CHAPTER - 8
CHAPTER - 8

8.1. CONCLUSIONS

The mafic-ultramafic rocks of Mandawra and the adjoining areas located in eight outcrops (Mandawra-Siron-Purani Pindar-Dangli-Ikona Khurd-Hanumatgarh-Rajola-Gorakalan) covering nearly 200 sq km area disposed between N24°25'20"-N24°17'30" and E78°45'00"-N79°00'00" have been mapped in 1:6000 using Survey of India topographic sheets (54L/15 NE, NW, SW and SE). These are disposed mainly in E-W to NNE-SSW trend and exposed within the ABC. These outcrops are discontinuous, low-lying and are separated from each other by black soil and granitic rocks. The minimum and maximum elevations of the area from the mean sea level are 349 and 425 m, respectively. The topography of the area is flat with gentle slope towards northeast with isolated uplands.

The area is mainly drained by river Dhasan and its tributary Rohini. The flow directions of these two major streams are towards NE following the regional slope of the area. The mapped area can be divided into four NE-trending basins of varying basin area. The basin divides cuts across the overall outcrop trend (E-W) of the mafic-ultramafic rocks in this area. The overall drainage pattern of area is dendritic to subdendritict having 1st to 5th order streams with 900 streams in total. Interestingly the stream orientations of Mandawra and adjoining areas are parallel to major tectonic planes and tectonically emplaced lithounits of the ABC indicating their tectonic control. The three major tectonic structures of the ABC include the mafic dykes (NW-SE; Pati et al., 2008), the regional shear fabrics (E-W; Pati, 1999) and NNE-SSW to NE-SW-trending GQV (giant quartz veins; Pati et al., 2007).
The mineralogical and textural characteristic indicate that the mafic-ultramafic rocks exposed in parts of the Madaura and adjoining areas comprise metadunites, metaperidotites, talc-tremolite schist, metaperidotites, metagabbro and dolerite based on their characteristic textural relationship and preserved petrochemical signatures. Present study suggests that the ultramafic rocks are older than the 2.5 Ga granitoids of the ABC and are intruded by gabbroic rocks followed by dolerites of tholeiitic affinity.

The host granitoid is mylonitised with strong S-C fabric showing E-W trend with subvertical dip due north and running parallel to the strike of marginal Bijawar basin. The remote sensing study has shown that the E-W trending ultramafic outcrops have been sinistrally displaced over more than 2 km in the NNE-SSW direction. This trend is parallel to the orientation of the Giant Quartz Veins (Pati et al., 2007).

The alteration signature in these rocks is observed in meso- and microscopic scale and based on chemical index of alteration \[\text{CIA} = \frac{\text{Al}_2\text{O}_3}{\text{Al}_2\text{O}_3 + \text{CaO} + \text{Na}_2\text{O} + \text{K}_2\text{O}}\], it is interesting to note that the dolerites are observed to be most altered followed by talc-tremolite schist→metaperidotite→metagabbro→metadunite. The metadunite is visibly altered but chemically the least affected by secondary processes. The petrographic study shows the evidences of variable alteration in these rocks and also supported by varied LOI (0.2 to 12.66 wt%) measured in these rocks.

The presence of talc, serpentine, hornblende, tremolite, actinolite, chlorite, epidote, sericite and calcite suggests that these rocks have undergone predominantly hydration reaction under greenschist facies condition. There are two phases of metamorphism in these rocks. The first one is marked by the development of talc-serpentine after
olivine and the second one is denoted by the development of tremolite/actinolite/cummingtonite and porphyroblasts of hornblende. The important metamorphic assemblages in this area include:

6. Tremolite-hornblende-actinolite-chlorite-magnetite-quartz
7. Tremolite-phlogopite-magnetite-chlorite-quartz
8. Talc-serpentine- magnetite-phlogopite-chlorite-quartz
9. Talc-tremolite-hornblende-actinolite-chlorite-magnetite-quartz
10. Hornblende-tremolite-epidote-chlorite-magnetite-quartz

Pati et al. (2010) have shown that parts of ABC underwent two thermal/hydrothermal events, at ca. 1 Ga (Grenvillian orogeny) and ca. 600 Ma (Pan-African orogeny), respectively and this supports the present findings.

The petrochemical study of 54 representative rock samples collected from various lithological units comprise samples of metagabbro (11 numbers), metaperidotite (21 numbers), metadunite (04 numbers), talc-tremolite schist (14 numbers) and dolerite (04 numbers). The Mg# of mafic-ultramafic rocks of Mandawra and adjoining areas show substantially higher values except for a few metagabbro and dolerites. The range of Mg# for metagabbro (24.85-71.03), metaperidotite (23.90-77.30), metadunite (67.00-71.71), talc-tremolite schist (65.18-80.35) as compared to dolerite (28.90-47.63) is high. Thus, the mafic-ultramafic rocks of Mandawra and adjoining areas seem to be of strong primary character with Mg# lying around ~70 except for dolerite (Mg# 41).

The altered and metamorphosed mafic-ultramafic rocks of basaltic affinity are classified based on TiO$_2$-Zr/(P$_2$O$_5$*10) and all the rock type plot in the tholeiitic domain contrary to modal and normative mineralogy. However, in Al$_2$O$_3$-FeO$_t$/(FeO$_t$+MgO) diagram the samples show
komatiitic affinity as well. The normative mineralogy has been applied to plot the dolerites and metagabbros in plagioclase-clinopyroxene-orthopyroxene ternary and they plot in the gabbro field. The ultramafic rocks plot in harzburgite, lherzolite, olivine orthopyroxenite and olivine websterite fields in the olivine-clinopyroxene-orthopyroxene ternary diagram.

The data are plotted in V-Ti/1000 binary to distinguish their island-arc to ocean floor affinity and it is very striking to observe these rocks to lie in the island-arc tholeiite (IAT) field and some of the metagabbros and dolerites plot in the ocean floor basalt (OFB) field similar to MORB. The normative mineralogy suggested the presence of olivine tholeiite typical of MORB affinity supporting the conclusions of the tectono-magmatic discrimination plot.

The mafic-ultramafic rocks of Mandawra and the adjoining areas show higher total REE content (ΣREE: 3.25-100.58). The marked chemical difference between gabbro and dolerite (LREE enriched) is indicative of variation either in nature and degree of protolith (viz. Iherzolite). As a first approximation the fractionated REE patterns of mafic-ultramafic rocks indicate their derivation from partial melting of a less fractionated REE source. Further it suggests that the metagabbros and talc-tremolite schists of Mandawra and the adjoining areas can be considered to be the derived from spinel-rich peridotite source material because they have similarity with chondritic rocks of well as have high Mg# value (>70). Normalised REE patterns show a regular decrease from light to heavy REE showing variable Eu anomaly. The marked abundance in LREE over HREE, irrespective of the MgO content, is suggestive of a metasomatic process that might have enriched LREE and other
incompatible elements. The REE spider plot is very clear that the depletion of LREE is not seen in any of the samples.

The 54 bulk rock analyses of mafic-ultramafic rocks of Mandawra and the adjoining areas are plotted in Sun and McDonough (1989)’s MORB-normalized multicationic parameter diagram. The metagabbro, metadunite, metaperidotite, and talc-tremolite schist show similar pattern Nb depletion (Nb/Nb*) values of 0.50, 0, 0.30 and 0.40, respectively typical of island arc affinity. In addition they depict Pb enrichment, and Zr and Ti depletion suggesting their formation under arc-related subduction setting. Dolerite exhibits Nb enrichment with (Nb/Nb*) values of 1.24 and is distinct but has slight similarity with metagabbro compositions.

The data shows an increasing trend from IPGE to PPGE in dolerite and metagabbro with Au enrichment. The Os-Ir shows a dip in these two rocks. The Rh enrichment followed by Pt depletion and Pd-Au enrichment defines the general pattern. In case of ultramafic compositions flat Os-Ir patterns similar to fertile upper mantle compositions are distinct. The total PGE in these rocks is very low (ΣPGE=10.8-226.2 ppb). This is not economic but anomalous compared to the Clark’s value. The PGE distribution patterns in ultramafic compositions are similar (PPGE>IPGE) and it is characteristic of chromite-bearing ultramafic rocks and ultramafic cumulates belonging to the ophiolite belts. This conclusion is supported by the Pd/Ir-Ni/Cu plot where the mafic-ultramafic rocks of Mandawra and adjoining areas plot predominantly in the ophiolite-komatiite and high-MgO basalts fields.

This study has shown the anomalous PGE (including Au) content in mafic-ultramafic rocks of Mandawra and adjoining areas. The field and petrochemical data suggest that these PGE-bearing mafic-ultramafic
rocks of Mandawra and adjoining areas formed in an Archean island arc plate convergent setting similar to earlier study carried out in Mau ranipur area, Mahoba district, U.P., India of the ABC.

8.2. SUGGESTIONS FOR FUTURE STUDY:

The altered and metamorphosed nature of these rocks requires isotopic and geochronological data for proper petrogenetic interpretation and to ascertain their chronological status.

The sample collected from deeper drill cores could be more meaningful for not only petrochemical characterization but also for proper evaluation of the PGE content in these rocks.

It would be interesting to cut channels across the concealed contacts of the respective adjacent lithounits to elucidate their spatial relationship with the host and related lithounits exposed in the area.