

# METAMORPHIC HISTORY OF SAUSAR ROCKS IN THE NORTHEASTERN PART OF THE NAGPUR DISTRICT, MAHARASHTRA

V. N. AGRAWAL

*Department of Geology, Kumaun University, Nainital 263 001*

## ABSTRACT

The Precambrian rocks of the Sausar Group occurring in the northeastern part of the Nagpur district have a polyphase structural history and have undergone Barrovian type of regional metamorphism with sillimanite-almandine assemblages. Textual evidence is given here to show that metamorphism in the area has been a polyphase event involving three main episodes of metamorphic crystallisation which have occurred before, during and after the second ( $F_2$ ) fold phase. The metamorphic climax, marked by the growth of sillimanite in pelitic rocks, is shown to have occurred following the second ( $F_2$ ) fold movements. Retrogressive mineral growth is shown to have begun with the incidence of the third ( $F_3$ ) fold movements in the area.

## INTRODUCTION

THE Precambrian metamorphic rocks of the Sausar Group underlie a fold belt about 130 miles long and ranging in width upto 16 miles, that extends from Balaghat in the east to Chhindwara in the west. The rocks show Barrovian type of regional metamorphism with Kyanite-sillimanite sequences in the higher grades, the grade of metamorphism gradually increasing from southeast to northwest over the belt. The area concerning the present study is situated in the middle part of the Sausar belt covered by the Reserved Forests of Chorbaoli and Deolapar (one inch sheets 55, 0/6, 7) in the northeastern part of the Nagpur District, Maharashtra (Fig. 1). It falls

metamorphic (index) minerals in relation to the established sequence of structures ( $F_1$ - $F_3$ ) in the pelitic rocks which are considered to be the most sensitive material to temperature changes. Minor structures related to various fold phases have been employed as 'time-markers', and the growth of porphyroblastic minerals dated with respect to them. The technique used has been described earlier by Rast<sup>9</sup>, Zwart<sup>11,12</sup>, Sturt and Harris<sup>10</sup>, Johnson<sup>5,6</sup> and Harte and Johnson<sup>4</sup>.

## TIMES OF FORMATION OF MINERALS

### *Development of Micas*

Micas have first developed as tiny flakes during the initial fold movements, defining the primary schistosity ( $S_1$ ) axial planar to first ( $F_1$ ) fold structures. This is revealed by the fine grained schistose fabric related to  $F_1$  still preserved as  $e_1$ 's in pre- $F_2$  porphyroblasts. Recrystallisation of micas has occurred during the second ( $F_2$ ) fold phase, as suggested by the occurrence of relatively coarser flakes of biotite and muscovite with (001) aligned on axial planes of minor  $F_2$  structures in pelitic schists. In thin sections of some specimens of pelitic schists large biotite flakes are found to be arranged on the hinges of  $F_2$  crenulations in a herringbone pattern, without showing any sign of bending or breaking, which suggests that biotite has continued to grow in post- $F_2$  period mimetically on  $F_2$  fold hinges. As observed today, micas defining the primary regional schistosity appear identical with those aligned on axial planes of minor  $F_2$  structures and with unstrained micas occurring on hinges of  $F_2$  crenulations. This suggests that the initial fine grained schistose fabric that developed during the formation of  $F_1$  structures, has been modified subsequently by recrystallisation and growth of micas during  $F_2$ -post- $F_2$  period. This has also been accompanied by a general coarsening of the matrix fabric.

Specimens of Mansar schists from Deolapar show the development of porphyroblastic muscovite flakes

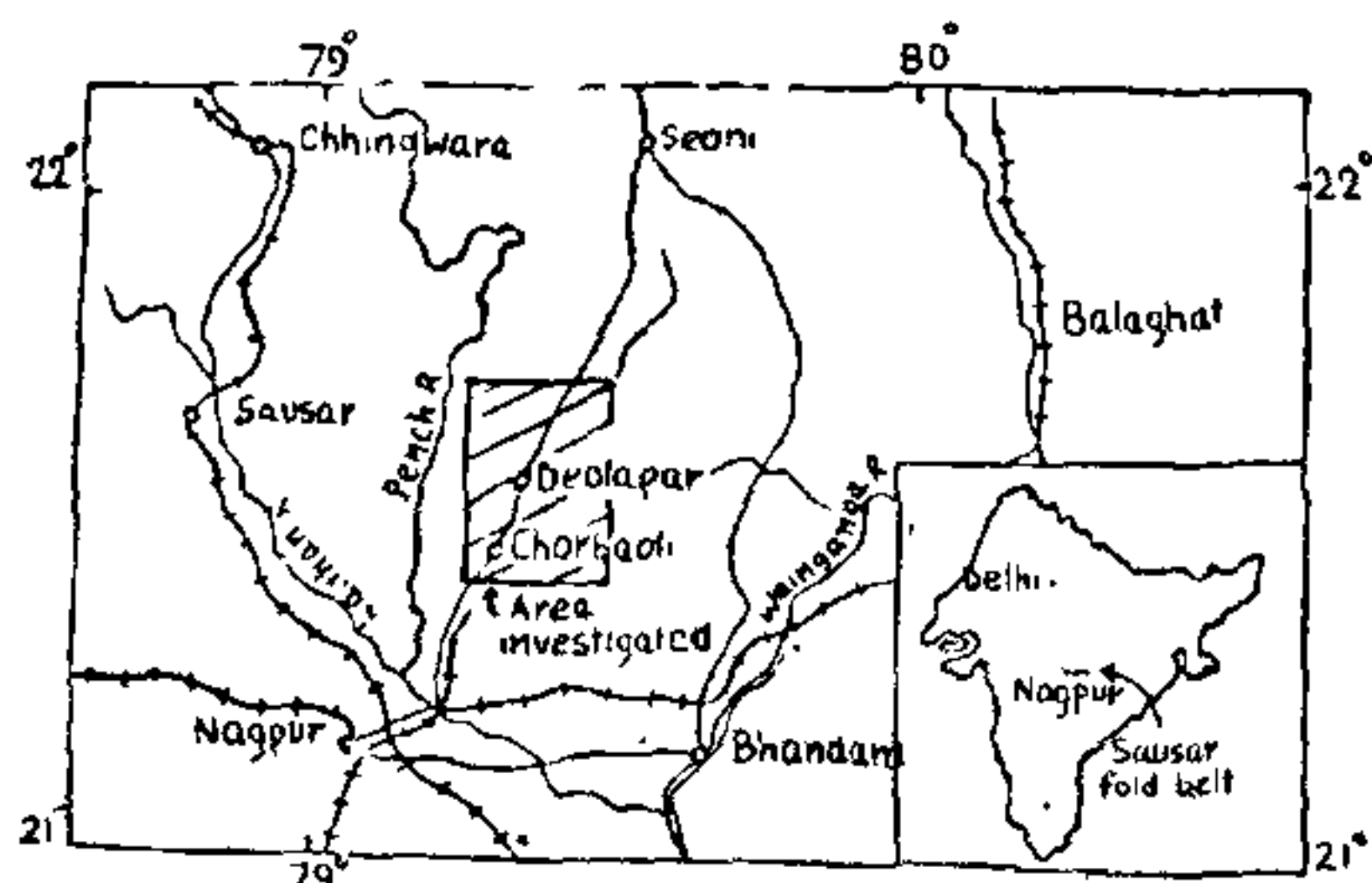


FIG. 1

within the sillimanite zone of the regional scheme of metamorphic zones suggested by earlier workers (Narayanaswami *et al.*<sup>7</sup>). Sausar rocks over this part of the belt have been affected by at least three fold phases ( $F_1$ - $F_3$ ) and have undergone metamorphism of the almandine-amphibolite facies with sillimanite-almandine assemblages developed in pelitic rocks (Agrawal<sup>1,3</sup>). The purpose of the present investigation has been to study the variation in metamorphic grade in time in the above rocks. This has been achieved by determining the periods of growth of successive

overgrowing the second schistosity ( $S_2$ ). While micas defining  $S_2$  are affected by  $F_3$  crenulations, the porphyroblastic muscovite shows no sign of strain, which suggests that the latter may have developed during or after  $F_3$  movements.

#### Development of Garnet

Garnet is a common constituent of pelitic schists of Mansar and Junawani formations. It occurs frequently in biotite gneisses and, occasionally, in granulites of Kadbihera formation. Inclusions of quartz, iron ore and micas are common in garnets. Elongate inclusions of these minerals, mostly arranged in straight trails across the porphyroblasts of garnet, define a fine grained  $S_i$  (internal schistosity) which is usually oriented at a high angle to  $S_e$  (matrix schistosity) without showing any continuity with the latter. Large flakes of biotite and muscovite defining  $S_e$  abut directly against the boundaries of porphyroblasts, enclosing at the same time smaller grains of garnet. The inclusions forming  $S_i$ 's are considerably smaller than grains of the same minerals in matrix schistosity ( $S_e$ ), indicating that garnets have grown in a schistose fabric that was finer grained than the matrix schistosity. Garnets, developed in Mansar schists of Deolapar, occasionally contain symmetrically curved trails of inclusions which are finer grained than the same minerals in  $S_e$ . The curved  $S_i$ 's, like straight  $S_i$ 's, are usually oriented at an angle to  $S_e$  without any continuity with the latter. The  $S_i$ - $S_e$  relations suggest that garnets have grown mainly in the static period between the first ( $F_1$ ) and second ( $F_2$ ) fold movements. In Deolapar, garnet growth seems to have begun before the first ( $F_1$ ) fold movements had ceased, thereby indicating that higher temperatures may have prevailed in the northern part of the area at the time.

#### Development of Sillimanite

Sillimanite is developed in pelitic schists of Mansar and Junawani formations and also in biotite gneisses. Fibrolite, occurring as bundles of fibres, is more common, although long slender crystals are also developed in places. Fibrolite is usually associated with the second schistosity ( $S_e$ ). It shows preference for reddish brown biotite in its site of nucleation, and there is clear evidence of its growth at the expense of the latter. Relics of biotite are found in mats of fibrolite in most of the thin sections from Mansar schists. In some cases merely pleochroic halos are visible in pools of fibrolite.  $F_3$  crenulations which deform the micas of second schistosity ( $S_2$ ) also seem to affect the fibrolite. The biotite-fibrolite relationship suggests that the growth of fibrolite has occurred in the static

period between the second ( $F_2$ ) and the third ( $F_3$ ) fold movements.

#### Retrogressive Mineral Growth

In the area investigated there is evidence of limited retrograde metamorphism. Pelitic schists show retrogressive alteration of biotite and garnet to chlorite in the beginning stages. The concentration of retrogressive chlorite in zones of  $F_3$  crenulations seems to suggest that the retrogressive change began with the incidence of the third ( $F_3$ ) fold movements.

#### RELATIONS BETWEEN METAMORPHISM AND DEFORMATION

The time relationships of structural and metamorphic episodes in the area under consideration are summarised in Table I. The results show that the metamorphism in the area has been a polyphase event involving three main episodes of metamorphic crystallisation that have occurred before, during, and after the second ( $F_2$ ) fold phase. At each successive stage of metamorphic crystallisation a higher grade mineral assemblage has developed which suggests that the metamorphism has been progressive in time. The final fabric of the metamorphic rocks is the end product of interactions of successive metamorphic and structural events and may be regarded as a 'composite fabric'.

In the initial stages of deformation, metamorphic conditions in the range of biotite grade, probably of a higher grade in the northern part, seem to have prevailed in the area, which have favoured the development of folds ( $F_1$ ) of 'similar' type (Class 2, cf. Ramsay<sup>8</sup>), accompanied by an axial plane schistosity ( $S_1$ ). This has been followed by a static (post- $F_1$  and pre- $F_2$ ) episode of metamorphism during which time porphyroblasts of garnet have developed in pelitic schists throughout the area, enclosing the fine grained schistose fabric related to first ( $F_1$ ) fold phase as inclusion trails ( $S_i$ 's). With the incidence of the second ( $F_2$ ) fold movements the earlier schistosity ( $S_1$ ) has been deformed, accompanied by rotation and deformation of enclosed porphyroblasts of garnet. A new schistosity ( $S_2$ ) axial planar to second fold structures has developed, defined by large flakes of biotite and muscovite which have recrystallised synkinematically with the second ( $F_2$ ) fold phase.  $F_3$  folds range in style between Class 2 and Class 1c (cf. Ramsay<sup>8</sup>). The widespread recrystallisation and growth of micas that began in the second ( $F_2$ ) fold phase, marking the Syn- $F_2$  episode of metamorphism, and probably outlasted it, has transformed the fine-grained schistose fabric related to  $F_1$  into a coarse schistosity. The

TABLE I

Periods of mineral growth in relation to the structural time-scale in psammitic-pelitic rocks of the Sausar group in Chorbaoli-Deolapar area, Nagpur District, Maharashtra

Structural Episodes	Metamorphic episodes	
	Kadambikhera formation	Mansar/Junawani formations
$F_1$ Overtaken Isoclinal to Recumbent folds (= Deolapar Nappe) with E-W to ESE-WNW axial planes	Biotite and muscovite  Post-kinematic growth of garnet (almandine)	Biotite and muscovite Synkinematic growth of garnet (in Deolapar)  Post-kinematic growth of garnet (almandine)
$F_2$ Close to tight asymmetric folds with E-W to ESE-WNW axial planes	Synkinematic to post-kinematic growth of biotite/muscovite	Synkinematic to post-kinematic growth of biotite/muscovite
A GENERAL COARSENING OF THE MATRIX FABRIC		
$F_3$ Open upright folds with NNE-SSW axial planes	Retrograde metamorphism Garnet → } Chlorite Biotite → }	Post-kinematic growth of Sillimanite (breakdown of biotite)  Retrograde Metamorphism Garnet → } Chlorite Biotite → }

residual  $F_1$  fabric is preserved only as Si's in pre- $F_2$  porphyroblasts. Not only micas have grown during  $F_2$ -post- $F_2$  period, but a general coarsening of the mineral grains making up the matrix schistosity ( $S_e$ ) about pre- $F_2$  garnet porphyroblasts has occurred during that period. Metamorphism has reached a climax in the static period between the second ( $F_2$ ) and the third ( $F_3$ ) fold phase, marked by breakdown of  $S_2$ -biotite and growth of sillimanite. By the time of incidence of the third ( $F_3$ ) fold phase temperatures started declining as suggested by the style of fold structures of this generation, which approximate to Class 1B (cf. Ramsay<sup>8</sup>) and are associated with fracture cleavage marking the beginning of brittle deformation. The concentration of retrogressive chlorite in zones of  $F_3$  crenulations in pelitic schists suggests that retrograde metamorphism may have begun with the incidence of the third ( $F_3$ ) fold phase.

#### ACKNOWLEDGEMENT

Suggestion; received from Dr. M. R. W. Johnson of Grant Institute of Geology, Edinburgh, during the course of preparation of the paper are gratefully acknowledged.

1. Agrawal, V. N., "The structure and genesis of the manganese ores and associated rocks of the Sausar series around Chorbaoli, Nagpur District, Maharashtra, Univ. Saugar", *Ph.D. Thesis*, 1968 (Unpublished).

2. Agrawal, V. N., *Proc. Ind. Nat. Sci. Acad.*, 1974, 40 A (2), 101.
3. —, *J. Geol. Soc. Ind.*, 1975, 16 (2), 176.
4. Harte, B. and Johnson, M. R. W., "Metamorphic history of Dalradian rocks in Glens Clova, Esk and Lethnot, Angus, Scotland," *Scott. J. Geol.*, 1969, 5 (1), 54.
5. Johnson, M. R. W., "Relations of movement and metamorphism in Banffshire," *Trans. Edin. Geol. Soc.*, 1962, 19, 29.
6. —, "Some time relations of movement and metamorphism in the Scottish Highlands," *Geol. Mijnb.*, 1963, 42, 121.
7. Narayanaswami, S. et al., "The geology and manganese ore deposits of the Manganese Belt in Madhya Pradesh and adjoining parts of Maharashtra," *Bull. Geol. Surv. Ind.*, Ser. A—Econ. Geol., 1963, Pt. 1.
8. Ramsay, J. G., *Folding and Fracturing of Rocks*, New York, 1967.
9. Rast, N., "Metamorphic history of the Schichallion Complex, Perthshire," *Trans. R. Soc. Edin.*, 1958, 63, 413.
10. Sturt, B. A. and Harris, A. L., "The metamorphic history of the Loch Tummel area, Central Perthshire, Scotland," *Lpool Manch. Geol. J.*, 1961, 2, 689.
11. Zwart, H. J., "Relations between folding and metamorphism in the Central Pyrenees and their chronological succession," *Geol. Mijnb.*, 1960, 39, 163.
12. —, "On the determination of polymetamorphic mineral associations and its application to the Boast area (Central Pyrenees)," *Ibid.*, 1962, 52, 38.