Chapter IX

Summary and Synthesis

quod erat demonstrandum
SUMMARY AND SYNTHESIS

It must be admitted at the outset that this thesis embodies observations that are essentially field based and on the basis of the orientation and strain data collected in the field and it is supported by just the microscopic studies and some computer simulation work. It is a pity that this work is indeed shorn of the geochemical data that speaks volumes on the genetic aspects of granites, more particularly with regard to the source rock and whether the granites were derived from crustal or mantle material. It is also shown of the isotopic dates save the one by Choudhary et al. (1983) with seems outdated in the context of the state of the art of geochronological studies as more sophisticated dates such as the SHRIMP are becoming more fashionable and acceptable by the geological community.
From whatever data that the author has tried to present, it seems doubtless that the granite pluton of Untala (name obsolete since the original village of Untala is now renamed as Vallabhnagar which is also a rail station on western rail metre gauge) can be classed as compositionally expanded Cu-Mo bearing one mica granite of I-type of Chappel and White (1974). As discussed in the chapter on the kinematics of emplacement, it is apparent that the crystals outweighed the mush in the crystal mush aggregate during the last phase of intrusions by ballooning as the porphyritic varieties that are so common in most granites are absent in the Untala pluton.

Without doubt, the Untala pluton must be the oldest pluton in the Aravalli range but its age of 2.95 Ga by Choudhary et al. (1983) is still open to question. Heron (1953) was not without good eyes and sound observational capacity to have classed this as equivalent to Erinpura granite. The acidic core of this rock does resemble in the field the Erinpura granite. It is plausible to believe that the diapirism may have been episodic starting from the pre-tectonic phase to the post-tectonic outlasting even the Delhi orogeny. Besides, we have no knowledge what parts of the granitic complex were sampled by Choudhary et al. (1983) and it is indeed very honest and modest on the part of Choudhary et al. (1983) when they themselves mention that the parts of this complex may actually be post-Aravalli and some even post-Delhi. Although a landmark work
on dating, it is greatness of Choudhary et al. (1983) when they admit that their
ages should by no means be taken to be foolproof.

The author has tried in this work to show that the Untala pluton is pre-
Aravalli in age and its outer rim was remobilised at the onset of Aravalli
orogeny. However, there is a great deal of controversy, as to whether the
rocks into which the pluton appears to have emplaced are migmatised Aravallis
as believed by Naha et al. (1966), Naha and Halyburton (1974) or they are pre-
Aravalli rocks of Archaean age as advocated by Roy (1988). The rocks are
mainly leptyno-amphibolites with metamorphism of almandine-amphibolite
facies and such rocks are strikingly in contrast with low grade Aravalli
metamorphites. However, some of the rocks in this region have semblance to
those of Delhi Supergroup but calcareous rocks are less in abundance. The
author believes that the rocks of higher grade are locally produced due to high
temperatures generated during the anatexis and may be migmatised equivalent
of the Aravalli rocks. If this view is favoured, the outer rings of the pluton
were perhaps mobilised during the Aravalli orogeny. Another fact that lends
support to the pre-tectonic (in part also syntectonic) nature of granitic pluton is
its shape which has tapering ends that suggest that it underwent clockwise
rotation of at least 25° during the orogenic movement. The three-dimensional
shape of the diapir appears to be like that of a “tadpole” and not a mushroom
really, and the diapir could be classed as rather an immature diapir.
Because of the overprinting of tectonic deformation, the component of original ballooning or expansion related strains cannot be easily separated. It appears that these strains were generally low and generally oblate except for the regions where the pluton tapers in plan and where initial ballooning related cleavage trajectories envelop to enclosed a triple point. At this place the strains are constrictional. Typical ballooning related strains could be determined only at the outer periphery where xenolith shapes in two orthogonal sections could be measured. Further away, the xenoliths are very highly deformed by tectonic deformation, intensely drawn into ribbons in plan and in other sections normal to fabric and also folded which place considerable constraint on strain determination work. Apart from this, the ductile shear zones which could be used to determine the finite strain related exclusively to ballooning are rare in the area.

The concentricity of the tonalitic and leucogranitic to granodioritic rings around the more acidic and K-felspar rich granitic core is quite conspicuous and indeed the pluton does show in this regard the compositional expansion. The more amenable mafic outer rings have been involved in intense later deformation.

The asymmetrical pull apart structures formed as a result of foliation parallel dextral shear are the commonest feature around the pluton and the
kinematic indicators help to work out the shear strain values in some cases, particularly where sigmoidality of cleavage is observed or angle between shear and schistosity planes is known and finally from the displaced markers. The general conclusion is that the shear strain values are high near the tapering ends of the pluton where foliation departs weakly or strongly from its original otherwise consistent trend of N340° to N350°.

It may be pointed out here that the earlier work carried out by Roday et al. (1995) and Roday and Singh (1998) suggests that the Bundelkhand granite massif is much sheared sinistrally along nearly EW subvertical planes. In contrast, in case of this pluton which lies to the west of Bundelkhand batholith and Bearch granite shows more of dextral shearing along NS to NNE-SSW trends and the EW sinistral shears are generally represented by sinistral strike slip faults which appear to be genetically related to the D3 deformation. The palaeostress analysis of these faults suggests that the orientation σ1 has varied in time and space from initial ENE trending subhorizontal one to later NNE trending gently plunging one, a history that tallies well with granite emplacement history in Bundelkhand. The similarity is noteworthy but may be simply fortuitous. The asymmetrical pull part structures have been studied at great length and in details by the author as these abound in some parts of the region that are easily accessible and also better exposed. The ballooning
related strain studies were carried out only from deformed xenoliths and no
other material as it was not considered reliable enough to give meaningful results.

As far as deformation events are concerned, these have been three in
number namely $D_1$, $D_2$ and $D_3$. The aspects of these in detail together with the
fold structures and interference patterns are described in the relevant chapter on
geological and structural setup. The boudinage is common as is the rotation of
individual boudins under the effect of shear. The chapters in this thesis are
made more illustrative by means of field photographs rather than too many
interpretations and meaningless discussion and the author has tried to keep the
presentation brief and exactly to the point. He has, however, not tried to
solve the controversies and has also failed to attempt to analyse the complete
structural scenario but this is owing to lack of exposures as would any
structural geologists who has visited this area tell you.

There is another aspect to the Untala pluton and that lies in its being
intruded by a younger carbonatite plug that is perhaps best exposed between
Newania and Kikawas villages and also north of Vallabhanagar and east of
Fatehnagar near Anjanikhera, as shown on the geological map. The fenitised
carbonatite has tectonically produced gneissic banding as in case of impure
marbles. This also shows folding on the ESE axis as do the steeply plunging
reclined folds in the supracrustal rocks around the pluton.
The overall shape in three dimensions, from the available data suggests this to be that of the circular to elliptical conical one with “ladpole” like general shape and both sides of the cone dipping at variable angles to the east.

The tectonic cleavage trajectories envelop around the pluton and also traverse across it domainally as shown in fig. 4.31 by the author and therefore the acid granitic core actually occupies the core of the antiform on major scale.

Because of the development of plagioclase and garnet porphyroblasts, it was attempted to relate from the Si-Se relationships the metamorphic episods in relation to deformational events. The peak of the first metamorphism was reached during $D_2$ deformation and that of $M_2$ during the $D_3$ phase of deformation.

There are generally two generations of lineations developed in the supracrustal rocks, the early folds are reclined, very steeply plunging and these lineations are in the form of mineral lineations, striping or intersection morphologic lineations. The second generation folds have also a strong vergence and therefore the early lineations through folded by later folds hardly show complete reversal of direction of plunge owing to overturning of the limbs of the $D_2$ related folds.

Computer simulation to produce snowball garnets was carried out using CorelDRAW Versions 7.0, as also that of diapirism by using the program
DIAPIR. The path of trajectories of cleavage outside the pluton and inside it was also simulated using the software CorelDRAW version 7.0.

Regarding the kinematic emplacement of the pluton, all aspects are reviewed in the preceding chapter. The facts that must be considered for advocating any kinematics must consider the following points:

(a) Shape of pluton in plan,

(b) Three-dimensional shape of pluton as deciphered from the structural data,

(c) Variation of finite strains around pluton,

(d) Cleavage trajectories and lineations orientations,

(e) Kinematic indicators,

(f) Concentricity of compositional variation of the members of calc-alkaline magma series etc. These were all taken into consideration while building up a model that suggests diapiric emplacement followed by tectonic deformation that involved transcurrent shear.

The principal conclusions that could be drawn from the work embodied in this thesis can be summarised as follows:

(i) The Untala pluton is a typical pre-tectonic diapiric body and is most possibly in part of Pre-Aravalli origin.

(ii) That the granites are of I-type compositionally expanded members of a calc-alkaline series which reflects on their mantle source as well as antiquity as supported by radiometric dates.
(iii) That the pluton shows typical concentric arrangement of individual members of the calc-alkaline magma series becoming progressively acidic towards the core and mafic or basic outwards.

(iv) The ballooning related finite strains are difficult to be separated except at the outermost part of the innermost acidic ring, as determined from shapes of deformed xenoliths in orthogonal sections. The strains are oblate on the flat sides of pluton and slightly prolate at the tapering points where ballooning related foliation trajectories enclose triple points of plane to constrictional strain. Elsewhere the strans are superimposed by tectonic deformation.

(v) The body has an oval shape and tapering ends which suggest that it behaved as a partly rigid and partly deformable body and was rotated as well as distorted by a clockwise shear that is more pronounced where the angle between $\sigma_1$ and foliation departs from perpendicularity at the tapering ends of pluton.

(vi) The pluton has an overall three-dimensional shape of a circular to elliptical conical one with "tadpole" like geometry with both flat sides dipping steeply to the east.

(vii) The tectonic gneissic foliation traverses across the pluton in the form of sigmoidal trajectories and the pluton appears to have given rise to
synformal structures with strong vergence on both sides and it occurs in the core of a conical antiformal structure.

(viii) The metamorphism $M_1$ was strong and was at its highest when $D_2$ deformation was built up as suggested by petrographic studies and Si-Se relations in porphyroblastic minerals, particularly rotated garnets. The metamorphism $M_2$ was a thermal high presumably related to $D_3$ deformation but temperature gradually declined which produced brittle deformation and development of faults towards the end of the orogenic cycle.

(ix) Computer simulation studies were attempted using software packages to simulate pluton shape and strains and its structures and for snowball garnets. The computer programs for heterogeneous simple shear and ballooning together with an option of simple shear and pure shear and also circular or elliptical ballooning was carried out together with a program to compute $\sigma_1$ orientations and paleostress analysis as the orientation of the maximum principal compressive stress has varied through time and has given rise to the reversal of movements along some of the oblique slip and strike slip faults.

Also developed during the course of research in collaboration with the research Supervisor, a 1GB software to be run under windows 95 along with
the WEB pages titled “A TO Z OF STRUCTURAL GEOLOGY AND TECTONICS : A THESAURUS ON CD ROM DEDICATED TO THE MEMORY OF LATE PROF. K. NAHA”. The software will be tremendous use to teachers, research students and research scholars in the various geological institutions in India as a first hand READY RECKONER in the field of structural geology.