CHAPTER VII

SUMMARY & SYNTHESIS
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Most of the granitoids of the Bundelkhand massif neither belong to the I nor to S type but presumably seem to belong to an anorogenic setting and could be classed as A type granites. The evidence of the presence of I type granites at deeper levels within the crust is found in the xenoliths of the early synkinematic diapiric components which presumably form typical mantled gneiss domes. However, it does not seem that the grade of metamorphism was very high during the deformation of the supracrustal sequence and the granites were seemingly being emplaced in a relatively lower P-T regime, typical of weak metamorphism such as is found at shallow crustal depths. The composition of exposed granitoids together with those of the xenoliths ranges from quartz-diorite to alkali granites but a vast majority of rocks constituting nearly 90 per cent of intrusives are high or moderate K granites or adamellitic granites and the principal differences between them are the texture and grain size rather than composition since they are on the acidic side of the adamellitic divide. The supracrustal sequence is typically a low grade greenschist to epidote-amphibolite facies sequence and characteristic of many Archaean greenstone belt sequences, shorn of the bimodal volcanism.

The principal fabric of quartz reefs/veins has been produced by the brittle-ductile inhomogeneous sinistral simple shear under a gradually rotating stress field or possibly three separately oriented stress fields but more
likely the former.

The ductile shear zones within the massif belong principally to an initial NE-SW directed $\alpha$ but the later one related to WNW-ESE directed $\alpha$ are also common. The least common of the shear zones are those related to the NS directed maximum principal compression. The shearing or noncoaxial deformation postdates the emplacement of most of the exposed granitoids and the previous deformation which folded the supracrustal sequence on the EW axes can only be noticed at but few places and the accompanying plutons of synkinematic types are not encountered. The late veined gneisses are found at some places in the massif, generally in contact with the supracrustals in the Ghisauli-Mauranipur area and in the parts where the granites are overlain by the younger Bijawar Group rocks (e.g. near Hirapur at the southern extremity of the massif).

In migmatites, in proximity of the supracrustal sequence, the sense of shearing can be known from several kinematic indicators such as foliation fish, asymmetrical augens, the C and S surface relationship and the sense of rotation of feldspar megacrysts and the sense of asymmetry of the pressure shadows at the tips of megacrysts. In the other areas, the shear sense can be known from the minor shear zones, tear drop shape sense of xenoliths and the sense of rotation of some of the circular xenoliths or from the faulting response of the rigid particles in an otherwise well foliated and schistose rock.
The positive dilational brittle-ductile shear zones are common in the massif and suggest that the expansion or ballooning force was particularly common during the emplacement of granitic bodies.

One of the conspicuous features of the massif is the presence of an EW trending major fault, approximately in the central part of the massif, with the northern block having moved up relative to the southern. Thus the geological setup of the two blocks is different as also the two major concentric rings which form the dominant map pattern in Fig. 2.1. While the younger stocks and bosses of very coarse grained latest of the intrusive phases is common in the northern half, their paucity is very conspicuous in the southern. The quartz reefs are generally restricted to the inner more acidic core. The basic dykes, more common in the outer ring, are generally found restricted to the southern fault block than to the one to the north. The fault has brought up the rocks belonging to the supracrustal sequence in the northern block whose exposures in the southern fault block are not common barring the southernmost part near Girar and Baraitha.

The ductile shearing is generally restricted to the contact with the supracrustal rocks and at the boundary with the Bijawar Group rocks which lie unconformably over the granites or directly rest partly or wholly on the rocks of the supracrustal sequence. Thus the granites and the supracrustals both form a floor for the Bijawar Group rocks.
The supracrustal sequence is folded synkinematically with the emplacement of granitic bodies into F1 and F1' coaxial folds under a NS directed principal compression. The overturning direction of the major folds is opposed on the two sides of what might be termed a "mega-diapir" with the axial surfaces inclined steeply to the north at the southern margin of the massif or steep southerly in the northern belt of supracrustals passing through Ghisauli, Papaoni, Gora and Mauranipur.

In general, the finite strain is related to the two episodes of deformation, one related to the expansion or ballooning force of what have been termed by the author as "blind" diapirs together with possible interference of NS compression related tectonic deformation. The second deformative phase is presumably related to the emplacement of anorogenic postkinematic granites, generally by HSS under NE directed α though the complex stress history has given rise to interference between structures of various generations.

It has been concluded that the xenoliths show effects of both these deformations. During the balloon skin stretching, they were deformed into uniaxially oblate shapes or nearly so, but the k value increased as a result of second noncoaxial deformation whose λ1 was horizontal in contrast to the previous expansion related deformation. That the pre-HSS shapes of xenoliths were of shape with k=0 is supported by the strain analysis of xenoliths and computation of their initial axial ratios using classic mathematical relationships.
derived by Elliott (1970), Dunnet (1969) and Lisle (1979b; see also Lisle 1985).

Based on the relationship between xenolith shapes and the position of the crystals and crystal-fluid interface, the initial diameter of any layer of a given composition in a diapir showing compositional concentricity can be known as shown by Ramsay and using this, it was found in case of the ring-like body of tonalite and plagiogranite (to monzodiorite) that its initial ratio of diameters of slightly elliptical outline was 1.33 but this increased to nearly 1.5 as a result of later noncoaxial deformation. While the original aspect ratio was 16:12 (in terms of km.), its present aspect ratio is 25:17.

As the faults affecting the massif are abundant and related to different stress fields, the fault sets in any given sector form a heterogeneous set. It has been shown that the faults are all strike slip in nature with generally a reverse component of slip along them as adduced by the examination of slickensided fibres. Further, they appear to be related to three distinctly separated stress fields or could be related to a gradual change in the orientation of the maximum principal compressive stress. The initial stress field was due to a NE-SW \( \alpha \), followed by a NS trending one and finally a WNW-ESE trending one which has caused a reversal of sense along many pre-existing faults. Hence faults having identical trends but opposed sense of slip are often met with in the field. The palaeostress analysis was carried
out by contouring of $\alpha$ based on PTOTAL. Also, the values of total, normal and shear stresses and total angular shear strain were computed using an orthonet and separation into homogeneous subsets in a given sector was carried out by using the premise that $\tau$ would exceed $\sigma_n$ in case of faults for which a given $\alpha$ orientation holds good. The stress ratios were computed following Lisle and Fry and Simon-Gomez and maps of the massif were prepared to show the variation of $\alpha$ of a given stress field, that of $\sigma_1$, $\sigma_2$, $\sigma_3$, $\tau$, $R$ and $F$ and the results were compared with that of the finite strain analysis. In any given domain, there is a good deal of correspondence between orientations of $\alpha_1$, $\alpha_2$ and $\alpha_3$ and the principal strains $\lambda_1$, $\lambda_2$ and $\lambda_3$.

Finally, computer simulation of diapirism was carried out and the mapping of strain values in terms of the mean strain magnitude and mean ellipsoid shape under different set of variables was conducted. The simulations were to find out the extent of interference of ballooning strains and tectonic strains. The simulations were carried out under various combinations of simple shear, pure shear and ballooning. The results show that the high strain zones are superimposed on the low strain zones with progressive ballooning. The oblate rings grow in size with increase in the expansion parameter. The prolate rings gradually dwindle with increased ballooning except when the tectonic strains constrain the expansion. Two sets of subperpendicular foliations but no subvertical lineations suggests that these anorogenic or A type granites
have presumably been emplaced in a transcurrent type motions
possibly along pop outs of weak transpression; this seems to
be substantiated by the reverse component of slip along most
of the faults. Some of the shapes of bosses and stocks match
with the shapes obtained during the simulation study and
lends support to the fact that the initial ballooning has
been elliptical rather than circular in horizontal planes. It
is not intended to point out here the major conclusions drawn
by the author during the course of his doctoral work since
these have already been enumerated at different places in the
body of the thesis. Mention of these would simply be an
exercise of futile repetition. Needless to say, the author
has carried out work on entirely different lines and come up
with the results hitherto not reached by any worker engaged
in research in this country of granitoids in this part of the
Indian peninsula.