CHAPTER 2

# PETROGRAPHY OF QUARTZITE (META-ARENITES) OF ALWAR BASIN

## 2.1 Introduction

Mineralogical studies provide very important information pertaining to provenance of sandstone. Sandstones are mixtures of mineral grains and rock fragments coming from naturally disintegrated products of erosion of rocks of diverse composition and types. Sands of composite provenance can be described as mixture of quartzose sand from stable cratons, quartzo-feldspathic sand from basement uplifts or arc plutons, feldspatholithic sand from arc volcanics and quartzolithic sands of several types from different kinds of recycled orogens that yield varying proportion of quartzose and lithic grains (Dickinson, 1985). The detrital composition of sandstone is controlled by several factors such as character of the sedimentary provenance, tectonic setting (Dickinson and Suczek, 1979; Ingersoll and Suczek, 1979; Dickinson, 1985 and Valloni, 1985), transport mechanism (Luchhi, 1985) and effect of climate (Basu, 1985; Suttner and Dutta, 1986 and Girty, 1991).

Minerals may be destroyed or altered by the weathering or during transportation en-route to the sedimentation site or by diagenesis. The key relation between provenance to basin are governed hy plate tectonics, which thus ultimately controls the distribution of the different types of sandstones. (Dickinson and Suczek, 1979; Ingresoll and Suczek, 1979; Dickinson, 1985; Valloni, 1985), transport mechanism (Lucchi, 1985; Velbel, 1985), effect of climate (Suttner, 1974; Mack, 1984; Basu, 1985; Suttner and Dutta, 1986; Akhtar and Ahmad, 1991) and diagenetic modification (McBride, 1985; Akhtar et al., 1992; Ahmad and Bhat, 2006; Ahmad et al., 2008). Source and tectonic setting of sandstones can be determined hy detrital modes. 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.

## 2.2 Method of study

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. Terminology of Krynine (1940) and Folk (1980) was adopted for describing several varieties of quartz and other framework constituents. 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). The process was first proposed by Crook (1974) which was later modified by Dickinson et al., (1983). Petrofacies analysis can furnish vital clues regarding the provenance and its tectonic setup, source rock composition, role of climate, relief, transport and digenesis (Dorsly, 1988; Critelli and Ingersoll, 1994). In turn these clues can be applied to interpret correctly the tectono-sedimentary evolution of geo-province and its sedimentary cover (Schwab, 1981; Dickinson et al., 1983; Mack, 1984; Graham et al., 1993 and Lowe, 1995). Many studies have pointed to an intimate relationship between detrital sand composition and tectonic setting (Crook, 1974; Ingersol, 1978; Potter, 1978; Dickinson and Suczek, 1979, Ingersoll and Suczek, 1979; Dickinson and Valloni, 1980; Schwab, 1981; Bhatia, 1985;

Dickinson, 1985. Bhatia and Crook, 1986; Schwab, 1986; Decelles and Hertel, 1989; Cox and Lowe, 1995; Ahmad and Bhat, 2006).

The proportion of detrital framework grains, plotted on triangular diagram, provides effective discrimination of a variety of plate-tectonic settings and has been used as a powerful tool for determining the origin and tectonic reconstruction of terrigenous deposits (Graham et al., 1976; Dickinson, 1985). But sometimes correlation between tectonic setting and sandstone petrofacies does not hold good due to various factors that influence the detrital mineralogy (Ingersoll, 1990; Jhonson 1993). The tropical warm and humid climate aided by low relief is the most effective agent of modification of original detrital compositions by intense chemical, weathering (Basu, 1985; Girty, 1991). Other modifying agents are sediment transport across tectonic boundaries and their deposition in tectonically alien basin (Velbel, 1985; Lucchi, 1985), varying tectonic style at provenance and mixing from two sources (Ingersoll, 1990), sediment recycling (Cox and Lowe, 1995), sediment reworking in depositional environment (Espejo and Gamundi, 1994) and diagenesis (McBride, 1985). These factors must be taken into account at the time of interpreting provenance and tectonic settings (Mack, 1984; Zuffa, 1985). Hence, it is necessary to synthesize the petrofacies for a logical identification of tectonic provenance. Dickinson (1985) grouped the provenance related to continental sources into four major types: stable cratons, basement uplifts, magmatic arcs and recycled orogens.

**2.3 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 %).

### 2.3.1 Quartz

Quartz is the most dominant constituents and its varieties have been recognized on the basis of Folk's (1980) classification. Most of the quartz grains are monocrystalline along with some polycrystalline quartz grains. The monocrystalline common quartz generally shows undulatory extinction. Polycrystalline quartz grains posses both sharp and sutured intercrystalline boundaries. 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 common quartz grains occur as subaquant and mostly subangular to subrounded grains. The grains are monocrystalline (Figure 2.1 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 averages at 0.54 % of the detrital fraction. It occurs commonly in the form of monocrystalline grains and occasionally as semicomposite grains which were designated as 'pseudo' polycrystalline quartz grains by Pettijohn et.al. (1972). These grains show parallel arrangement of subindividual but not quite in optical continuity and have straight to slightly undulose extinction. Monocrystalline grains have abundant vacuoles giving cloudy appearance.

*Recrystallised Metamorphic Quartz* Recrystallised metamorphic quartz comprises 0.91 to 10.47 % and averages at 0.54 % of the total detrital constituents. It occurs in the form of polycrystalline grains of fine to coarse size and equant to subaquant shape. The grains are made up of a mosaic of microcrystalline to fine grained sub-individuals. The sub-individuals are equidimentional with straight boundaries and widely different optical boundaries. In some recrystallized metamorphic quartz grains sub individual are polygonal in shape and hence 'polygonized' quartz (Folk, 1980).

*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. The sub-individuals are in sub parallel to almost parallel orientation with smooth and sutured boundaries along which tiny mica flakes. The sub-individuals show highly undulose extinction. Sometimes the sub-individuals occur independently as monocrystalline grains which are easily recognized and distinguished from monocrystalline 'common' quartz by characteristic features, such as elongated and lensoid shape, abundant healed features and highly undulose extinction.

### 2.3.2 Mica

Both muscovite and biotite (Figure 2.1 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. Detrital mica grains were recognized both as their relatively large size and defined detrital boundaries. Some of the mica grains appear to have been formed by recrystallization of clay minerals during deformation (Tyagi 1980). In addition, detrital mica grains usually show the effect of compaction. Such grains, are seen to occur around the adjacent quartz grains. Chlorite occurs along with unaltered biotites as well as separately with opaques.

### 2.3.3 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 2.1 C). Some angular to sub-angular grains also occur. Both fresh and altered varieties of feldspar grains are common in the studied samples.

### 2.3.4 Accessory mineral

Tourmaline (Figure 2.1 D), garnet, rutile and zircon (Figure 2.1 E) represent the heavy minerals and occur in minor amounts.

## 2.4 Classification based on Dickinson's scheme (1985)

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 2.1). The data are plotted in three triangular diagrams i.e. Qt-F-L, Qm-F-Lt and Qm-P-K of Dickinson (1985). Both Qt-F-L and Qm-F-Lt plots (Figure 2.2 and 2.3) 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 2.4) show only partial grain populations but reveal the character of polycrystalline and monocrystalline components of the framework. Generally, the sandstone from different tectonic settings have characteristic detrital components and characterstic chemistry (Crook, 1974; Dickinson and Suczek, 1979; Valloni and Maynard, 1981; Dickinson et al., 1983; Bhatia 1983; Kroonenberg, 1994). The determination of the tectonic setting of sandstones using the framework mineral composition was first proposed by Crook (1974), and has since undergone considerable refinement (Dickinson and Suczek, 1979). 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 2.2).

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 orogen provenance (Figure 2.3). 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 2.4).

**2.5 Tectono pruvenance**

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). Undulating extinction of quartz point to possible plutonic sources. Similarly stable accessory minerals, including zircon and rutile reveal felsic to intermediate plutonic and metamorphic rocks 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. The overall analysis of petrofacies data 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.

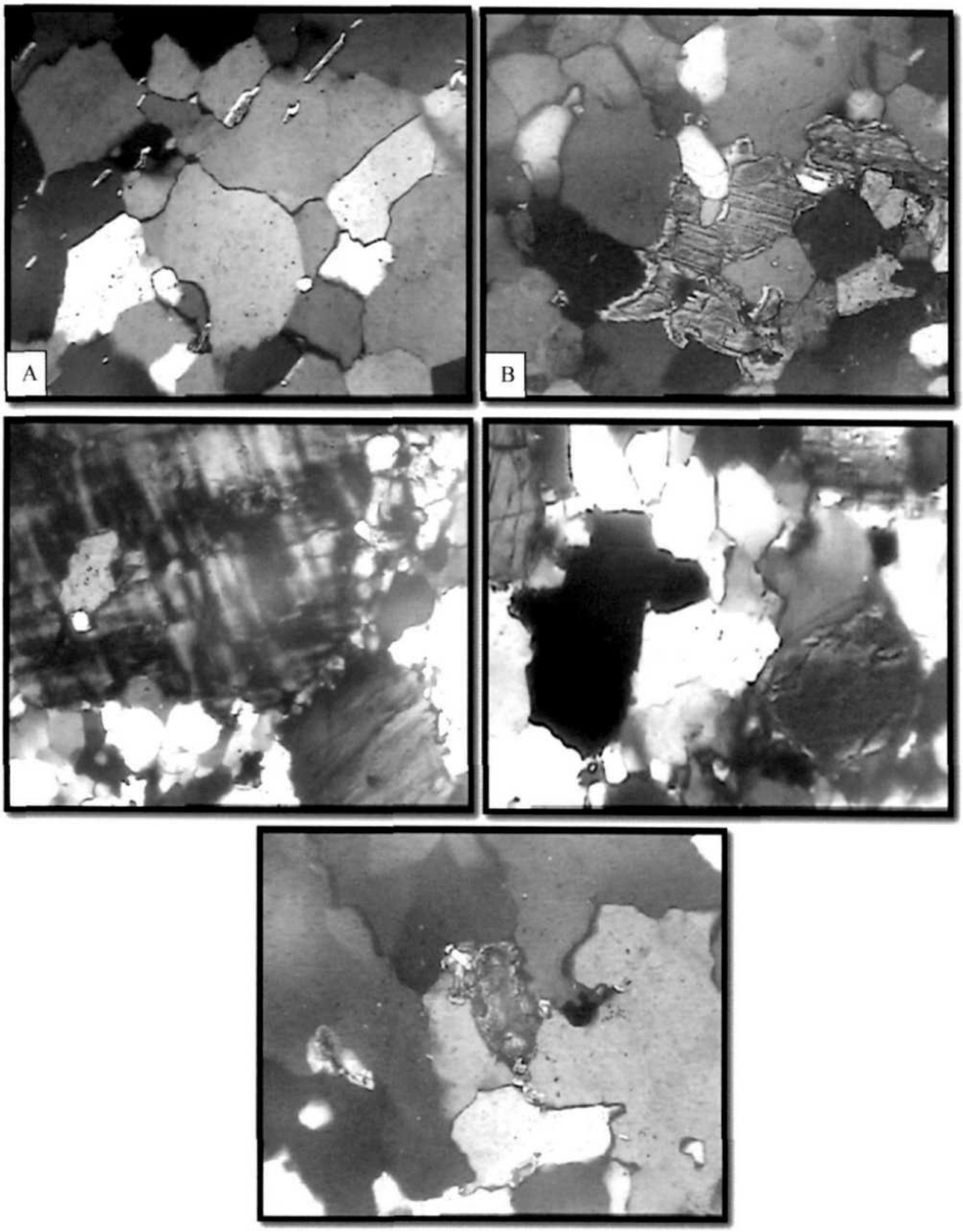

Figure 2.1- Microphotographs of A- Monocrystalline quartz grains, B- Biotite C- Feldspar grain, D- Tourmalline, E- Zircon.

**Table 2.1- 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= Plagioclase 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) |

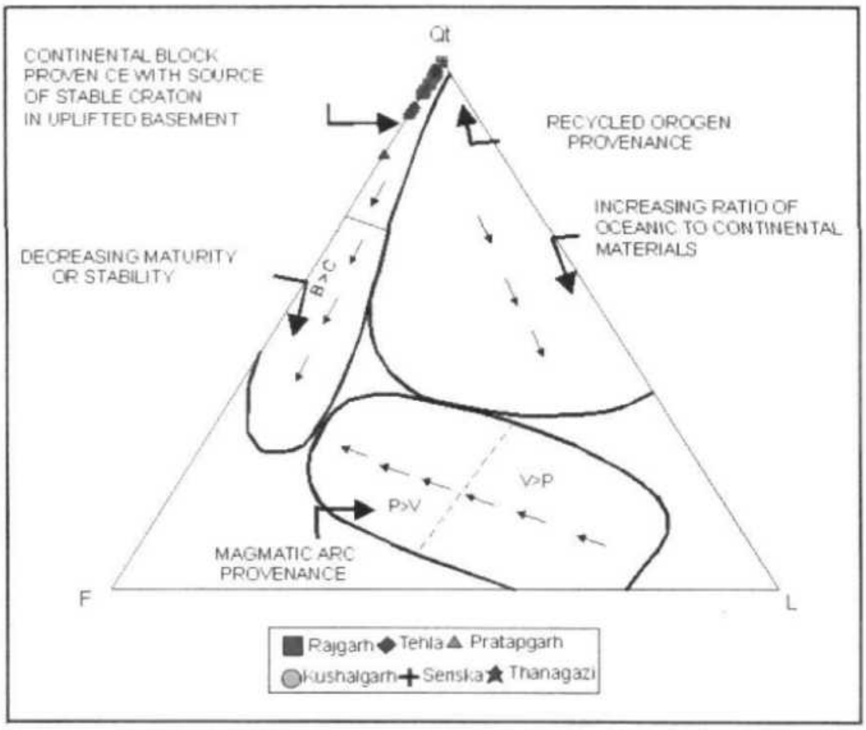


Figure2.2 – Classification of Alwar Basin Quartzites, according to Dickinson (1985).

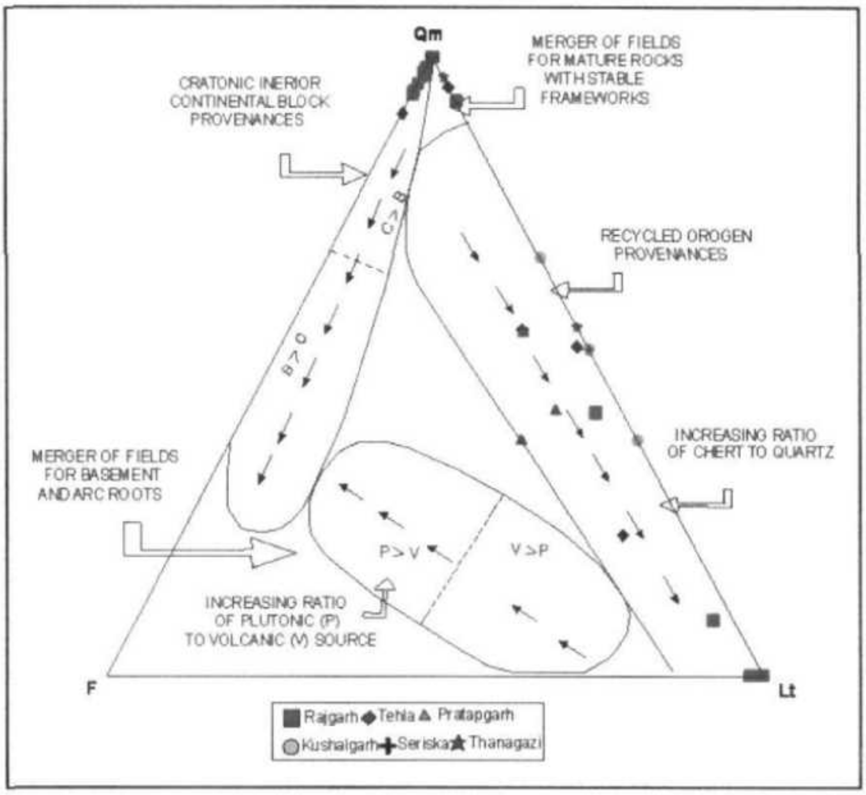


Figure 2.3 - Classification of Alwar Basin Quartzites, according to Dickinson (1985).

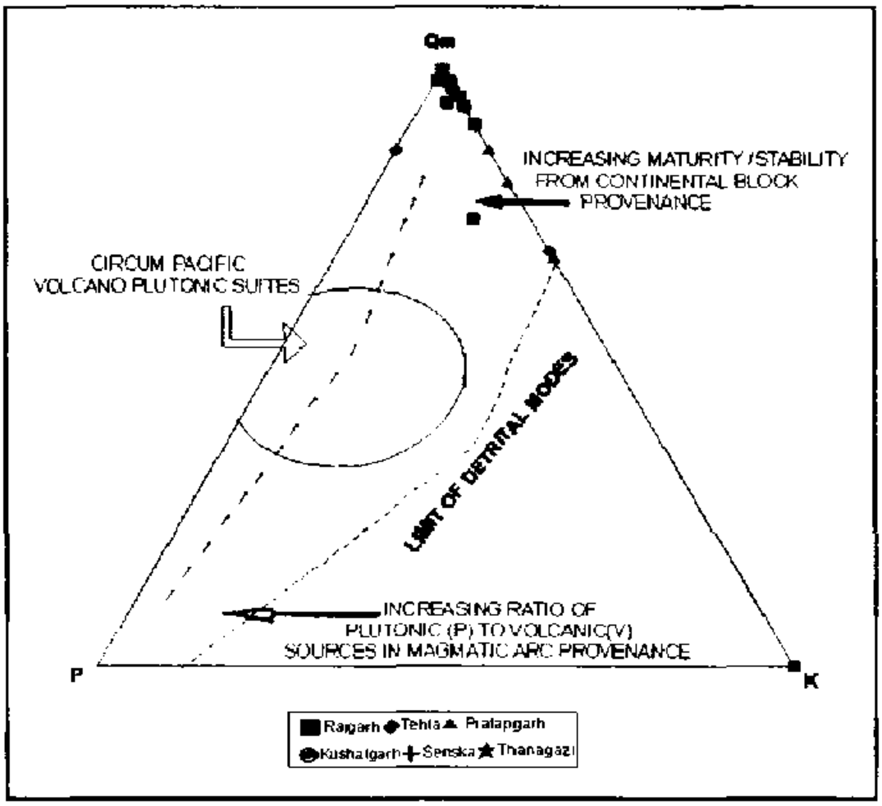


Figure 2.4 - Classification of Alwar Basin Quartzites, according to Dickinson (1985).

**Table 2.2 : 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 |

Table 2.3 – 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 |