CHAPTER 8

SUMMARY

The structural geology of the Pre-Cambrian rocks of Lunavada region had remained a mystery for several decades and the present study has for, the first time, provided considerable data and information which enables a better understanding of the tectonics of Southern Aravalli Mountain Belt (SAMB). Some of the important findings of the present study are listed below.

8.1. SALIENT FINDINGS OF THE STUDY

1. The region underwent three episodes of deformation-D_1, D_2 and D_3 with the first two episodes resulting in NE-SW trending tight coaxial isoclinal folds while the third event gave to open WNW-ESE trending folds.
2. The superposition of the three fold events gave rise to varied regional scale interference patterns in different parts of the study area. The superposition of the coaxial F_1 and F_2 folds gave rise to regional Type-III interference pattern in the southern parts of the study area. Type-I interference developed due to superposition of WNW-ESE trending F_3 folds on NE-SW trending F_1-F_2 folds mainly in the central and southern parts of the study area. F_3 folds developed on limbs of F_2-F_2 folds.
3. Degree of overturning of the D_1-D_2 folds increases from N to S.
4. AMS data adequately fits with the field structural data, thus indicating a close relationship between the magnetic ellipsoid and the structure of the area. In a

few samples, the magnetic foliation does not coincide with the field planar data. In such samples the AMS provides evidence of deformation events which could not be recorded on the mesoscopic scale. Using this technique, D_3 folds could be recognized in a few samples where this deformation did not leave a recordable mesoscopic imprint. Similarly, it has been possible to recognize D_2 folds in other parts of the area.

5. Regional metamorphism progressed upto lower amphibolite facies with the formation of garnet in some of the schists. Regional metamorphism associated with the D_1 and D_2 deformation was progressive upto major part of the D_2 event. Chlorite and biotite formed during D_1 and these progressed further to form garnet and new biotite porphyroblasts during D_2 deformation. The progressive regional metamorphic events related to D_1 and major part of D_2 deformations have been termed as M_1 and M_{2-1} metamorphisms respectively. Some retrogressive metamorphism (M_{2-2}) occurred during the waning phases of D_2 deformation during which garnet and biotite retrograded to chlorite at their rims and along fractures.
6. Grade of metamorphism of the metapelites tends to show an increase from N to S implying that the southern parts of the study area represent deeper crustal levels brought up syntectonically or subsequent to the peak metamorphism (also see 8 and 9 below).
7. Garnets in the garnet biotite schists show growth zoning. A few garnets also observed to have undergone diffusion zoning at the rims. This occurred on account of retrogressive metamorphism during the cooling history of the rocks subsequent to achievement of peak metamorphic conditions.

8. On the basis of thermobarometric calculations it has been concluded that there was release of pressure with slight change of temperatures during the growth of garnet from core to rim. This implies uplift during garnet growth (syn-D_2 uplift).
9. Study of fluid inclusions has led to the conclusion that the high density CO_2 rich inclusions were entrapped at garnet rim P-T conditions. The lower density CO_2 inclusions were entrapped at lower pressures. This supports the conclusions drawn from thermobarometry that the rocks were uplifted subsequent to peak metamorphism.
10. The regional metamorphism was followed by a thermal event related to the intrusion of the Godhra Granite which led to extensive annealing of minerals in rocks close to the granite contact. This fact has been adequately established on the basis of CSD study of quartz crystals in schists and quartzites of the study area. The CSD study showed that the quartz crystals in quartzites as well as schists lying close to the margin of Godhra Granite are (i) coarse, (ii) have a sharp extinction, straight grain boundaries and 120° triple points, (iii) have less number of total crystals in unit area, (iv) have a large mean crystal size and (v) show bell shaped CSD plot. All these imply extensive annealing and grain growth due to heat supplied by the Godhra Granite. Conversely the quartzites and schists lying at a greater distance from the granite are (a) fine, (b) have undulose extinction and serrated grain boundaries, (c) have large number of total crystals in unit area, (d) have a low mean crystal size and (e) show near linear CSD plots. These features point to absence of any significant annealing and grain growth in samples away from the granite margin.

11. Emplacement of Godhra Granite not only affected the texture of the rocks but also brought along with it fluids which were entrapped as inclusions. Microthermometry has revealed that some of the aqueous fluid inclusions have salinities of NaCl (Type-2 inclusions, Chapter 7). The NaCl rich fluid was probably derived from hydrothermal solutions related to Godhra Granite intrusion.

An integration of the above results has enabled the author to throw light on the mechanisms of deformation which were operative on different scales during the structural evolution of the Lunavada Pre-Cambrian rocks. This aspect has been summarized in the following section.

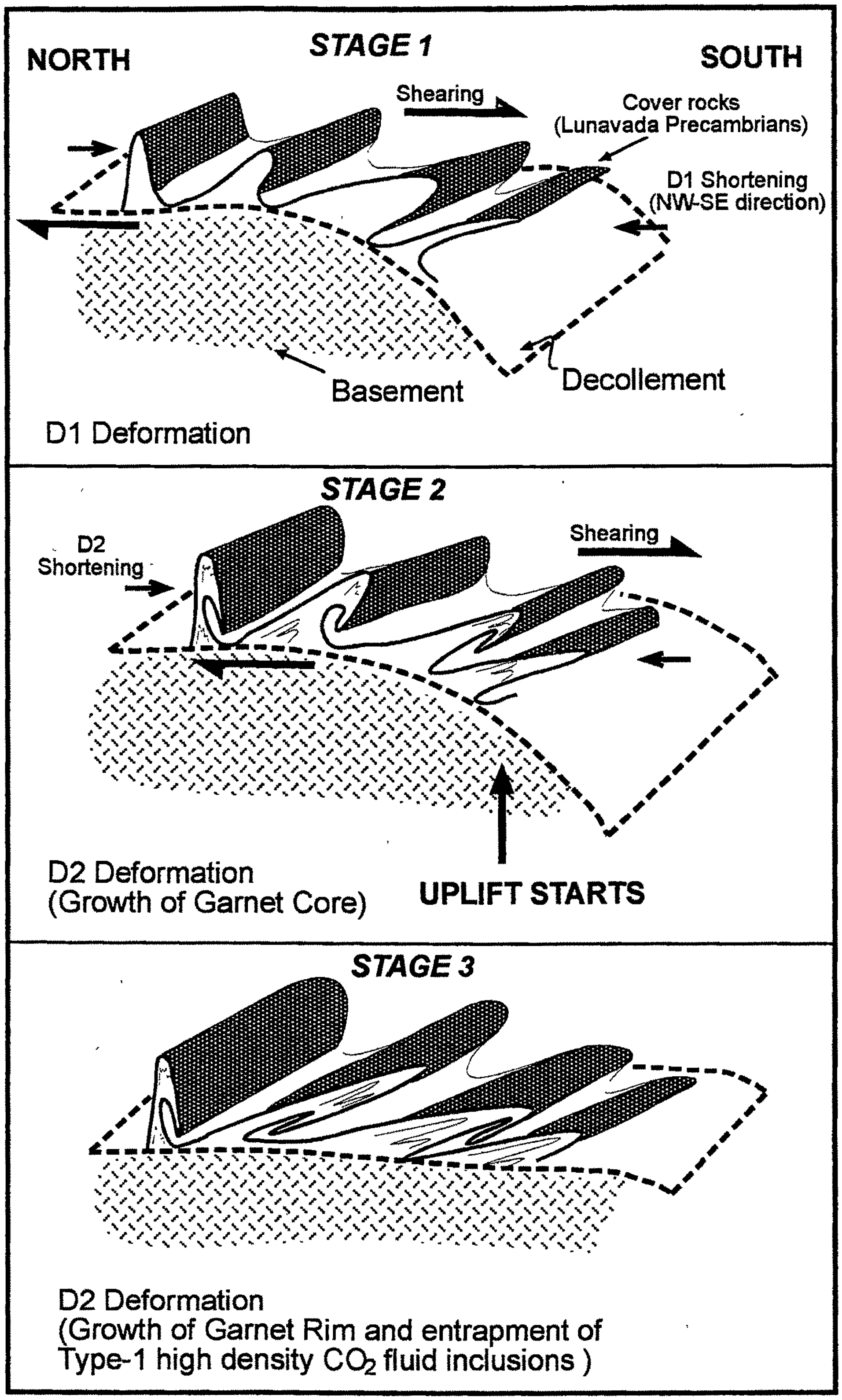

Fig. 8.1. Schematic model explaining the uplift mechanism during D2 deformation in the Lunavada region.

8.2. DEFORMATIONAL MECHANISMS

Varied deformational mechanisms were operative during the structural evolution of the Lunavada Pre-Cambrian rocks. The author has analyzed the different mechanisms which were active at the regional as well as microscale.

a. On the regional scale the rocks initially underwent ductile deformation which resulted in folding of the rocks. The details have been documented in Chapter 4 that the schists show presence of a mineral lineation trending NW-SE on foliation (S1-S2) of F_1-F_2 folds. Since the trend of these folds is NE-SW, it is logically concluded that they developed due to NW-SE shortening and the NW-SE trending mineral lineation developed as a stretching lineation during these fold events. Moreover, the degree of overturning of the F_1-F_2 folds is observed to increase from N to S in the study area. In light of these evidences it is postulated that the F_1-F_2 folds must have developed in a tectonic environment with NW-SE shortening direction along with a simple shear component. In other words, there was a simple as well as pure shear component active during the D_1-D_2 deformation events.
b. That the region underwent uplift has been well documented from geothermobarometric calculations of microprobe data and fluid inclusion studies (Chapter 7). Combining this fact with the evidences discussed above the author has attempted to construct a model to explain the regional folding and uplift mechanism during the D_2 deformation event (Fig. 8.1). Accordingly it is postulated that the quartzites and schists constituting the Lunavada region form part of the cover rocks lying directly on a basement. Although the

basement rocks are not exposed within the limits of the area investigated, their presence has been documented in areas to the S of the present study area by Gupta and Mukherjee (1938). Since the degree of overturning of the first two folds increases from N to S and there is presence of a stretching mineral lineation in the direction of D_1-D_2 shortening, it is envisaged that there was a décollement between the unexposed basement and the cover rocks; the folding and shearing of the cover rocks occurred on account of movement along this décollement. Major part of these two deformations synchronized with progressive regional metamorphism (M_1 and M_{2-1}, Chapter 6). During D_2 deformation garnet and biotite porphyroblasts developed and this growth was accompanied with uplift (decompression); this fact is brought out from geothermobarometry (Chapter 7). It is clear from Fig. 6.1 that the grade of metamorphism shows an increase from N to S in the study area and this fact would imply that the southern parts of the Lunavada region represent a deeper crust. This fact is supported by the uplift mechanism interpreted on the basis of geothermobarometric studies. Moreover, fluid inclusion studies have revealed that the high density CO_2 rich inclusions were entrapped at the rim P-T conditions of garnet porphyroblast whereas the lower density CO_2 inclusions were entrapped at lower pressures (Chapter 7). This is indicative of the fact that the high density CO_2 inclusions underwent entrapment when the rocks had already uplifted and decompressed to rim P-T conditions. On the other hand the lower density CO_2 inclusions got entrapped when the rocks were further uplifted towards the surface of the earth subsequent to rim conditions.

c. The D_3 deformation gave rise to NW-SE to WNW-ESE trending folds which indicates NE-SW to NNE-SSW direction for D_3 shortening. The D_1-D_2 deformations resulted in NE-SW trending axial planes and fractures. These lie at a oblique angle to shortening direction of D_3 deformation which would favour shearing, a fact which is well documented in Fig. 5.5. According to the present author this is the reason for the tectonized and sheared region lying to the N of Lunavada (Fig. 3.1). It is important to mention that the northern part of the study area comprises chlorite schists while the southern parts of the study area (i.e. S of Lunavada-Santrampur tract) comprise garnet biotite schists. This suggests that while the latter represents deeper and hotter part of the crust, the former forms upper and colder parts. This indicates that the region to the S of Lunavada has had a greater tendency to deform in a more ductile manner as compared to the northern parts of the study area. As a result, the NW-SE D_3 shortening gave rise to development of open F_3 folds in the southern and central parts of the study area which comprise mica schists while the same shortening caused a relatively less ductile (or brittle-ductile) deformation of the northern parts of the study area made up of chlorite grade schists. This caused some dislocation and movement along existing NE-SW trending weak planes and development of the highly tectonized zone in the north.

d. Different deformation mechanisms have been interpreted on the microscale on the basis of microstructural studies. The rocks underwent dynamic recrystallization during a major part of their deformational history. A comparative account of different quartzite occurrences lying close and far from the granite (Chapter 6), indicates that these rocks underwent dynamic recrystallization by a mechanism such as Grain Boundary Mechanism (GBM) to initially give rise to serrated grain boundaries. This mechanism was active during the deformation of the rocks. Later on, the quartz crystals appear to have undergone static recrystallization by Grain Boundary Area Reduction (GBAR) to give rise to straight grain boundaries and 120° triple points. GBAR was an active mechanism subsequent to the deformation of the rocks and is correlated to the heat supplied by the intrusion of Godhra Granite.

e. Varied mechanisms are recognized to have been active on the microscale during the six stages of crenulation cleavage development (Chapter 6). On the basis of microstructural criteria it has been concluded that pressure solution which results in migration of quartz from limbs of microfolds to hinges, was an active mechanism during the first three stages of crenulation cleavage development. Most of the quartz migrated from the limbs to hinges of microfolds by the end of stage 3. Continued deformation resulted in shearing along limbs of the microfolds. During these later stages of crenulation, crystal plastic deformation and intracrystalline deformation became the dominant mechanisms. These mechanisms gave rise to undulose extinction in mica crystals.

Although the present study pertains to a relatively small area of the southern Aravallis, yet it has thrown new light on the structural and metamorphic evolution of the region and furnished a wealth of data hitherto not available. The conclusions arrived at by the present author are of considerable significance, and provide vital clues towards a proper and correct understanding of the structure and metamorphism of the southern Aravalli region. A number of questions still remain unanswered and obviously the conclusions of the present study need further elaboration and evaluation. But, the relevance of the present investigation around Lunavada lies in the fact that the beginning made by the present author has to be followed up by extending identical investigations in the surrounding areas also. Such studies are essential if the complexities of the Southern Aravalli Mountain Belt have to be fully unraveled.