ABSTRACT

PETROLOGICAL AND GEOCHEMICAL STUDY OF THE GRANITIC ROCKS OF BUNDELKHAND MASSIF IN THE JHANSI, LALITPUR AREA, U.P., INDIA

By

Md. Erfan Ali Mondal

The Bundelkhand massif of batholithic dimension occupies a vast area in central India. The batholith comprises of mainly granitoid plutons. Other magmatic phases include pegmatites, aplites, rhyolites and mafic-ultramafic suites. The massif is traversed by a number of quartz veins and basic dykes. Series of granitoids were emplaced into the basement consisting of gneisses, migmatites, banded iron formations, basic to felsic volcanics, etc. which probably represents an Archean greenstone belt. The granitoids were emplaced in an already deformed basement. The massif is covered by younger rocks of Bijawar and Vindhyan Groups and Indo-Gangetic alluvium.

The Bundelkhand massif represents a complex protracted history of evolution during Archean - Paleoproterozoic. This study is aimed to understand the nature of the granitoids and their possible origin. Efforts have also been made to analyse the geochemical characteristics of spatially distributed granitoids. Nature and possible origin of the mafic magmatic enclaves have also been studied. An attempt has also been made to decipher the geodynamic environment of the emplacement of the granitoids.

On the bases of field relations, three genetically and compositionally distinct granitoid phases have been deciphered and delineated. These phases are hornblende granitoid, boitite granitoid and leucogranitoid, in order of age. Field evidence support an igneous origin of the granitoids. Although the granitoids are mostly underformed, at places, they have suffered shearing and as a result have acquired foliation. Sometimes the shearing has converted the granitoids to schistose rocks.

Hornblende granitoid, a dark coloured rock, is the oldest granitoid phase of the massif. The granitoid is massive and compact, the grain size is coarse and uniform. The biotite granitoid exhibits porphyritic texture and is intrusive into hornblende granitoid. The leucogranitoid is the youngest granitoid phase, its grain size varies from fine to coarse. The massif hosts a number of mafic magmatic enclaves of varying shape, size, orientation and composition.

The Bundelkhand granitoids are one-mica granitoid containing biotite only. Other primary phases are quartz, plagioclase and K-feldspars. Hornblende is present only in the two older granitoid phases i.e. hornblende granitoid and biotite granitoid. The older hornblende granitoid and biotite granitoid have higher modal proportion of ferromagnesian minerals and plagioclase. In younger leucogranitoid ferromagnesian constituents are negligible; whereas the content of K-feldspars and quartz concomitantly increases in leucogranitoid. Magnetite when present occurs in general in association with hornblende and biotite. The mafic magmatic enclaves are composed of pyroxene, hornblende, plagioclase and magnetite. Apatite in general is acicular in enclaves, whereas it is stubby in the host granitoids. The enclaves

are invariably finer grained than their host and exhibit magmatic texture. The granitoids cover a large compositional spectrum on IUGS (modal) classification scheme and define a calc-alkaline granodiorite (medium-K) trend.

Field, mineralogical and geochemical characteristics point to I-type nature of the granitoids. However, increasing assimilation of crustal rocks has imparted peraluminous characteristics to the later phases. Early crystallization of hornblende may also account for peraluminous nature of the later phases of the granitoids. Majority of the granitoids exhibit calc-alkaline nature on AFM and ternary diagrams based on Al- Fe + Ti - Mg and K - Na - Ca. Mafic magmatic enclaves show alkaline affinity on AFM diagram. However, on R1-R2 multicationic diagram, different granitoid phases range from calcic through calcalkalic to alkalic - calcic. K/Rb values for different phases of Bundelkhand granitoids range from 95 to 375 which is, in general, compatible with calc-alkaline suites else where. The older phases of the granitoids are metaluminous, whereas the younger ones are peraluminous. The granitoids show cafemic to alumino-cafemic magmatic associations.

Almost all major elements exhibit linear to near-linear trends against SiO_2. A wide scattering is observed for all the trace elements on Harker's diagram. The curved trend on CaO vs.SiO_2 is indicative of hornblende fractionation. The inter-elemental relationship of Rb and Sr may be correlated with biotite and plagioclase fractionation The variation trends of Sr vs. Ba reflect biotite and K-feldspar fractionation. Two distinct trends can be discerned from TiO_2 vs Zr diagram The trend shown by hornblende granitoids is consistent with biotite fractionation, whereas the rest of the granitoids correspond to

fractionation trends produced by plagioclase and biotite and/or hornblende.

The granitoids as well as the mafic magmatic enclaves display LREE enrichment pattern. The Yb contents of the hornblende granitoids are similar to the classical Archean tonalite, trondhjemite, granodiorite suites where Yb content is low, $Yb_N < 8.5$, whereas the biotite granitoids and the leucogranitoids, in respect of high Yb contents ($4.5 < Yb_N < 20$) are more akin to post-2.5 Ga granitoids emplaced in a subduction zone environment. Almost all samples have negative Eu anomalies except for a few which have either no anomaly or slightly positive Eu anomaly. The fractionated REE patterns and HREE depletion may point to retention of garnet and/or hornblende in residue. The REE patterns of the granitoids in general, closely correspond to those of calc-alkaline volcanic arc rocks of continental margin magmatism.

Majority of the biotite granitoids and leucogranitoids plot between cotectic 1 and 4 Kb water vapour presure. The hornblende granitoids mostly plot well below 4 Kb cotectic curve on the normative Qz-Ab-Or diagram. The granitoids as a whole define a path which is very close to the experimentally determined path followed by a trachytic liquid fractionating a single feldspar and evolving towards a quarternary minimum. Early crystallization of hornblende and biotite, lack of pyroxenes and presence of alkali-feldspar phenocrysts may point to greater than 4 or 5% water content in the melt. The temperature of formation of the granitoids as depicted by M parameter is inferred to be between 800 °C to 950 °C .

Fractional crystallization is not considered to be the dominant process for the evolution of the massif because inter-elemental relationship do not show variation trends expected for a composite massif evolved by fractional crystallization process from a common parent magma. On Zr vs. TiO_2 diagram, the trend shown by the hornblende granitoids does not coincide with the trend produced by the rest of the granitoids, indicating thereby that all the graitoid types are not comagmatic. Further, the broad gentle slopes on compatible vs. imcompatible elements diagrams are not consistent with fractional crystallization model. Although the granitoid samples sometimes follow the predicted trends of simple two end-member mixing model, the model is hard to reconcile with the great scattering of data, particularly of the trace elements on element-element plots. Restite unmixing model also does not seem to be a viable mechanism since the strong linear correlation for every element on element - element plot which is implicit in restite model is not observed for the granitoids. Also, no restite phase has been observed.

Plots of compatible vs. incompatible elements of Bundelkhand granitoids define a broad gentle slope closely following the assimilation-fractional crystallization trends. From the gentle slope of Rb vs. Sr and Ba vs. Ni and Co, partial melting trend can be deciphered. It may be concluded that the dominant process for the evolution of the granitoids is partial fusion; the magma at a later stage may have undergone assimilation-fractional crystallization. The I-type geochemistry, metaluminous nature, low values of Rb/Sr and cafemic magmatic associations of the hornblende granitoids are indicative of derivation of the hornblende granitoids from mantle sources. The cafemic to aluminocafemic magmatic association, metaluminous to peraluminous

nature of the biotite granitoids and leucogranitoids may be considered to have been generated from mantle or from a hybrid source of mantle and crust with major contribution from mantle. Y/Nb ratio of the granitoids is in general > 1.2 which is a characteristic geochemical feature of magmas derived from sources chemically similar to island arc.

The mafic magmatic enclaves are enriched in Ba, Rb, Sr, K and P. They are also enriched in LREE and contain higher amount of HREE than do their host granitoids. These features coupled with the enrichment of Ba, Rb, Sr, K and P can be explained by metasomatic enrichment of mantle source by LILE, LREE and P_2O_5. It is suggested that basic magma produced by partial melting of mantle wedge which was enriched by subduction zone components was ripped off and carried by granitic magma. From field, pertrographical and geochemical characteristics, it is contented that the mafic magmatic enclaves do not represent restite phases.

The granitoid samples show affinity of volcanic arc tectonic setting on a number of tectonic discriminant diagrams. Multi-element spidergrams also point to similar tectonic environment. The Bundelkhand granitoids show selective enrichment of Th compared to Ta and follow the trend of subduction related source variation trend. The granitoids of the massif show a progressive change in composition from calc-alkaline in the southern region to alkali-calcic in the northern region. The change in composition is linked to increase in arc maturity. Other geochemical trends suggest that the Bundelkhand arc matures from south to north.

On the bases of field and geochemical features akin to volcanic arc graitoids, it is proposed that the granitoids of Bundelkhand massif represent an arc-related tectonic setting associated with subduction of an oceanic plate under a continental margin. The gravity high and the occurrence of mafic-ultramafic suites on the southern margin of the massif may indicate possible ophiolite (?) obduction or existence of an oceanic crust and consequent subduction of the oceanic crust in the southern portion of the massif. The apparent lack of typical ophiolite, blue schist facies metamorphic rocks and continental sedimentary rocks can alternatively be accounted for by invoking "A-subduction" in which subcontinental lithosphere sinks in an ensialic environment. The basic dyke swarms which have pervasively invaded the massif can also be linked to A-subduction.