CHAPTER - V

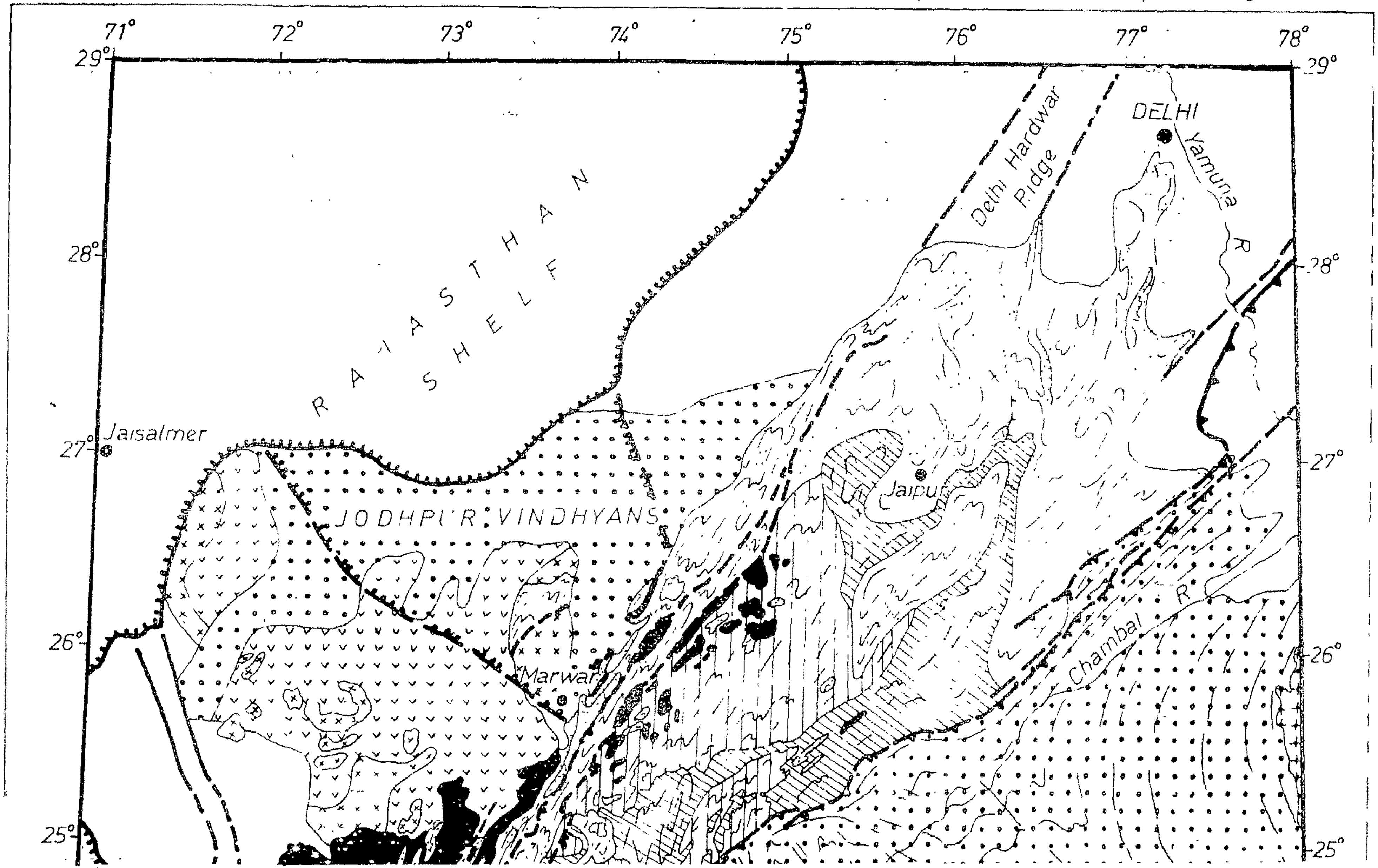
STRUCTURAL GEOLOGY

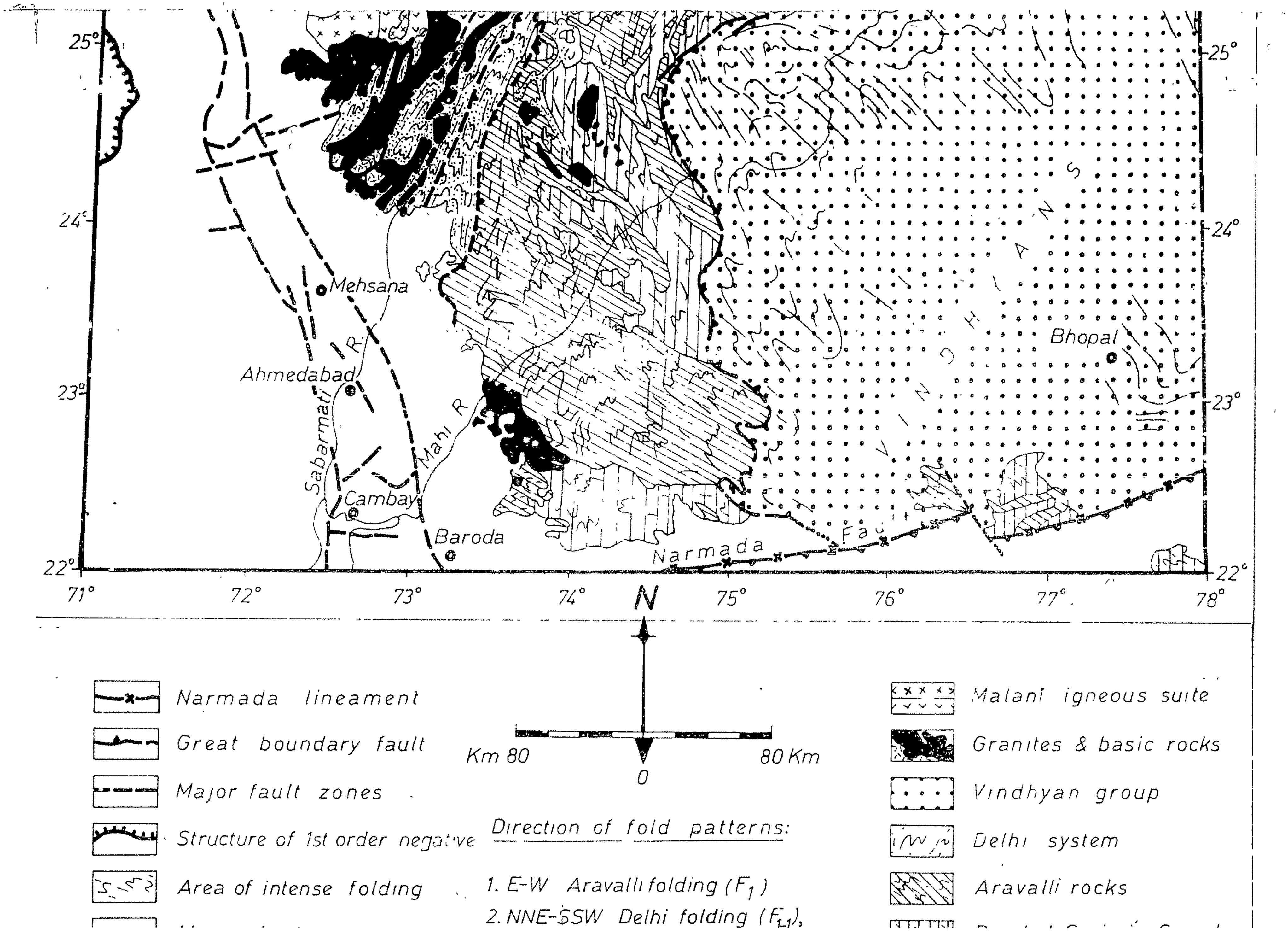
INTRODUCTION

None of the previous workers was able to understand the structural geology of the area fully. Though the rocks to the east of the study area comprising the nose portion of the Delhi Synclinorium typically reveal strong NNE-SSW folding, the rocks arould Ambamata could not be fitted in the broad structural framework (Fig. V.1a). The outcrop pattern and succession of rock formation also did not reveal the actual structures present. Very little details of the structural geology of the area is thus available in the works of Sharma (1931) and Heron & Ghosh (1938).

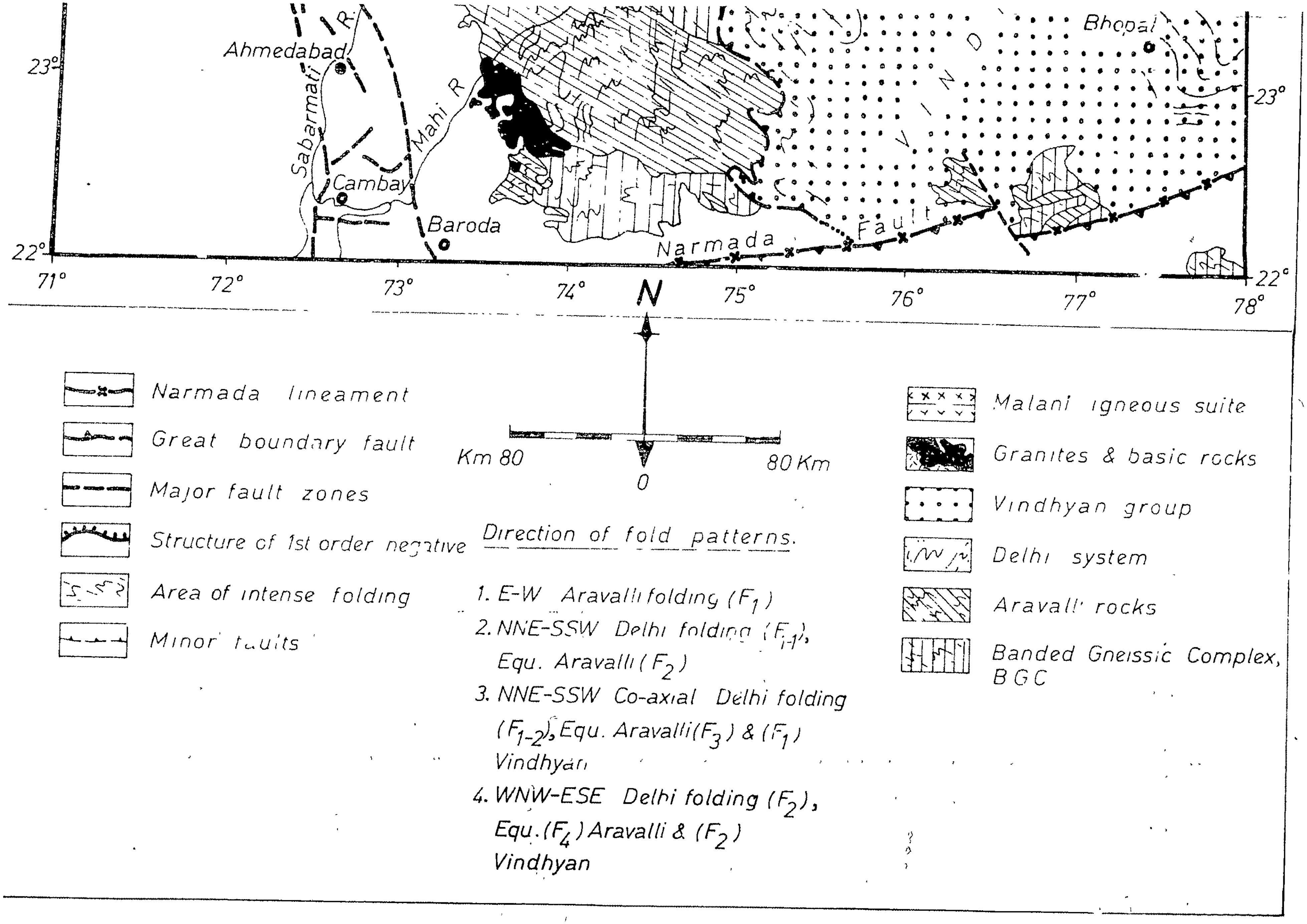
REGIONAL TECTONIC MAP OF NORTHWESTERN INDIA, (COMPILED)

Fig. V. 1a.





25°
24°
23°
22°
71°
72°
73°
74°
75°
76°
77°
78°
Mehsana
Ahmedabad
Sabarmati R
Cambay
Mahi R
Baroda
Narmada
Fau
Bhopal
V I N D H Y A N S
N
Km 80
0
80 Km
Narmada lineament
Great boundary fault
Major fault zones
Structure of 1st order negative
Area of intense folding
Direction of fold patterns:
1. E-W Aravalli folding (F_1)
2. NNE-SSW Delhi folding (F_{1-1}),
Malani igneous suite
Granites & basic rocks
Vindhyan group
Delhi system
Aravalli rocks



Ahmedabad
Sabarmati
R
Cambay
Mahi R
Baroda
Narmada
Fault
V I N D
Bhopal
23°
22°
71°
72°
73°
74°
75°
76°
77°
78°
N
Km 80
0
80 Km
Narmada lineament
Great boundary fault
Major fault zones
Structure of 1st order negative
Area of intense folding
Minor faults
Direction of fold patterns.
1. E-W Aravalli folding (F_1)
2. NNE-SSW Delhi folding (F_{1-1}), Equ. Aravalli (F_2)
3. NNE-SSW Co-axial Delhi folding (F_{1-2}), Equ. Aravalli (F_3) & (F_1) Vindhyan
4. WNW-ESE Delhi folding (F_2), Equ. (F_4) Aravalli & (F_2) Vindhyan
Malani igneous suite
Granites & basic rocks
Vindhyan group
Delhi system
Aravalli rocks
Banded Gneissic Complex, BGC

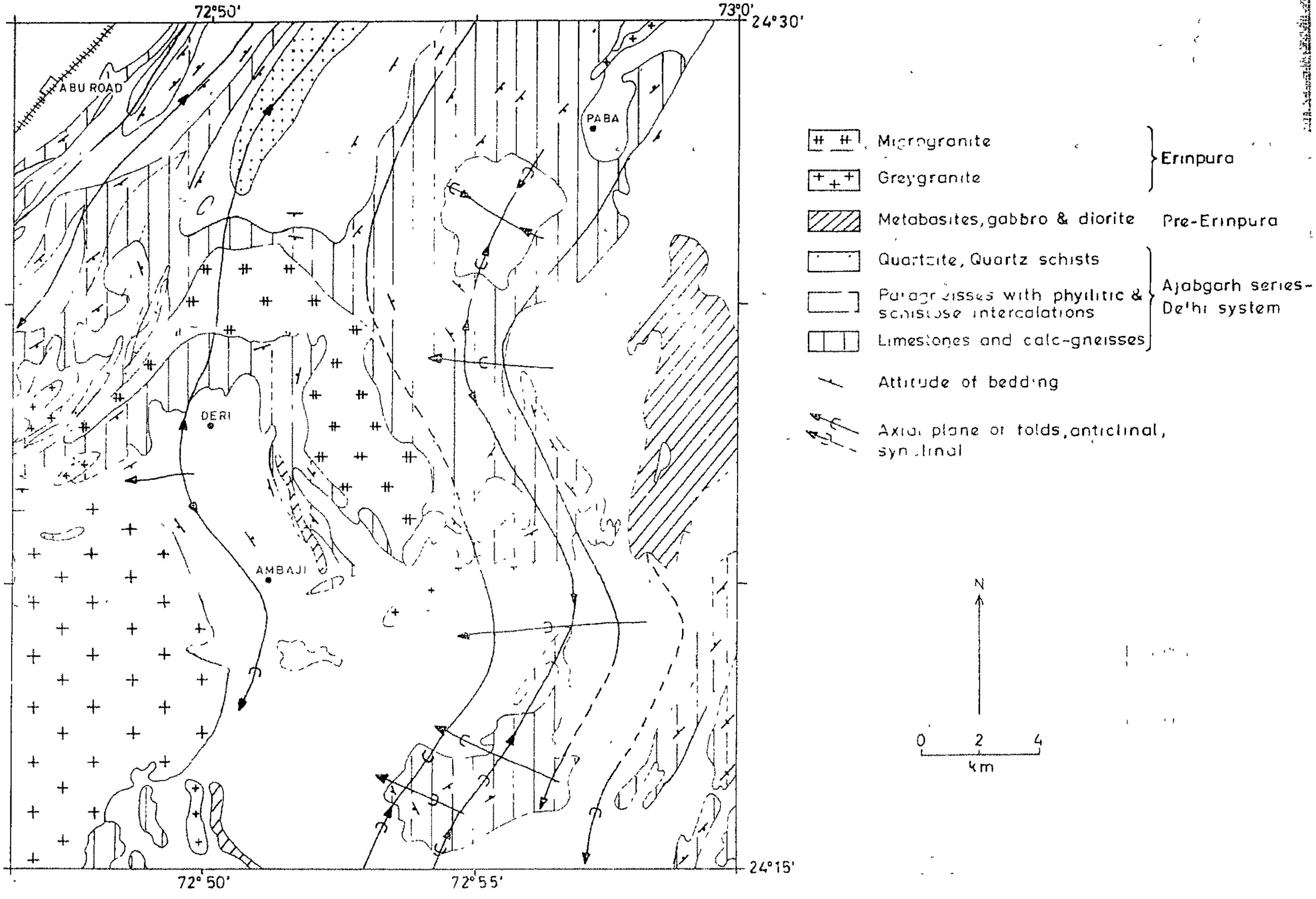
More recently, the G.S.I. officers (Shekar et al., 1969) while dealing with the Ambamata base metal deposit described the area to comprise cross fold tectonism. In their words, "The NE-SW trending syncline of the area with low plunge towards the northwest is the refolded portion of a NNE-SSW trending major fold, thought to be resultant of the cross fold tectonism.

The metasediments of the prospect striking NW-SE to E-W with generally steep dips towards the north-east form the western limb of this syncline, the eastern limb being near Jariba. The western limb itself shows slightly overturned minor north-westerly folds". Recently the G.S.I. officers in their unpublished report described more details about the structural features (Fig. V.1b) of the area as follows :

1. The area comprises a doubly plunging syncline with a structural low in the vicinity of the state border.
2. The fold axes are reoriented by F_2 fold movement resulting in an axis plunging at moderate to low angle towards the northwest, passing through the Ambamata prospect in the south, and another axis, plunging towards the SSW passing west to Deri prospect.

GEOLOGICAL MAP OF PARTS OF BANASKANTHA DISTRICT, GUJARAT AND SIROHI DISTRICT, RAJASTHAN (from unpublished G.S.I. report)

Fig. V. 1b.



3. The rocks forming the northeastern limb of Ambamata syncline strike WNW in the Ambamata area and gradually swerve towards NW, NNW and northward at the limits of the prospect and enter the Deri prospect maintaining the northward trend.

4. The southeastern limb of the syncline trends WNW in the Ambamata prospect and a little further beyond, and gradually veers towards west, embracing a boss of granite.

5. The shears and faults are similarly oriented.

These authors have given a fairly exhaustive account of the shear zones, fractures and joint pattern of the area.

Obviously, the structure visualised by them, involved cross folding, the F_2 folds to be broadly E-W. Of course, they have not fully understood the earlier fold (F_1) pattern over which the F_2 were superimposed.

The present author could unravel the structural complexity and fit in the sequence and outcrop pattern, only after a critical perusal of the regional structural geology worked out by Sychanthavong (1978)

STRUCTURAL FRAMEWORK OF NORTH GUJARAT

The details of the contribution by Sychanthavong (1978) have already been given in Chapter III, and his two main fundamental findings on which the structural interpretation of Ambamata area is based, are as under :

1. Ortho-amphibolites comprise tight fold cores and represent the basement involved in Delhi foldings.
2. The most striking NNE-SSW folding, referred to by all previous workers, in fact consists of not one but two episodes of co-axial foldings. This concept-double folding on similar axial plane and axis, is very useful in exploring the outcrop patterns of Delhis all over the North Gujarat.

In the Kherod-Posina area, Sychanthavong (op. cit.) established an interesting relationship between the Principal Stress axes related to F_1, F_2 and F_3. He explained the remarkable straight NNE-SSW trends of the strike, together with great variation in the direction and plunge of F_1 and F_2 fold axes by envisaging following stress picture.

"The rocks have been deformed, folded and fractured by a long process of continuous deformation comprising three successive episodes each with its own stress field. The F_1 anf F_2, for the most part being near co-axial, have almost identical orientation of Principal Stress axes.

Obviously, the two deformations were two stages of a single event. In early stage F_1 folds developed, while during the later stage, F_1 were folded by F_2, and the longitudinal fractures developed. The author has adequately shown above that during F_1 and F_2, the maximum compressional stress (σ_1^1 and σ_1^2) were horizontal and WNW-ESE trending perpendicular to the axial planes of F_1 and F_2 and also to the longitudinal fractures. The F_3 had a different stress field, the maximum compression (σ_1^3) having an orientation NNE-SSW.

An interesting feature of this deformational sequence is that the stress axes of F_1 and F_2 still maintain their original directions. The analysis has revealed that during F_2, the σ_1^1 and σ_3^1 were rotated in a veritical plane normal to σ_2^2. The σ_2^2 has the same trend as σ_2^1, and it does not show any change.

During F_3, the rotation of σ_2^1 and σ_2^2 took place along a subvertical plane normal to σ_3^3. As this plane has the same strike as that of the S_1 and S_2, the overall strike trends of the various planar structures continued to be NNE-SSW. It is thus seen that during F_3 also, the compressional stresses, though acting from SSW-NNE were almost horizontal.

σ_1^3 - NNE-SSW subhorizontal coinciding with σ_2^1 and σ_2^2.
(= B_1 and B_2 fold axes)

σ_2^3 - Subvertical

σ_3^3 - WNW-ESE subhorizontal and coinciding with σ_1^2.

The deformation during F_3, would have therefore following effects on earlier stress axes :

1. No effect on σ_1^1 and σ_1^2
2. Rotation of σ_2^1 and σ_3^1, σ_2^2 and σ_3^2 in a plane normal to σ_3^3 (=F_3 fold axis B_3)."

As a result of this, the F_1 and F_2 axial planes do not show any deviation in their strikes, but the axes plunge due NNE and SSW at a variety of angles. But coming to the Ambamata area, the relationship of the stress fields during F_1-F_2 and F_3, somewhat changes and thus the effect of F_3 is seen not only in the plunge orientation of F_1-F_2 axes but also in the trends of the axial plan~~g~~es and the strikes of beddings.

Applying the criteria worked out by Sychanthavong to Ambamata area, the author has visualised a F_3 stress field wherein the bend of σ_1^3 axis coincided with the trend of

σ_2^1 and σ_2^2, but was inclined. Obviously, σ_2^3 and σ_3^3 were not respectively subvertical and subhorizontal as seen in the Posina-Kherod area. Furthermore, during F_3 folding, σ_2^1 and σ_2^2 were twisted vertically in the Kherod-Posina area while obliquely in the Ambamata area. This twisted 'S' shaped deformation was responsible for the deflection in strike directions giving rise to outcrop pattern so different from seen in Kherod~~a~~-Posina.

Considering the sequence of folds F_1 and F_2 (NNE-SSW) over which F_3 (WNW-ESE) were superimposed, the structural pattern of the area and the neighbourhood has been very convincingly worked out by the present author and illustrated in the sketch map showing the structural framework (Fig.V.2).

STRUCTURE OF THE AMBAMATA AREA

Fold Pattern

The outcrop pattern and foliation trends, as well as behaviour of ortho-amphibolite, very clearly show effects of two fold events. The early folding consists of very tight-folds which follow tortuous trends on account of the effects of late WNW-ESE folding. The various folds have been mostly inferred on the basis of the stratigraphy i.e. younger formation within older formation pointing to a syncline, while the opposite relationship pointing to an anticline. Broard structural trends of the area and its neighbourhood have also been studied on the landsat imageries.

The three fold episodes visualised by Sychanthavong (1978) are not so clearly revealed in the study area. A perusal of the regional tectonic map (Fig. V.2), shows only some prominent F_1 and F_3 folds and only one F_2 fold. In the southern half of the area, the outcrop pattern comprises interference of F_1 and F_3. The ortho-amphibolites together with hornblende gneiss form a close inlier like structure and represent a F_1 anticline over which a F_3 (WNW-ESE) fold, perhaps an open antiform, has been superimposed. The fragmentary calcareous bands within the gneisses, recorded near the village Rinchhri, have been interpreted as a very tight synclinal fold of F_1.

In the northern part, the main basin like structure typically comprises a big open F_3 (WNW-ESE) synform, which has distorted the tight F_1 syncline which is inferred to extend along the granites of Minagarh ridge. It is the same syncline which represented by calcareous bands in the south.

In the extreme north, the outcrops of finegrained pink granite and calcareous rocks, take a swing from NW-SE to NE-SW. This fold appears to be F_2 (Plate V.1a) as its axial plane is also NNE-SSW. But unlike the Posina-Kherod area of Sychanthavong (op.cit.) this F_2 fold is rather open.

PLATE V.1

Field photograph of Calc-schist showing sharp angular F_2 folds (N-S) superimposed over tight F_1 folds. Loc. River bed 1.5 km N of Parli Chhapri.

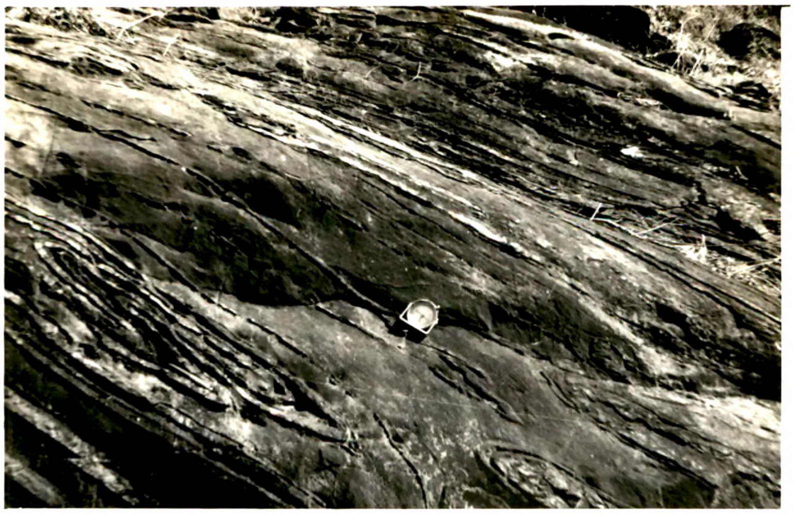
It is quite evident that the pink granite has arisen along cracks or fractures in the axial zone of F_1. This fact is typically shown by the fingers of similar rock cutting the pelitic gneiss in the northeast of Rasanio ridge (Δ 737).

Occasionally tight folds related to F_1 and open angular folds related to F_3 are seen in calcareous rocks. At some place calc-schists have preserved ideal interference patterns between F_1 and F_2 (Plate V.2) and F_1 and F_3 (Plate V.3). In fact, these minor folds typically reveal the presence of regional tight folding. As the frequency of minor folds is restricted, their systematic analysis was not possible. Similarly, the area to the NW of Ambamata, sporadically contains minor folds related to F_3 and these are seen to plunge moderately due WNW.

Fractures

The entire area is extensively fractured. Considerable shearing and small scale faulting mostly parallel to the regional foliation appear to be related to F_1. The various meta-dolerite 'sills' have obviously arisen along the fractures which run parallel to the axial planes of F_1 (and also bedding).

PLATE V.2



Field photograph of Calc-schist showing tight refolded (eyed) folds (F_1 X F_2) Loc. River bed 2 Km NW of Mala village

PLATE V.3

Field photograph of Calc-schist showing E-W F_3 folds superimposed over tight F_1 folds. Loc. Near Rinchhri village.

Deformation in relation to granite intrusion:

Granites of Erinpura age show very interesting time-relationship with fold history. The major hills, ridges and bosses of coarse biotitic granite and cutting through all the structures, ~~and~~ are obviously post F_3. But the pink finegrained granite (free from biotite) that occurs along the F_1 syncline, is seen affected by both F_2 and F_3, and leads one to conclude that this granite is older and Pre-F_2.