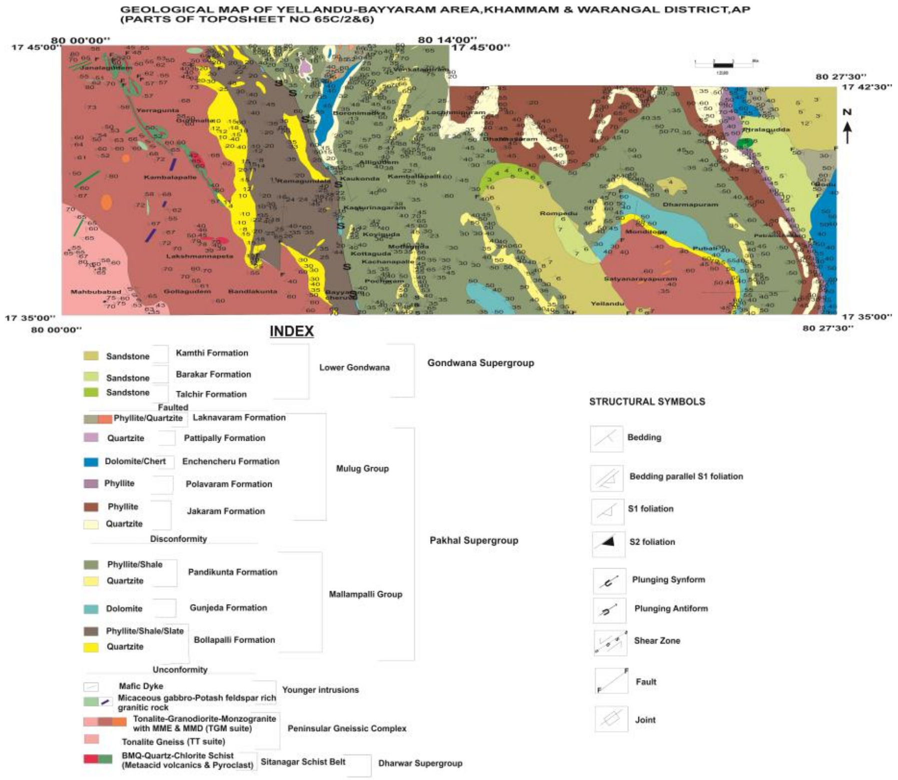

Fig 1: Geological map of the Yellandu–Bayyaramarea, Khammam and Warangal District, Telangana (after Adhikary et al.2014)

Petrography:

In thin section, the phyllite is composed of silt to clay size feldspars, quartz, chlorite and muscovite. The chlorite and muscovite definethe foliation.Stretched quartz crystals are also seen along the foliation plane.Thin section studies of phyllite revealed the presence of staurolite and garnet occupy as porpyroblast in a groundmass of biotite(Fig:4&5), quartz, and feldspar. Here the garnet occurs as porpyroblast as well as inclusions within the staurolite porphyroblast. The garnet grain boundary is corroded in nature and the foliation is swerving around it. In some places foliation is swerving around the staurolite porphyroblast also. The textural study indicates that, this staurolite was formed at the time of prograde metamorphism phase from the breakdown of the garnet grain. So, these porphyroblasts are pre to syn-tectonic in nature. During the deformation, fine grained quartz, feldspar and biotite grains are reoriented andformed the major foliation plane. Phyllite of Pandikunta Formation is composed of very fine grained quartz andfeldspar. All quartz and feldspar grains show the prominent foliation and along the foliation some stretched quartz grains, muscovite and chlorite is present. The cross cutting relation of chlorite band is also present in the rock and it may be formed during the time of metamorphism.

Fig:2 Development of garnet along the foliation plane in Pandikunta phyllite

Fig:3 Deformed pandikunta phyllite in Bayyaram area

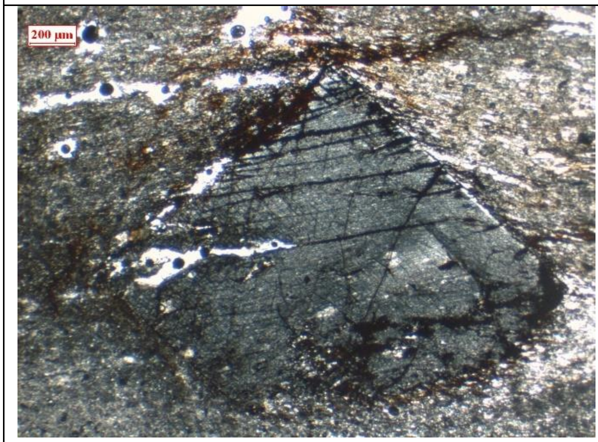

Fig:4 Major foliation swerved around the andalusite porphyroblast

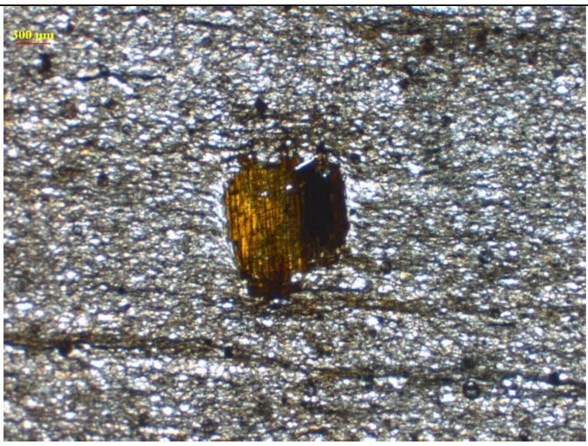

Fig:5 Major foliation swerved around the staurolite porphyroblast

Geochemical Analysis:

Crushing and pulverization of samples was done using standard procedures in the preparation of samples for whole-rock geochemical analysis.

The bulk-rock chemical data is shown in Table:1. The samples of the Mallampalli phyllites are characterized by low to moderate SiO_2 concentrations (range from 53 to 86 wt. %) and moderate to high Fe_2O_3 (total Fe as Fe_2O_3) + MgO contents 3 to 11wt. %. Al_2O_3/SiO_2 ratios are fairly constant (range from 0.01 to 0.33), but K_2O/Na_2O ratios are variable, ranging from 0.9 to 58. Using the geochemical classification diagram of Herron,1988,(Fig:6) the Mallampalli phyllites are classified as shale or wacke;

three samples, however, fall in Fe-sand field . This differentiation is due to high SiO2/Al2O3 ratios on the average for some of the carbon phyllites.

The K2O/Al2O3 ratio of sediments can be used as an indicator of the original composition of ancient sediments(Fig:7). The K2O/Al2O3 ratios for clay minerals and feldspars are different (0.0 to 0.3, 0.3 to 0.9, respectively; (Cox et al,1995). In most of the samples the K2O/Al2O3 ratios are close to the lower limit of the feldspar range, which suggest that the feldspar is the dominant mineral in these phyllites. Cox et al,1995 indicates that the compositional trends in muds derived by weathering of progressively more granitic source material are similar to those in recycled muds; both become richer in Al2O3 and K2O.

The abundance of Cr and Ni in siliciclastic sediments are considered as a useful indicator in provenance studies. Average Cr and Ni abundances and Cr/Ni ratios of average phyllites of the Mallampalli metasediments are 100.6 p.p.m., 25.8 p.p.m. and 1.52 respectively (Table 1), and for early Proterozoic upper crust are 59 p.p.m., 31p.p.m and 1.90 (Condie, K.C et al 1993). According to Wrafter and Graham 1989 a medium concentration of Cr indicates a graniticprovenance, and Bock et al,1998 have indicated that Ferromagnesian elements (eg., Fe, Cr, Ni) are less enriched in granitic igneous rocks and elevated abundances of these elements in the sediments and sedimentary rocks may indicate the addition of components derived from adjoining mafic lithology's. The Cr, Ni and Cr/Ni data above suggest therefore a granitic source for the Mallampalli Phyllites.

Table 1: Whole rock and trance elements analysis of the Mallampalli Phyllite

Sample Ref. No.	SiO2	TiO2	Al2O3	Total Fe as Fe2O3	MnO	MgO	CaO	Na2O	K2O	CIA	ICV	PIA	Ba	Sr	Sc	V	Cr	Co	Ni	Y	Zr	Yb
PCS/23/DA	60.85	0.98	18.17	4.72	0.02	2.95	0.28	0.13	6.47	72.53	0.86	98.00	776	83	20	77	112	22	48	39	319	0.65
PCS/29/DA	53.90	1.03	20.92	8.67	0.06	1.62	0.12	0.55	6.49	74.50	0.89	97.00	945	68	46	143	231	19	68	31	277	3.70
PCS/254/DA	61.94	0.68	19.64	4.20	0.02	2.48	0.60	0.58	5.39	74.94	0.71	94.00	1303	10	45	90	134	17	26	41	155	3.81
BRS/224/DA	70.5	0.7	17.9	1.16	0.02	1.5	0.1	0.13	4.34	79.6	0.45	99.0	100	53	31	52	110	8.9	6.7	47	211	1.7

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BRS/226/DA	86.66	0.32	6.29	1.22	0.02	0.8	0.28	0.1	1.84	73.91	0.72	94.00	318	36	19	468	84	8.4	19	54	137	2.83
BRS/235/DA	72.93	0.05	1.84	19.81	0.1	0.1	0.14	0.1	0.1	74.4	11.09	88.00	144	39	58	47	11	17	95	5	15	1.65
BRS/254/DA	64.26	0.69	19.6	4.23	0.02	1.7	0.25	0.58	5.53	75.51	0.66	96.00	1362	120	48	89	154	11	39	51	168	0.98
PCS/101/DA	83.35	0.03	0.81	10.95	0.72	0.1	0.25	0.06	0.21	60.9	15.21	72.00	655.7	6.2	4	29.3	28.5	26	29	12.1	5	1.76
PCS/107/DA	58.95	0.73	19.1	9.438	0.09	1.9	0.29	0.9	3.75	79.46	0.89	94.00	626.3	54.5	14	97.3	165.7	22	64	25.2	198.2	2.11
PCS/531/SS	63.56	0.59	17.1	7.21	0.01	1	0.09	0.11	6.4	72.19	0.90	99.00	382.5	23.3	11	53.5	79.3	5.5	14	17.8	107.2	2.14
PCS/293/DR	63.74	1.24	21.1	3.117	0.01	0.3	0.1	0.49	5.19	78.52	0.49	97.00	880.1	64.5	15	67.7	142.8	11	23	50.1	365.6	6.07
PCS/802/DR	80.24	0.47	11.3	2.731	0.02	0.2	0.11	0.14	2.02	83.23	0.50	98.00	279.7	13.4	6.7	25	40	11	2	18.4	175.8	2.08
PCS/794/SS	77.35	0.03	3.14	15.16	0.13	0.2	0.29	0.07	0.11	86.98	5.08	90.00	87.5	8.8	5.1	27.3	17.4	32	18	6.4	21	1.05
PCS/102/DA	61.49	0.80	20.43	5.21	0.04	1.21	0.13	0.22	6.07	76.08	0.67	98.00	886.2	20.2	18.2	105.6	228.8	19.5	69.2	34.6	248.2	1.1
PCS/	6	0.	18	9.	0.	0.	0.	0.	3.	7	0.	9	6	4	1	1	8	6	2	1	1	2

106/DA	0.58	76	.86	64	01	68	45	59	78	9.64	84	5.00	46.3	5.2	8.7	02.2	7.0	.6	.0	5.8	26.6	.1
EPUC	66.9	0.6	14.9	4.5	0	2	3.2	3.3	3.2	51.2	1.12	51.50	700	280	15	81	59	15	31	32	180	2.32

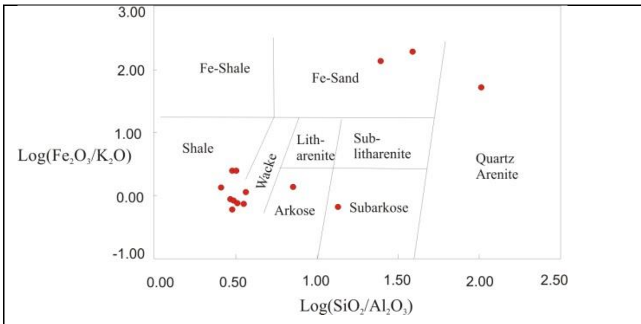

Fig:6 The geochemical classification of the Mallampalli phyllites(Herron,1988)

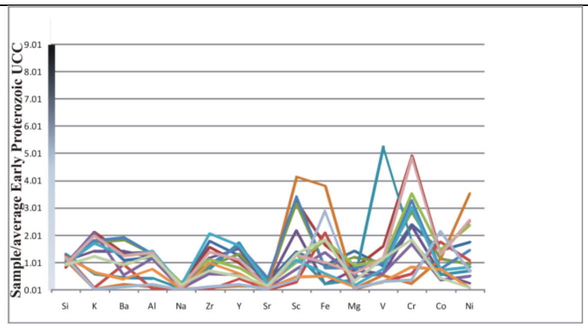

Fig:7 Uppercrust-normalized patterns for phyllite samples from the Pakhal Supergroup

Paleoweathering conditions and metasomatism:

The Chemical Index of Alteration (CIA) is widely used to quantify the degree of source-area weathering and to constrain the paleoweathering conditions of ancient shales and phyllites (Nesbitt, H. Wet al,1982, Fedo, C.M et al,1995 &1996). This index, defined as Nesbitt and Young,1982: CIA = [Al2O3/(Al2O3+CaO*+Na2O+K2O)] × 100 (in molar proportions), where CaO* represents the CaO content in the silicate fraction, measures the degree of feldspar alteration to aluminous clay minerals. Values of about 50 indicate fresh bedrock (no chemical weathering), and values close to 100 indicate complete conversion of feldspars to clay minerals intense chemical weathering;(Fig:8) (Fedo, C.M et al,1995 &1996). CIA values for the analyzed phyllites are variable and typically range from 51 to 86 (average 66). Paleoweathering conditions as well as post-depositional K metasomatism can be visualized in an Al2O3–CaO +Na2O–K2O (A–CN–K) diagram. From this diagram, trends resulting from the chemical weathering of crystalline bedrock are roughly parallel to the A – K boundary. The analyzed Mallampalli phyllites, plotted in A– CN–K diagram, define a linear array that is distinctly different from the expected weathering trend. A straight line through the data intersects the feldspar join at a point indicating the fresh composition of potential bedrock; in this case the bedrock source is dominantly granitic in composition. The weathering trend as depicted in the A–CN–K diagram indicate that the analysedphyllites have undergone less post-depositional K metasomatism.

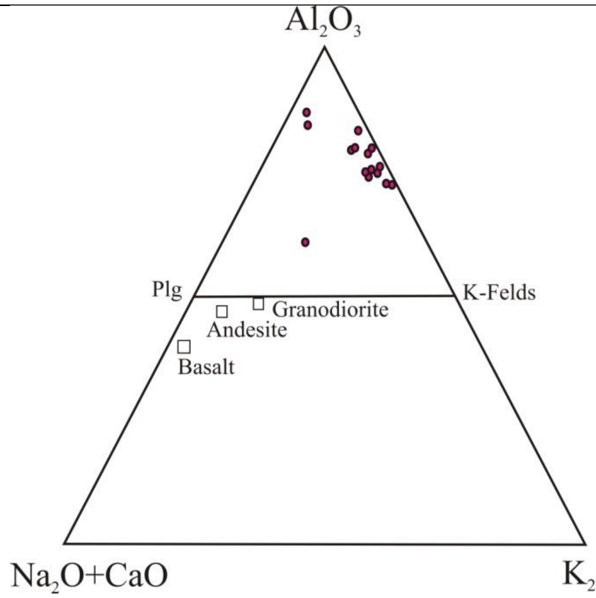

Fig:8 ACNK diagram for the Mallampalli phyllites from the Pakhal Supergroup (Fedo, C.M et al,1995)

Provenance:

The geochemical signatures of clastic sediments have been used to find out the provenance characteristics (Taylor ;1985,Condie;1992,Cullers;1995, Armstong-Altrin;2004). Based on geochemical data the Mallampalli phyllites presented here may be compared with clastic rocks from different tectonic setting in Australia and New Zealand (Roser;1986). On the binary relation of SiO2 versus K2O/Na2O(Fig:9), the Mallampalli phyllites dominantly plot in the passive margin and with some straddling around the active continental margin setting probably due to less K-metasomatism effect in the area. Therefore, the major element characteristics of the phyllites suggest passive margin setting. The major element data/analysis above indicates illites predominance in the clays. However, the Al2O3 and K2O averages are relatively rich which suggest a granitic source or recycled mud. The CIA values point to this possible granitic source material as composed predominantly of a granitic parent material.

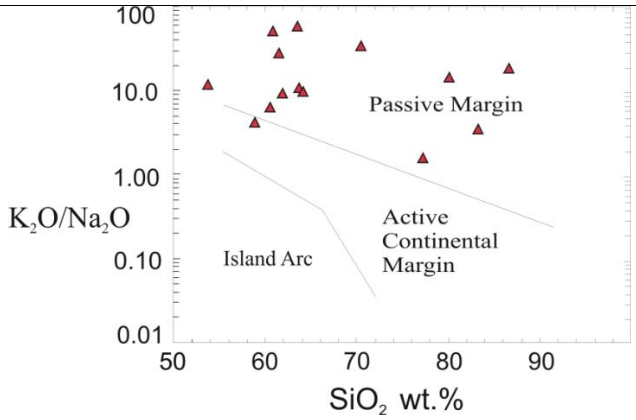

Fig:9 Tectonic discrimination diagram for the Mallampalli Phyllites of Pakhal Supergroup (Roser,B.P et al 1986)

Conclusion:

The Proterozoic phyllites of the Pakhal Supergroup generally indicate a single geochemical group by their major- and trace-element abundances. Their moderately highto high CIA values suggest that these rocks experienced a relatively weak to moderately high chemical weathering from a granitic source rock. The transition metal geochemistry as well as SiO2-K2O/Na2O binary plot also support that these phyllites originated from a granitic igneous source and were deposited in passive continental margin setting.

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