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Petrofacies and Tectono-provenance of Clastic sedimentary Rocks of the Palaeoproterozoic Alwar basin, North-Eastern Rajasthan

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ABSTRACT:

The Alwar basin, occurring in the central part of NDFB, contains ~6000 m thick package of volcanic and sedimentary rocks comprising eleven formations. The lower most three formations are included in Raialo Group, overlying four formations in Alwar Group and the upper most four formations in Ajabgarh Group. In the studied quartzite of the Alwar basin the dominant constituent is quartz with small proportion of mica, feldspar followed by some heavy minerals including tourmaline, garnet, rutile and zircon.

On the basis of Dickinson's ternary diagram Qt-F-L, Qm-F-Lt the samples plotted in the field of craton interior block provenance, continental block and recycled orogen provenance and in Qm-P-K diagram the data also lie in the continental block provenance, reflecting maturity of the sediments and stability of the source area. The plots suggest that the provenance of the Alwar quartzite is mainly granitic batholithic or granite gneisses. Presence of alkali feldspar indicates their source is both plutonic and metamorphic rocks which suggest that sediment of Alwar basin were derived from mixed source.

KEYWORDS: Petrofacies, Provenance, Alwar Basin, Rajasthan

1. INTRODUCTION:

The Delhi Supergroup Supracrustal rocks constitute a linear volcano-sedimentary belt which extends all along the western margin of ADFB from Gulf of Cambay in the northwest to Delhi in the northeast. The belt is broadly divided as South Delhi Fold Belt (SDFB) and North Delhi Fold Belt (NDFB). However, the rocks of these two sub-belts show mark differences in various characteristics such as volcanic/sediment ratio, nature of mafic-ultramafic rocks, base metal mineralization and related sulpher and lead isotopic ratios and the ages of granitic intrusions (Deb and Sarkar,1990). However, some workers claim continuity of Delhi Supergroup rocks from south to north based on continuous lithostratigraphy, similar structural history and metamorphic patterns (Singh, 1988; Naha et. al., 1984, Sharma, 1988). Heron (1953) divided the rocks of the Delhi belt into two units: the lower Alwar Series and the upper Ajabgarh series now referred to as groups. The Alwar Group is dominantly arenaceous and is represented by phyllites – schists, arkosic quartzite, amphibole quartzite, marble etc. The Ajabgarh Group is characteristically calcareous and argillaceous with a large amount of volcanic products.

South Delhi Belt:

The belt contains carbonate facies rocks, mafic-ultramafic volcanics, and mafic plutonic rocks such as gabbro, and leucogabbro and felsic volcanites. The felsic plutonic rocks range in age from 850 Ma to 750 Ma (Gopalan., 1990). An ophiolitic association comprising pillowed basalts, layered gabbro, serpentenites, pyroxynite and sometimes sheeted dykes and andesites occurs as a linear zone along the entire length of South Delhi belt (Khan et al., 2005). The rocks of South Delhi belt are regionally metamorphosed upto amphibolite facies metamorphism (Sharma, 1988).

North Delhi Belt

The northern part of Delhi belt, occurring to the north of Ajmer is constituted by three sedimentary sub-basins. These are from east to west: the Bayana sub-basin, the Alwar sub-basin and the Khetri sub-basin (Singh, 1988). The first two taper towards south whereas the third one appears to extend towards south into South Delhi belt.These sub-basins developed as grabens in a gneissic

basement and sedimentation was largely controlled by vertical tectonism. The volcano-sedimentary infills of these basins have been classified into Alwar and Ajabgarh groups (Heron, 1953) in each basin. However, they bear differences in their stratigraphic development (Singh, 1982). The sedimentation in north Delhi belt commenced with carbonate shelf deposits in two isolated areas followed by coarse clastic sediments of Alwar Group (Singh, 1988). The present study thesauruses type of rocks are present in the study area, locate the provenance of the sedimentary sequence of Alwar Basin to distinguish petrofacies as per Dickinson scheme, tectonic setting of sedimentary basin and palaeoclimatic conditions prevailing during sedimentation.

2. GEOLOGY OF THE ALWAR BASIN:

The present study area is part of Alwar basin that constitutes the central part of NDFB covering parts of north eastern Rajasthan. The NDFB, which occurs as a considerably narrow linear belt in south and central Rajasthan, fans out over a wider zone in north eastern Rajasthan (Figure 1.1). This fanning resulted because in this part of Delhi basin sedimentation took place in several partially isolated depositaries (Singh, 1982). Alwar basin formed one such depocentre which was separated from Bayana in the east and Khetri basin in the west by Pre-Delhi basement complex (Figure 1.1). The area of present study constitutes the eastern part of Alwar basin.

The detailed account of stratigraphy and sedimentological aspects of Delhi Supergroup of Alwar basin in Rajgarh area has been given by Singh (1982). The rock types found in the belt are chiefly sedimentary metamorphites comprising various types of schists, phyllites interlayered with massive quartzite, conglomerates, marbles, and amphibolites. The metasedimentary fill of the Alwar basin is divided into the Raialo (mafic volcanics, marble, quartzites) the Alwar (dominantly arenaceous) and the Ajabgarh (argillaceous and calcareous) Groups (Table 1.1).

The Alwar basin is nearly 6000 m thick package of volcanic and sedimentary rocks comprising eleven formations. The lower most three formations are included in Raialo Group, overlying four formations in Alwar Group and the upper most four formations in Ajabgarh Group (Singh, 1982) (Table 1.1). The rock types found in the basin are chiefly sedimentary metamorphites comprising various types of schists, phyllite interlayered with massive quartzite, metagreywacke, marbles, calc-silicate rocks and amphibolites.

3. METHOD OF STUDY:

Present study is focused on petrography and provenance of quartzite of Alwar Basin. Mineralogical studies provide very important information pertaining to provenance of sandstone. The key relation between provenances to basin is governed by plate tectonics, which thus ultimately controls the distribution of the different types of sandstones. In present study the petrographic study has been carried out on thin sections of quartzites of Delhi Supergroup, from the Alwar basin to determine their detrital composition. The mineralogical composition is used to constrain the provenance characteristics and tectonic setting of Alwar basin clastic rocks.

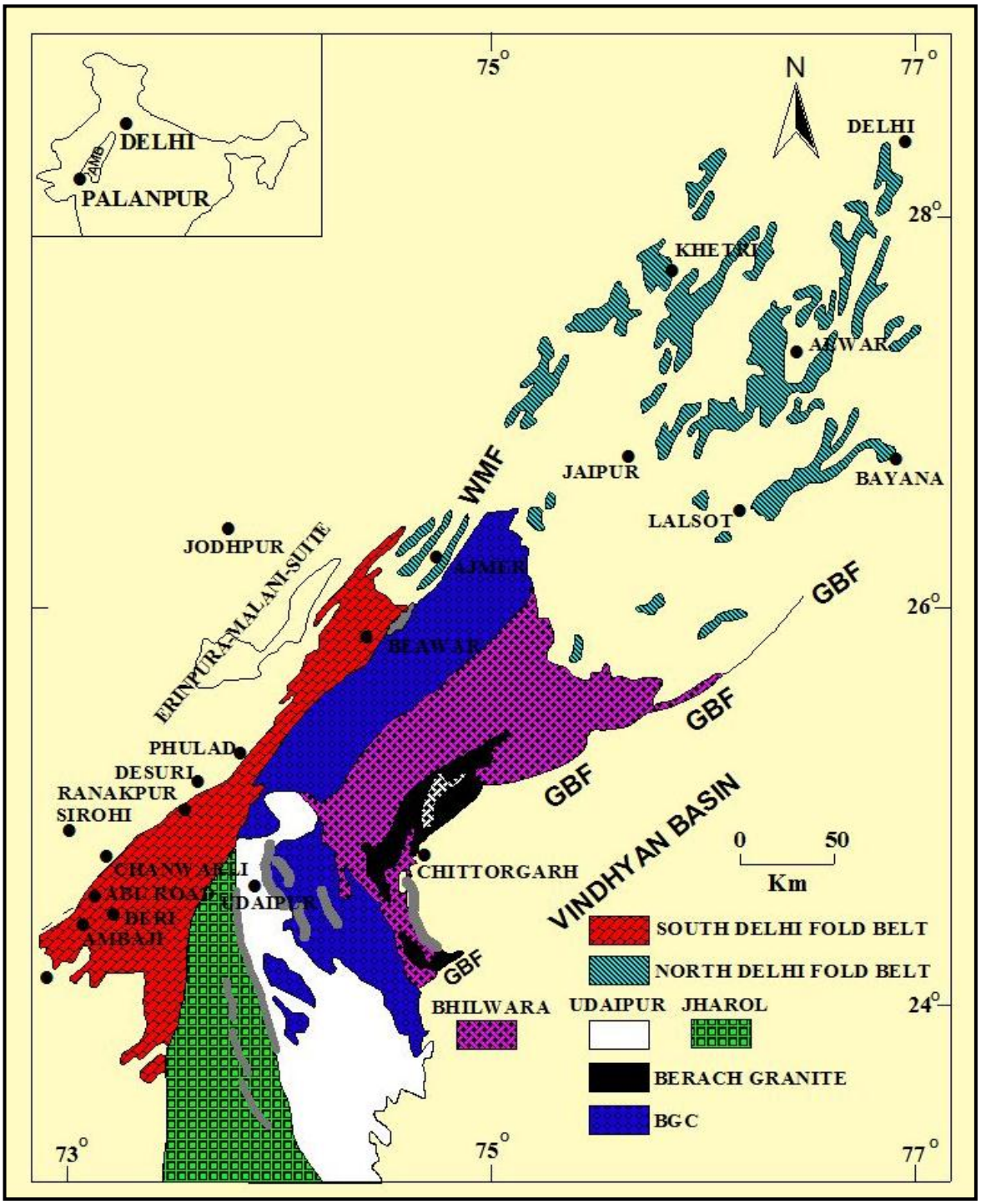

Figure 1.1 Geological map of Aravalli Craton showing distribution of Aravalli – Delhi Supracrustals sequences, large sedimentary basins, and basement complex. After Roy (1988).

Table1.1: Stratigraphic sequence of Delhi Supergroup in eastern part of Alwar basin (Singh, 1982a)

Group	Formation	Lithology	Max. Thickness
	Arauli- Mandan	Carbonaceous phyllites with thin intercalations of grey quartzites	80 m
	Barkol	Quartzites, phyllites and schists	150 m
Ajabgarh	Thana Ghazi	Carbonaceous phyllites, thin bands of grey brecciated quartzites grey marble.	150 m
	Sriska	Ferrugenous quartzite, siliceous marble, thin bands of phyllite	150 m
	Kushalgarh	Siliceous marble, calc gneiss, amphibolites, amphibole quartzite, phyllite, quartzite	200 m
----------unconformity----------			
	Pratapgarh	Quartz- sericite schist, massive quartzite, minor conglomerate	900 m
	Kankwarhi	Quatz- sericite schist, schistose quartzite, siltstone and marble	250 m
Alwar			
	Rajgarh	Arkose and feldspathic quartzite polymictic conglomerate	1200 m
----------unconformity ----------			
	Tehla	Mafic flow with conglometate, quartzite, phyllite, marble and calc gneiss	2020 m
Raialo	Serrate quartzite	Quartzite, conglomerate and sericite schist	300 m
	Dogeta	Marble, thin quartzite , schist and phyllite interbeds, conglomerate	900 m
----------Major Hiatus ----------			
Pre- Delhi Basement	**Granites, pegmatites, schists, marble, shales phyllite, quartzite, amphibolites and Banded Iron Formations**		

To determine the detrital mineral composition of quartzite samples of Alwar basin, both qualitatively and quantitatively, 48 samples were studied under the microscope. These include 11 samples from Tehla Formation, 22 from the Rajgarh Formation, 4 from the Pratapgarh Formation, 3 from the Kushalgarh Formation, 3 from the Seriska Formation and 5 from the Thana Ghazi Formation. The samples were selected in such a way so as they cover uniformly, both laterally and vertically, the outcrops of six formations. For quantitative analysis about 150-200 points per thin section were counted for determining the mode composition of rocks under investigation. Dickinson (1985) classification scheme for sandstone has been employed for the purpose of interpreting their provenance and plate tectonic setting. The detrital modes were recalculated to 100 as the sum of Qt, Qm, Qp, F, P, K, L, Lt, Lv and Ls (framework mineral composition).

4. DETRITAL MINERALOGY:

The detrital content of studied quartzites (meta-arenites) is mainly composed of several varieties of quartz followed by feldspars and mica. Average detrital mineralogy in the studied rocks includes monocryslalline quartz (73.06 %), polycrystalline quartz (18.4 %), feldspar (3.5 %), and mica (5.0 %).

Quartz:

Quartz is the most dominant constituents. Most of the quartz grains are monocrystalline along with some polycrystalline quartz grains. The varieties recorded are: common quartz (72.51 %), vein quartz (0.55 %), recrystallized metamorphic quartz (6.30 %) and stratched metamorphic quartz (12.4 %).

Common Quartz It is the dominant constituent and forms 8.72 to 100 % by volume with an average of 72.51 %. The grains are monocrystalline (Figure 1.2 A) and present a clear appearance having inclusions of tourmaline, mica and opaques. The grains show straight to slightly undulose extinction. *Vein Quartz* It constitutes 0.91 to 10.47 %, with an average at 0.54 % of the detrital fraction.

Recrystallised Metamorphic Quartz Recrystallised metamorphic quartz comprises 0.91 to 10.47 % and averages at 0.54 % of the total detrital constituents.

Stretched Metamorphic Quartz It constitutes 2.4 to 96.7 % and averages at 6.30 % of the detrital fraction. It occurs as a polycrystalline grains which are mostly made of elongated and lensoid sub-individuals of micro-quartz and fine grained quartz.

Mica:

Both muscovite and biotite (Figure 1.2 B) occur as tiny to large elongate flakes with frayed ends. The percentage of mica range from 0.23to 18.48 % percent and averages at 15.37 %. Detrital mica grains belong to two varieties and are brown and green coloured.

Feldspar:

Feldspar constitutes 0.91 to 10.47 % with an average of 0.54 %. Three varieties of feldspar have been recognized which include orthoclase, plagioclase and microcline. The size of feldspar grains generally ranges from 0.6 to 0.17 mm and is almost the same as that of the accompanying quartz grains. Feldspar grains are generally sub-equal with mostly sub-rounded to well round outlines (Figure 1.2 C).

Accessory mineral:

Tourmaline (Figure 1.2 D), garnet, rutile and zircon (Figure 1.2 E) represent the heavy minerals and occur in minor amounts.

5. PETROFACIES AND TECTONO-PROVENANCE:

Dickinson's classification (1985) puts emphasis on tectonic setting of the provenance which apparently exerts primary control on sandstone composition. However, secondary factors such as relief, climate, transport mechanism, depositional environment and digenesis can also play important role in determining the sandstone composition. In accordance with Dickinson's (1985) scheme, the detrital modes of the quartzites of Delhi Supergroup of Alwar basin are recalculated to 100 % as the sum of Qt, Qm, F, L and Lt (Table 1.2). The data are plotted in three triangular diagrams i.e. Qt-F-L, Qm-F-Lt and Qm-P-K of Dickinson (1985).

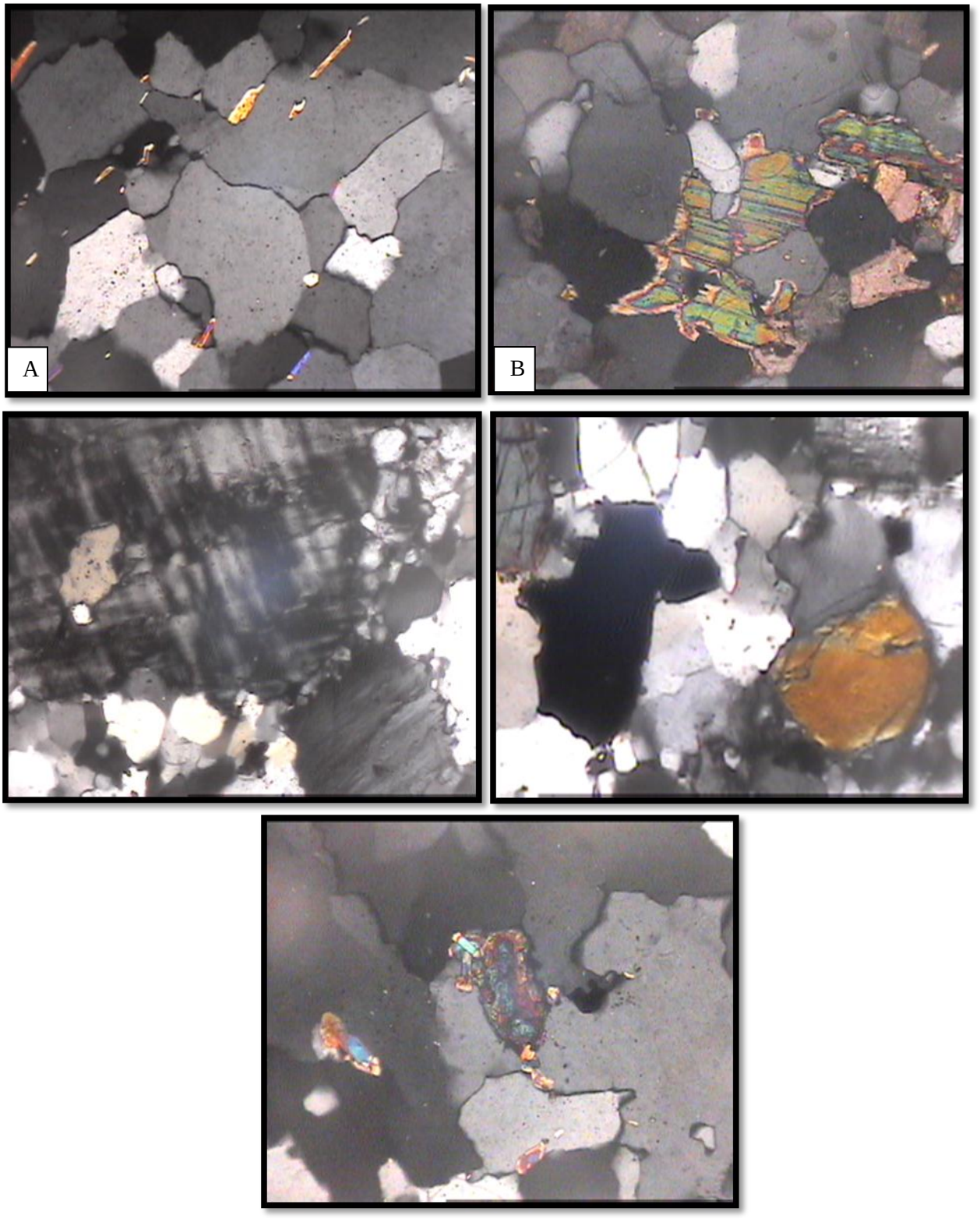

Figure 1.2- Microphotographs of A- Monocrystalline quartz grains, B- Biotite C- Feldspar grain, D- Tourmalline, E- Zircon

Table 1.2 : Percentage of detrital minerals in quartzites of the Alwar basin CQ=common quartz, VQ=vein quartz, RMQ= recrystallised metamorphic quartz, SMQ=stretched metamorphic quartz

	Mono Quartz		Poly Quartz		Mica		Feldspar			Rock Fragments
							K-Feldspar		Plagioclase	
	CQ%	VQ	RMQ	SMQ	Biotite	Muscovite	Orthoclase	Microcline		
	Tehla Formation									
Range	18.25-100.00	0.00-0.00	0.00-18.25	0.00-35.71	0.00-7.33	0.00-14.29	0.00-1.57	0.00-8.53	0.00-7.64	0.00-0.00
Average	65.66	0.00	6.88	15.18	3.82	4.17	0.26	2.74	1.27	0.00
	Rajgarh Formation									
Range	0.00-100.00	0.00-10.48	0.00-98.58	0.00-96.73	0.00-9.98	0.00-9.60	0.00-0.00	0.00-6.05	0.00-2.09	0.00-17.21
Average	73.44	0.53	9.09	10.72	1.93	1.94	0.00	1.36	0.21	0.78
	Pratapgarh Formation									
Range	35.56-91.70	0.00-0.00	0.00-16.58	0.00-31.54	0.23-3.61	1.44-4.28	0.00-12.57	0.00-3.74	0.00-0.00	0.00-0.00
Average	55.57	0.00	11.09	19.08	1.84	3.10	7.58	1.75	0.00	0.00
	Kushalgarh Formation									
Range	36.47-64.62	0.91-9.92	0.00-3.65	31.77-57.14	0.61-2.17	0.00-1.22	0.00-0.00	0.00-0.00	0.00-0.00	0.00-0.00
Average	47.82	4.09	1.22	45.29	1.18	0.41	0.00	0.00	0.00	0.00
	Seriska Formation									
Range	39.38-100.00	0.00-0.00	0.00-0.00	0.00-0.00	0.00-0.00	0.00-0.00	0.00-0.00	0.00-0.00	0.00-0.00	0.00-60.63
Average	73.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.24
	Thana Ghazi Formation									
Range	50.74-100.00	0.00-1.97	0.00-13.21	0.00-37.93	0.00-1.45	0.00-1.51	0.00-0.00	0.00-0.00	0.00-0.00	0.00-0.00
Average	80.08	0.39	5.19	13.55	0.29	0.50	0.00	0.00	0.00	0.00

Both Qt-F-L and Qm-F-Lt plots (Figure 1.3 and 1.4) show full grain population, but with different emphasis. In Qt-F-L diagram, where all quartzose grains are plotted together, the emphasis is on grain stability, and thus on weathering, provenance relief and transport mechanism as well as source rock. While in Qm-F-Lt, where all lithic fragments are plotted together, the emphasis is shifted towards the grain size of source rock, because fine grained rocks yield more lithic fragments in the sand size range. The Qm-P-K plot (Figure 1.5) show only partial grain populations but reveal the character of polycrystalline and monocrystalline components of the framework.). The present study revealed that monocrystalline quartz (Qm) is the dominant mode of our samples. Its percentage ranges from 0.91 to 100 with an average of 80. Polycrystalline quartz (QP) includes both recrystallized and stretched metamorphic quartz. Polycrystalline recrystallized quartz ranges from 3.65 % to 45.29 % and averages 20 %. The relative abundance of monocrystalline quartz to that

of polycrystalline quartz in the studied quartzites appears to reflect the maturity of the sediments because polycrystalline quartz of the sediments is eliminated by recycling and disintegrates in the zone of weathering as does strained quartz (Basu, 1985). The occurrence of small percentage of feldspar and lithic fragments in the studied quartzites may be attributed to the fact that they are lost in the soil profile in warm, humid climate with low relief or by abrasion during transit or lost in solution during diagenesis.

On the Qt – F – L diagram mean detrital modes plot near Qt pole and Qt-F-L leg, thereby suggesting a stable mature craton interior block provenance (Figure 1.3). A population shift towards the Qm-F-Lt leg is evident in the Qm-F-Lt diagram. This diagram shows that the plot of the data fall both in continental block and recycled orgen provenance (Figure 1.4). In Qm-P-K diagram the data lie in the continental block provenance, reflecting maturity of the sediments and stability of the source area (Figure 1.5).

Table 1.3- Classification and symbols of Grain types (after Dickinson, 1985)

A – Quartzose Grain(Qt-Qm-Qp)	Qt= Total Quartz grain
	Qm= Monocrystaline Quartz
	Qp= Polycrystaline Quartz
B- Feldspar Grain (F=P+K)	F= Total Feldspar grain
	P= Plagoclase grain
	K= K-Feldspar grain
C= Unstable lithic fragment (L=Lv+Ls)	L= Total Unstable lithic fragment
	Lv= Volcanic/Metavolcanic lithic fragment
	Ls= Sedimentary /Metasedimentary lithic fragment
D= Total lithic fragment	Lc= Extrabasinal detrital lime clast (not included in L or Lt)

Table 1.4 – Percentage and framework modes of quartzites of Delhi Supergroup of Alwar basin (based on Dickinson's Classification 1985).

	Qt	F	L	Qm	F	Lt	Qm	P	K
	Tehla Formation								
Range	90.09-100.00	0-9.90	0-0.00	22.77-100.00	0-9.90	0-67.33	69.69-100.00	0-13.33	0-30.30
Avg.	95.09	4.91	0.00	69.58	4.91	25.52	90.67	2.22	7.11
	Rajgarh Formation								
Range	93.91-100.00	0-6.08	0-0	0-100	0-6.08	0-100	0-100	0-8.33	0-100
Avg.	98.38	1.62	0.00	78.17	1.62	20.22	83.69	0.55	11.21
	Pratapgarh Formation								
Range	82.47-96.58	3.42-17.53	0-0	38.21-96.58	3.4-17.53	0-46.98	68.56-96.58	0-0	3.42-31.44
Avg.	90.14	9.86	0.00	58.41	9.86	31.73	83.28	0.00	16.72
	Kushalgarh Formation								
Range	100-100	0-0	0-0	38.08-67.53	0-0	32.47-61.92	100-100	0-0	0-0
Avg.	100.00	0.00	0.00	52.77	0.00	47.23	100.00	0.00	0.00
	Seriska Formation								
Range	100-100	0-0	0-0	100-100	0-0	0-0	100-100	0-0	0-0
Avg.	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00
	Thanagazi Formation								
Range	100-100	0-0	0-0	52.70-100	0-0	0-42.79	100-100	0-0	0-0
Avg.	100.00	0.00	0.00	81.13	0.00	18.87	100.00	0.00	0.00

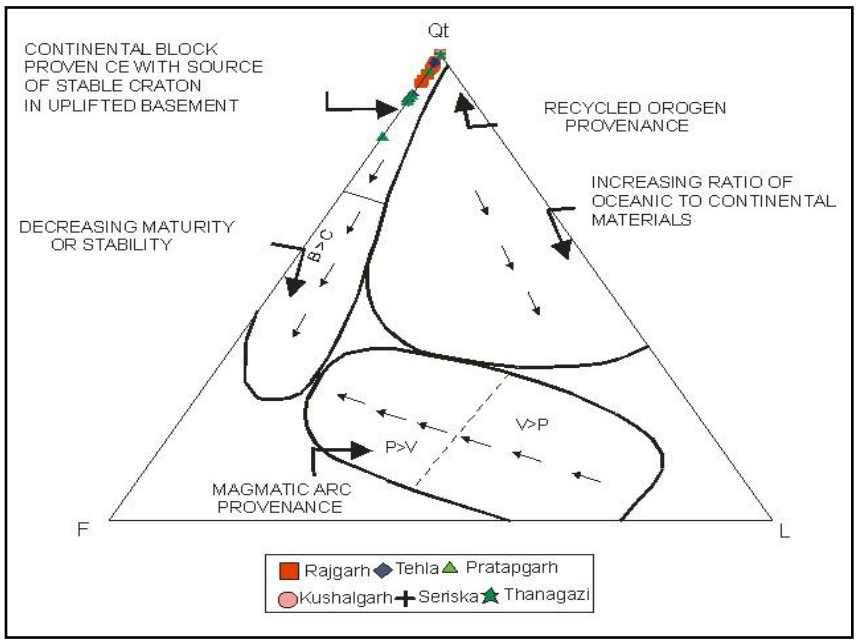

Figure1.3 – Classification of Alwar Basin Quartzites, according to Dickinson (1985)

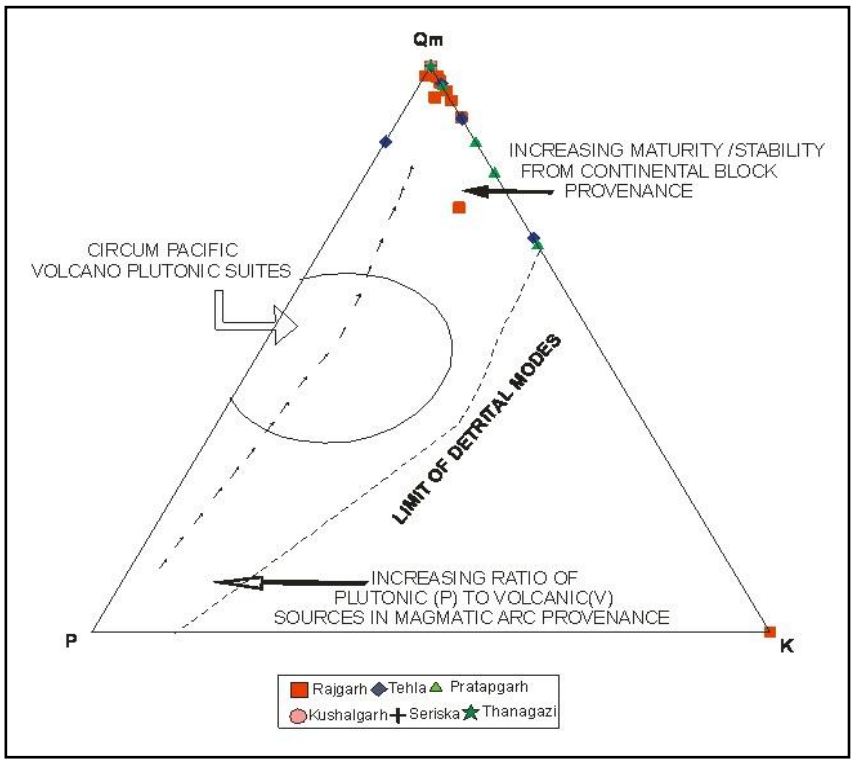

Figure 1.5 - Classification of Alwar Basin Quartzites, according to Dickinson (1985)

6. RESULT AND DISCUSSION

The quartzites of Alwar Basin contain quartz, both of igneous and metamorphic origins as well as feldspar and micas. The most abundant quartz is common quartz. It is mainly derived from granitic batholithic or granite gneisses. The recrystallized quartz indicates an origin from metaquartzites, highly metamorphosed granites and gneissic rocks. The stretched quartz was probably derived from granites, schists or quartz vein. Presence of Alkali feldspar indicates their source as both plutonic and metamorphic bodies. These characteristics suggest that the sediments of Alwar Basin meta-arenites were derived from a mixed provenance.

The dominance of quartz in these quartzites suggests that sedimentary detritus were prominently derived from a source terrain consisting predominantly of felsic rocks (Folk, 1972). The plots of Alwar basin quartzites on Qt-F-L and Qm-F-Lt diagram suggests that the detritus of sandtones were derived from the granite gneisses exhumed in the carton interior and medium to high grade metamorphosed suprarcrustal forming recycled orogen provenance. This suggests derivation of the quartzites from the stable part of the craton with perhaps some contribution from recycled orogens shedding quartzose debris of continental infinity into the basin (Dickinson et al., 1983). Nevertheless such provenance determination has to be considered with caution, because of the changes in the original composition which may be caused by diagenesis leading to the modification in the Qt-Fl-L plot (McBridge, 1985). The Qm-P-K diagram suggests the maturity stability of the source region stretched from a very long period of tectonic quiescence and mature geomorphology of the area.

Three important aspects of the Alwar basin quartzites are (i) high proportion of polycrystalline quartz, (ii) general absence of feldspar and (iii) high degree of textural maturity. These aspects need to be critically examined to evaluate the influence of various factors especially palaeoclimate on the composition of these rocks. The highly quartzose nature of the meta-arenite is generally attributed to humid tropical palaeoclimate and elimination of feldspar during diagenesis (Dickinson, 1985). The presence of high percentage of mica after quartz suggests that sand is derived from metamorphic

source which indicates mature detritus of a truly stable platform succession.

7. CONCLUSIONS:

On the basis of petrographical data of the quartzites of Alwar Basin the following denouement have been drawn:

1- Petrographic investigations indicate that the detrital content of studied quartzites (meta-arenites) is mainly composed of several varieties of quartz followed by feldspars and mica. The average detrital mineralogy includes monocryslalline quartz (73.06 %), polycrystalline quartz (18.4 %), feldspar (3.5 %), and mica (5.0 %) in addition to accessory minerals tourmaline, garnet, rutile and zircon.

2- petrofacies data, using Dickinson's scheme (1985), suggests that the sediments of Delhi Supergroup of the Alwar basin were derived from relatively low – lying granitoid and gneissic sources, supplemented by recycled sands from associated pre-existing sediments of Archaean age.

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