1.1 THE BUNDELKHAND GRANITIC MASSIF

The Bundelkhand granitic massif lies more or less in the heart of India; the centre of the massif at Tikamgarh in Madhya Pradesh is located more or less equidistant from Dwarka and Imphal along an EW line and Leh and Kanyakumari along a NS line. The massif is named after the Bundela Kings, descendants of the Kushwaha dynasty in Central India.

The outcrop of the massif appears approximately oval but detailed examination suggests that the boundaries in at least three directions are tectonic in nature. Its southern margin is approximately aligned parallel to the Narmada-Son-Damodar graben axis and the western parallel to the axis of the Godavari Rift System. The northern boundary is of a mixed type, at places faulted and at others an unconformity with the rocks of the Gwalior Group overlaying the granites.
The entire massif covers an area of 26,000 square kms; approximately equally shared by U.P. and M.P. states. Presumably granitic rocks of the massif continue as Faizabad Ridge as revealed by the geophysical studies carried out by the O.N.G.C. (Sastry, et al. 1971, see also Valdiya, 1973).

The massif indeed is a low erosion level greenstone-belt with enclaves of ultramafic and metabasic rocks, B.I. and fuchsite quartzites and tuffaceous slates forming very tight EW trending synclinal 'Keels' that suture a series of episodically intruded and diapirically risen granitic mass; the latter very likely by the 'ballooning' mechanism as suggested by Ramsay (1989) for the Chindamora batholith in the Barberton belt of South Africa (Zimbabwe).

The faults within the massif and along the axial planes in the older enclaves (Mehroni Schist Formation of Pascoe, 1950) form a tectonic fabric that again testifies that its southern and western boundaries are tectonic and fault controlled. Indeed, the faults do bring granites of different ages and types into juxtaposition either along ENE-WSW trending lines or along lines striking NW-SE.

Roday (pers. comm. 1990) has recently shown that a fault extending from Babina to Berwar, is rotational in nature to the west of which, no enclaves of older rocks are encountered. This fault lies parallel to the western margin but well away from it and is a line of separation between an older coarse grained Jhansi granite and a
Younger leucocratic granite (aplogranite).

The complex consists of as many as ten varieties of granites as reported by Basu (1986) but if some minor differences can be ignored, the granites can be grouped into no more than five broad varieties. Late K-felspar veins abound as in most of the granite greenstone terrains. Quartz reefs form a principal tectonic fabric, trending approximately NNE-SSW to NE-SW together with basic dyke swarms, the dykes emplaced in the general NW-SE direction.

The rocks of the Bijawar Group which occur to the south of the massif were shown to be deposited in a faulted trough by Prakash et al. (1975) in the Lalitpur district of U.P.

1.2 Correlation with other granitic plutons in the surrounding areas

The B.G.C. of Rajasthan has often been correlated with Bundelkhand granites and the famous Aravalli syntaxis near Chittorgarh was related by Pascoe (1950) to the resistance offered by the passive block of Bundelkhand granites, thereby curving the Aravalli Range sympathetic to the boundaries of the massif. But there are numerous differences between the two. Some of these are enumerated below:

(1) The B.G.C. contain gneissic bodies in large number
which are absent in the Bundelkhand granites.

(ii) The B.G.C. appears to be older since it contains granites as old as 2900 ma. (Choudhary, et al., 1983) which is the radiometric age for Berach granite.

(iii) The enclaves of B.I.F. are rare in B.G.C. and therefore the whole of B.G.C. is not a typical granite-greenstone province with the exception of Jehajpur sequence (Sinha Roy, 1989).

(iv) The B.G.C. contain rocks of the granulite facies of metamorphism along the western flank (Desai and Petel, 1979) as well as eastern (Sandmata granulites SE of Goram see Sharma, 1988).

(v) The mean radiometric ages for B.G.C. are much older than those for Bundelkhand granites. Of course, the data for the latter is still far from sufficient to reach definitive conclusions.

(vi) The base metal mineralization in the B.G.C. is abundant (e.g. Rampur-Aguchha which is the richest Pb-Zn deposit in Asia) while such mineralization is sporadic and not workable in the Bundelkhand granites.

(vii) The principle differences between the B.G.C. and the Bundelkhand granites is that the former forms a basement of a very strongly shortened mobile belt in the crust, while the latter do not.

(viii) The swarms of basic dykes and quartz reefs are more or less absent in the B.G.C. By this is meant 'swarms'
in particular, and not isolated occurrences of basic dykes in B.G.C. These are almost ubiquitous and form an integral part of the tectonic framework of the Bundelkhand granitic massif.

1.3 MODE OF DEFORMATION WITHIN THE BUNDELKHAND GRANITES

The granites within the massif show development of ductile shear zones in contact with the Supracrustals (Ramsay, 1980; Cobbold, 1977 a, 1977 b). These are banded perturbations that propagate parallel to their lengths. The deformation is generally of plane strain type. Two very important shear zones are the Aksha Shear Zone which extends for a length of 18 kms. (from the village Aksha, 7 kms. west of Jhansi on the Jhansi-Shivpuri road eastwards) and the other Ghisauni Shear Zone which begins from southeast of Babina to Mauranipur, a distance nearly 80 kms. The widths of both the shear zones are identical (about 3 kms. on the average). Sometimes it is possible to correlate the strain within the ductile shear zones, with the strain in the cover rocks and the one determined from deformed conglomerates (Maheshwari, 1989; Roday et al., 1990). Ghisauni shear zone with sigmoidal cleavage contains rafts of fuchsite quartzites, metabasites and B.I.F., detached but arranged parallel to the fabric planes.

The shear zones of the brittle-ductile type often exhibit positive or negative dilation (sigmoidal veins making
angle of $< 45^\circ$ or $> 45^\circ$ with zone walls respectively, see Durney, 1979, 1980; Casey, 1980) but the values of negative dilation are generally small. Though the deformation is by plane strain, the negative dilation gives values of strain that fall in the field of apparent flattening (see Ramsay and Wood, 1973).

Faults abound in the massif, most common being the transcurrent faults and their hybrid varieties (Price, 1966, pp. 84–85). Next in order are the extensional and the high angle reverse faults, the rotational faults being the least common. Only one rotational fault was encountered in the mapped area; viz. the west Dalipur fault.

Phosphorite mineralization in the Bijawar Group Supracrustal sequence is generally limited to the basin margins and appears to be fault controlled. The phosphorite however, is non-stromatolitic unlike the Aravallian at Jhamarkotra in Rajasthan (Ca Early Proterozoic). The enclaves of older rocks are nearly absent in the area mapped by the author (see Fig. 2.5 in the pouch) as are the dipyrric granites. But K-felspar porphyritic granite with strong preferred orientation of long axes of K-felspar crystals are common. The K-felspar crystals have their C axes oriented parallel to the ENE-WSW trending shear zones and faults and axial planes of folds in B.I.F. enclaves in the surrounding areas.
1.4 **General Stratigraphic Set-up**

Pascoe (1950) divided the rocks of the region in the oldest Bundelkhand granite, the Mehroni Schist Formation (this is indeed older than granites), the Bijawar and the Vindhyan Series. Jhingran (1959), Saxena (1957, 1961), Mishra and Mathur (1952) and Prakash et al. (1975) suggested that the granites were formed as a result of potash metasomatism of the pre-existing country rocks. Chatterjee (1971) revised this by suggesting that the Mehroni Schist Formation was older than Bundelkhand granites and that the Bijawar Group rocks were the time equivalent of the Aravalli Supergroup. The youngest rocks in the area are those of the Vindhyan Supergroup, the residual laterite cappings and the alluvial deposits.

Prakash et al. (1975) gave a classification which is summarised in Table 1.1 and Table 1.2 gives a comparative account of classifications proposed by Pascoe (1950), Jhingran (1959), Saxena (1961) and Prakash et al. (1975).

Pyrophyllite mineralization is common in the area, generally associated with quartz reefs.

The hypothesis of the K-metasomatism is not now accepted by many workers and the granites are generally believed to be intrusive or diapiric. Granites passing into phyllonites and protomylonites near the contact with Supracrustals is a common feature. The Bijawar basin
### TABLE 1.1

CLASSIFICATION ACCORDING TO PRAKASH et al. 1975

<table>
<thead>
<tr>
<th>Formation</th>
<th>Member</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granite member</td>
<td></td>
<td>Jasperoid filling</td>
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<tr>
<td></td>
<td></td>
<td>shear zones</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dolerite dykes (with relics of graphic granite).</td>
</tr>
<tr>
<td>Measora</td>
<td>Gabbro member</td>
<td>Quartz veins, pegmatites and graphic granite</td>
</tr>
<tr>
<td>Formation</td>
<td></td>
<td>Coarse to medium grained gabbros, Pillow lavas</td>
</tr>
<tr>
<td></td>
<td>Ultramafic</td>
<td>Peridotites, pyroxenites, (partially altered to Talc-serpentine-schist).</td>
</tr>
<tr>
<td></td>
<td>member</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>UNCONFORMITY</strong></td>
</tr>
<tr>
<td>Berwar</td>
<td></td>
<td>Iron formations, carbonate rocks, grey green slates, quartzites and conglomerates.</td>
</tr>
<tr>
<td></td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td><strong>UNCONFORMITY</strong></td>
</tr>
<tr>
<td>Rajaula</td>
<td></td>
<td>Biotite felspar gneisses, chlorite biotite-schists</td>
</tr>
<tr>
<td>Formation</td>
<td></td>
<td>granodiorites, metabasalts.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>BASEMENT UNEXPOSED</strong></td>
</tr>
</tbody>
</table>
## Table 1.2

<table>
<thead>
<tr>
<th>Comparative Stratigraphy by Different Workers in the Bundelkhand Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic dykes</td>
</tr>
<tr>
<td>Quartz reefs</td>
</tr>
<tr>
<td>Granites (all types)</td>
</tr>
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<td></td>
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</tbody>
</table>

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--- UNCONFORMITY ---

Hornblende-bearing dolerite trap rocks = Dharwar ?

Relic metasediments | Metasedimentary rocks |
|--------------------|-----------------------|
| Iron formations, carbonates, fuchsite quartzites (Babina-Mauranipur) = Upper Dharwar ?
= Aravalli ? – – – – – – – – Unconformity – – – –

Amphibolites,
biotite Felspar
foliated gneiss,
granodiorite garnet
sillimanite
gneisses of Kabrai
= Lower and Middle –
Dharwar ?

Granite
complex with
Quartz reefs
and with inclusions of Mehroni schists (Pre-Aravalli
Formation) = Pre-Dharwar ?

boundary to the west is shown progressively to have shifted
eastwards in the present area from south to north.

The Kuraicha Formation of Mishra and Sharma (1974)
is correlatable with the older enclaves of Berwar Formation
and Rajaula Formation of Prakash et al. (1975) as is the
sequence near Mauranipur.

1.5 THE BIJAWAR GROUP

The rocks of the Bijawar Group (Medlicott, 1859)
are sub-metamorphic in character and contain volcanics
with pillow structures and these are quench basalts with spinifex texture. The Dargawan 'traps' in the area under study are sills of mafic composition which have digested in part the strata they intruded.

The rocks of the Bijawar Group form a narrow belt flanking on both sides of the Vindhyan basin but the continuity of the belt is broken in places. The belt extends from east of Barwaha township in west Nimar (Khargon) district of M.P. and extends upto Sidhi in the east, a distance of nearly 700 kms. The deformation imprints gradually increase from west to east in the belt. Because of the ideal and nearly complete stratigraphic sequence near the town of Bijawar in Chhatarpur district of M.P., these rocks were originally named as 'Bijawar Series' (now Bijawar Group according to modern stratigraphic nomenclature). These rocks also have their homotaxial equivalents in the Son valley flanking the southern side of the Vindhyan Supergroup rocks. The southern exposures are found from Barmhan (north of Narsimhapur) eastwards upto Sidhi. At the southern margin, they show more intense deformation. They were originally called 'Transitional' rocks between the crystalline basement and Vindhyan Supergroup rocks which overlie them (Oldham et al., 1901). This term was later replaced by the term 'Bijawar Group' rocks. Auden (1933) who also mapped the Vindhyan rocks of the Son valley classified these as a volcanosedimentary
sequence related to the principal 'Bijawar Series'. Gupta (1982) assigned to this belt a status of a narrow greenstone belt. But his studies are not substantiated by any geochemical data, nor the large scale inversion, a common feature of greenstone belts is found in these rocks. The high grade metamorphic rocks near Sidhi (Joy and Bandopadhyay, 1988) on the southern flank of the so called Bijawar basin have been thought to belong to Bijawar Group rocks as are the famous marble rocks at Bhedaghat and pelitic schists near Lemetaghat near Jabalpur. However, high grade metamorphic assemblage such as presence of cordierite and andalusite schists, rocks of B.I.F. affinity etc. suggests that these rocks might be older than the Bijawar Group rocks. The ferruginous facies does dominate the Bijawar basin but typical cyclicity of sedimentation characteristic of the B.I.F. is missing. Thus it is reasonable to believe that the older B.I.F. constituted the chief provenance for the ferruginous facies found in Bijawar Group rocks.

The rocks of Bijawar Group of the Mirzapur area were studied by Swaroop and Saxena (1969) while those of the area under investigation by Rajaraman (1978).

The Bijawar Group rocks have been classified into two Formations, a lower consisting essentially of a calcareous facies of dolomites, limestones and cherts together with calcareous shales at the base generally
called the Bajna Formation and an upper Gangau Formation, consisting of ferruginous quartzites, shales, chaotic breccia, slates etc. At places, there appears to be a structural break between the Bajna and Gangau Formation (Mathur, 1954) but the unconformity between the two is not well-marked in some places due to lack of proper exposure. Penecontemporaneous slump structures abound in these rocks. Highly disharmonic folds, overturned folds etc. abound in rocks. Some of the sedimentary slump structures appear to be associated with tectonicity as deciphered from the criteria outlined by Elliott and Williams (1988) discussed in Chapter III.

1.6 MINERALIZATION

The most important mineralization in the area under investigation is that of phosphorite in the Basai shear zone/wrench fault which has been shown to be transtensional at places (present work). Another important belt occurs from Jhalsutar to Jugnu Pahar area.

The second in importance are the diaspore-pyrophyllite deposits associated with quartz reefs in Bundelkhand granites east of Dalipur and Bannaura villages. Sporadic base metal mineralization of chalcocpyrite and bornite is found in the chaotic breccia mass.
1.7 PRESENT WORK

A small area north of Hirapur was taken up for detailed study (Fig. 1.1 see inset) which includes the Bundelkhand granites and the Bijawar Group rocks. The distribution of the rock types is shown on the Geological map (Fig. 2.5 in pouch). The principal conclusion that emerges out of this work is that a large number of faults abound in the area and these faults have played a vital role in the configuration of the Bijawar basin. It has been shown that the Bijawar basin is successively shifted eastwards from south to north along ENE-WSW trending dextral faults. Rotational and hinge faults have been reported for the first time from the region. The faults have been analysed for the orientation of principal compressive stresses that generated them and the chronology of movements along most of the faults has been established.

The ductile shear zones have been studied in detail both by large scale mapping of small outcrops and an attempt has been made to establish a relationship between the basement and cover deformations. The minor folds have been geometrically analysed by thickness dip relations of folded layers and by Fourier analysis.

The sediment slump structures have been studied in detail and a model for their formation is suggested. Ductile
shear zones in granites of Tigoda have been mapped on large scale. The positive dilational shear zones near Kaikali in dolomite, which are related to the earliest of the shear movements are also analysed in detail. It has been shown that phosphorite mineralization is typically found in 'horses' (uplifted masses) along sinistral wrench faults as a result of complex transpressional-transtensional phenomena. Narrow widths of these wrench zones is attributed to transtension preponderant over transpression (see e.g. Naylor et al. 1986).

Since the finite strain determination work has been carried out in the region only at a couple of places, schematic ellipses (late and early) are drawn on the structural map based on data on shear zones, the type of dilation, attitude of fold hinges and on the basis of maximum displacement vector in shear zones.