CHAPTER -9

SUMMARY AND CONCLUSIONS

The northwestern part of the Indian shield, referred to as the Aravalli craton, evolved over through a wide time span ranging from >3000 Ma to about 500 Ma (Gopalan et al. 1990; Roy and Jakhar, 2002 and references therein). In this region the Archaean basement, referred to as the Banded Gneissic Complex (BGC), is overlain by numerous Proterozoic cover sequences (Deb and Sarkar 1990) belonging to the Palaeoproterozoic Aravalli and Mesoproterozoic Delhi supergroups. These two groups of rocks constitute the NE-SW trending Aravalli mountain belt or Aravalli Delhi Fold Belt (ADFB) which stretches for about 800 km from Palanpur in south to Delhi and adjoining areas in the north. The Delhi Supergroup forms the Aravalli prographic axis. It is sandwiched between the BGC/Bhilwara Supergroup, Aravalli Supergroup and its equivalent cover sequences in the east and Malani Volcanics, Marwar Supergroup (Late Proterozoic cover sequences) and Mesozoic-Cenozoic sediments in the west. In central Rajasthan the Delhi Fold Belt is narrow but fans out in the north and northeast and south. In the northeast the rocks are deposited in a number of isolated, fault bounded basins while in the central part (south of Ajmer) the Delhi Supergroup represents a more or less continuous sequence. The Delhi Fold Belt (DFB) is exposed in two main domains (Sinha-Roy et al., 1998), the North Delhi Fold Belt (NDFB) and the South Delhi Fold Belt (SDFB). The northern part of this belt referred to as NDFB, is broadly composed of the Delhi Supergroup occurring in three volcano-sedimentary basins. These are from east to west: the Bayana basin in the east, the Alwar basin in the centre and the Khetri basin in the west. The first two taper towards the south whereas the third appears to extend towards south into the SDFB.

The present study involves geochemical and petrographical examination, of clastic sedimentary rocks of Delhi supergroup comprising eastern part of the Alwar

basin of NDFB. The rock types found in the basin are chiefly sedimentary metamorphites comprising various types of schists, phyllites interlayered with massive quartzite, marbles, calc-silicate rocks and amphibolites. Although, the stratigraphic relationships between the various lithological units are not clear, the sequence is divided into the Alwar (dominantly arenaceous) and the Ajabgarh (argillaceous and calcareous) groups. The present study is the first, to report major and trace elements (including REE) compositions of clastic sedimentary rocks from the Alwar basin. Our aims are to report and utilize the geochemical data of the quartzites (meta-arenites) and metapelites of the Alwar basin to (i) constrain the composition of the source terrain, its weathering history and the tectonic setting at the time of their deposition and implication for continent assembly (ii) examine the applicability of geochemical data in interpreting the nature of continental crust particularly during Archean and Proterozoic time and the implications of these data for evolutionary trends of early crust in northern part of Indian shield .

Geochemical data comprising major, trace and rare earth elements of 28 samples of quartzites, and 24 samples of pelites representing various formations of Delhi Supergroup of the Alwar Basin are presented and utilized to achieve the aims and objectives.

Some major observations and conclusions based on the present investigation are highlighted below.

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. The overall analysis of 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.

2- Compositionally, almost all the quartzite samples of the Alwar basin, comes under the category of quartz arenite (SiO_2 = 80-88 %, Al_2O_3 = 4-9 %, Fe_2O_3 = 0.04 - 7.7 %, CaO = 0.09 - 0.2510 % and Na_2O = 0.02 - 0.32 %).

3- The Alwar basin quartzite and metapelite assemblage display a strong negative correlation between Al_2O_3 and SiO_2 (r = -0.94), suggesting that studied quartzites and metapelites are mixture of quartz and illite end members. The illite control is also indicate by moderate relationship between Al_2O_3 and K_2O (r = 0.46).

4- The SiO_2/Al2O3 ratios (6.05 – 319.67; avg. 56.94) of quarzites are high, indicative of their high maturity

5- In general the REE patterns of our samples of quartzite and metapelites are highly fractionated with $(La/Yb)_n$ = ~1 - 51.25. Apart from few anomalous samples, the Alwar basin clastic sedimentary rocks are characterized by significant enrichment in LREEs, the distinctive negative anomalies, and flat HREE patterns.

6- The quartzites of Alwar Group are more enriched in REE particularly in LREE and MREE relative to quartzites of Ajabgarh Group. Similarly the metapelites of

Alwar Group are more enriched in LREE but the MREE and HREE of the two groups remain same.

7- In comparison with average upper continental crust (AUCC) all the rock formations of the Alwar basin are characterized by strong depletion in CaO, Na_2O and Sr indicating high degree of weathering in the source area (Nesbitt et al., 1980).

8- Quartzites are depleted in many major and trace elements due to quartz dilution. Many of the samples have undergone post- depositional K - metasomatism.

9- No systematic differences in the REE patterns among different stratigraphic units are observed. However, $(La/Yb)_n$ ratio appears to show a stratigraphic control as it appears to decrease with decreasing age.

10- The upper crust suffered variable degree of weathering is indicated by depletion of Ca, Na, Sr and CIA, PIA, CIW and Th/U values and A-CN-K diagram. Chemical weathering condition, as indicated by clastic rocks of the Alwar basin is in conformity with worldwide humid and warm climate during the Paleoproterozoic period.

11- The geochemical data suggest that the quartzites were deposited in an oxygenated transgressive beach environment and the metapelites under anoxic conditions probably in a costal complex environment including lagoonal basins.

12- Major element discrimination scheme, TiO_2 - Zr, TiO_2 - Al_2O_3 plots and various diagrams involving immobile elements such as La, Sc, Th, Cr and their ratios such as Th/Sc, Cr/Th and Eu/Eu*, all suggest the dominance of felsic rocks in

provenance of Delhi Supergroup. The basin received variable contribution from Berach Granite, TTG and mafic enclaves of Archaean Banded Gneissic Complex (BGC) of the Aravalli Craton.

13- Provenance modelling based on REE patterns, immobile element ratios, and multi-element patterns, suggest that the source area of Alwar basin sediments was consisted of 50 % Berach granite, 30 % TTG gneisses and 20 % mafic enclaves of the BGC.

14- SiO_2 . K_2O/Na_2O, Na_2O- CaO - K_2O, Th-Sc-Zr/10, Ti/Zr vs. La/Sc discrimination diagrams suggest a continental rift setting for the Alwar basin. Our geochemical data in combination with available information on geochemistry and geochronology of the mafic volcanic rocks of NDFB suggest that the Alwar basin originated as a continental rift at the margin of the BGC craton at about 1832 Ma back.

15- The coeval formation of many rift- related basins in the northern part of the Indian Shield suggests that the North Indian Craton (NIC) suffered a major intracratonic extension during Palaeoproterozoic. This event represents an important extensional regime that triggered the commencement of dispersion of earth's first super continent which amalgamated at ~2.4 Ga involving cratons of South Australia, East Antarctica, India and North China.

16- The geochemical data of siliciclastic rocks of Delhi Supergroup of Alwar basin trends are generated during the present study, in combination with available geochemical data of about 2800 Ma old Achaean Naharmagra quartzites (Raza et al., 2010a) and about 1600 Ma old Vindhyan sandstones (Raza et al., 2010b)

of the Aravalli Craton are utilized to determine the compositional changes of upper crust at Archacan-Proterozoic Boundary (APB) in Aravalli craton. The data indicate systematic changes in various geochemical parameters during the period from 2800 Ma to 1800 Ma and finally to1600 Ma. The observed trends of changes are as follows:

a- K_2O/Na_2O ratio of ~1 at 2800 Ma during Archaean increased to around ~5 at 1800 Ma and ~9 at 1600 Ma during the Proterozoic.

b- A decrease in the $(Gd/Yb)_n$ ratio from 2. 97 in Archaean to 2. 22 and then 1.77 in Proterozoic.

c- The $(La/Yb)_n$ ratio mimics the $(Gd/Yb)_n$ ratio, and show similar change in upper crust. It changes from 28 to 12.46 and eventually to a value of 9.99. The temporal evolution of REE pattern is exactly opposite to that reported by Taylor and Mclennan, (1985) i.e. flat REE pattern with no europium anomaly

d- Sm/Nd ratio increases from 0.53 in Archaean to 0.58 and than 0.78 in Proterozoic.

e- Cr/Sc ratio varies from 57.87 in the Archaean to 18.11 and 16.68 in the Proterozoic.

f- La/Th ratio also changed temporally from 3.11 in Archaean Naharmagra quartzite and declined with increase in Th content in Proterozoic (Avg. Alwar basin quartzite 1.90, Avg. Vindhyan Sandstone, 1.94). The data indicate systematic unroofing of granite batholiths during the Proterozoic by upliftment and erosion of upper TTG cover.

g- Cr/Th varies from 24.60 in the Archaean to 4.41 and 14.85 in the Proterozoic.

The trends shown by various geochemical parameters through geological times, as discussed above, suggest that the continental crust in the north western part of the Indian shield is characterized by evolution from TTG dominated crust of Mesoarchean to a granitic dominated crust during the Palaeoproterozoic.