STRUCTURAL PETROLOGY OF SOME QUARTZITES OF PALNAD

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CONTENTS.

INTRODUCTION.

Structural petrology or 'petrofabrics' which deals with the study of rock fabric is a science which has developed during the last three decades. It comprises a study of all the spatial data, macroscopic and microscopic, which go to form a complete vector-picture so far as this is legible in the make-up of the rock. Thus, it is an integration of the mutual relationships of various kinds of crystalline aggregate within the rock, of the crystals of constituent minerals within such aggregates and even of the ionic groups and individual ions that make up the space-lattice of each component crystal. Investigations on rock fabric in minute detail may be said to have been begun by Sander (1930) and Schmidt (1932). They have systematized the new method of the study of rock structures by statistical determination of the pattern of orientation of crystallographic or other optical elements of the constituent minerals and have thus laid down the principles for kinematic and dynamic interpretation of the fabric. This method has later been taken up in the United States of America and pursued to a great extent. The treatises of Knopf and Ingerson (1938) and Fairbairn (1949) are very comprehensive in this respect as they deal with the field and laboratory technique. In India, this line of research was not introduced till a few years back. The only published work seems to be that of Sen (1948, 1949) which gives an account of the mineral orientation in the Manbhum granite.

It is very well known that the various members of the Archaean and Purana formations are deformed and in some cases there is great doubt as to their positions in the stratigraphic succession. In this respect, the Cuddapah and Kurnool formations with quartzites in various horizons afford an interesting study. In particular, in the Palnad taluk the geology of which has been studied by the author (1953), limestones, quartzites and shales, which King (1872) describes as Palnad beds, are so peculiarly associated that the quartzites seem to both overlie and underlie the limestones. The author has shown that quartzites of different stages of the Cuddapah system are involved and that they have been further faulted into their present positions. With a view to find out the amount of deformation and therefrom the source and direction of the movements that caused the deformation of the various quartzites this study of their fabric is undertaken. It is also intended to ascertain on the basis of the type and amount of deformation the possibility of their correlation with the various members in the standard Cuddapah and Kurnool succession.

The material on which this work is based was obtained from an area in Guntur District included in the Survey of India topographic sheet Nos. 56-P/11 and 15.

General Geologic Description of the Region.

The formations in the area comprise essentially the Upper Cuddapah quartzites which occur interbanded with siliceous shales and limestones and lie unconformably over the Archaean granite-gneisses. Banganapalli quartzitic sandstones and Palnad limestones also occur especially in the northern part of the area. The geological succession is as follows:

- Purana—
  - —Kurnool —
    - —Jammalamadugu group : Palnad limestones.
    - —Banganapalli group : Quartzitic sandstones.

  UNCONFORMITY.

  - —Upper Cuddapah —
    - —Kistna Series—
      - —Srisailam quartzites.
      - —Kolumnalla shales.
      - —Irlakonda quartzites.
    - —Nallamalai Series—
      - —Cumbum slates
      - —Byrenkonda quartzites.

UNCONFORMITY.

Archaean— .. .. —Granite-gneisses.

The quartzites usually form the hill masses and are well exposed. Here, along the eastern margin of the Cuddapah-Kurnool basin, they are only a few hundred feet thick. They have a general N.E.-S.W. strike and are mostly folded. The amount of dip varies, being commonly high around 50° and 60° tending here and there to verticality. Quartzites of Nallamalai series occurring in Galimottu Konda are overlain by quartzites of the Kistna series disconformably, variation in the amount of dip between the rocks of the two series only being significant. In the Kistna series various bands of quartzites occur intercalated with shales. They have been divided into two groups the lower one being called Irlakonda quartzites and the upper Srisailam quartzites as developed in the type area of Srisailam along the Kistna valley. It has not always been possible to assign some bands to one or the other of the two main horizons in the series. A striking example of the overturning of folded Kistna quartzite beds near Karempudi has been recorded by Mahadevan and Umamaheswararao (1951). Further, faulting has seriously affected the relative positions of the Cuddapah and Kurnool formations in the region. The geological structure of the area is thus intricate, the various members exhibiting very well the effects of deformation due to faulting and folding movements and also of possible recrystallization.

TEXT-FIGS. 1–8.—Petrofabric Diagrams of Some Quartzites of Palnad
(All measurements of quartz refer to the pole of the optic axis.)

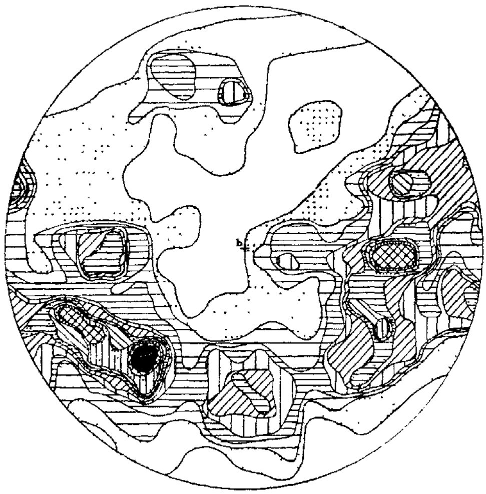


FIG. 1.

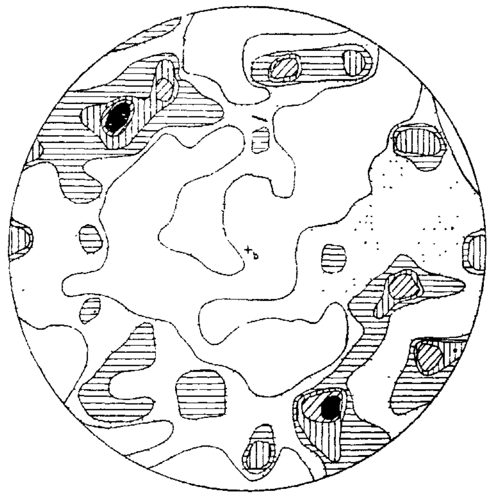


FIG. 2.

FIG. 1. Nullamalai (Byrenkonda) Quartzite (P11) from Sejara Konda (·1133).
210 quartz grains; 5-4·5-4-3·5-3-2·5-2-1·5-1-0·5%.

FIG. 2. Quartzite (P15) constituting the top band of the Nullamalai series, locally developed in Pasam Konda (·1386).
200 quartz grains; 5-4-3-2-1%.

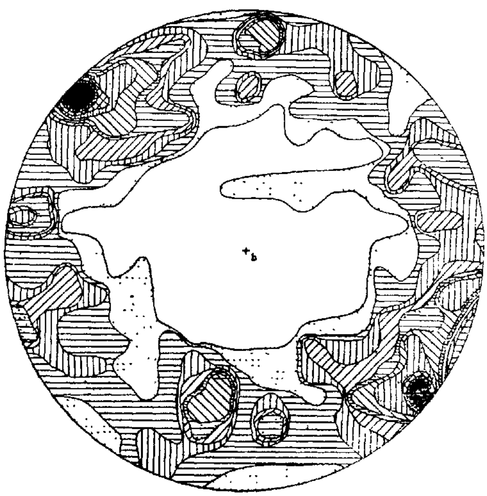


FIG. 3.

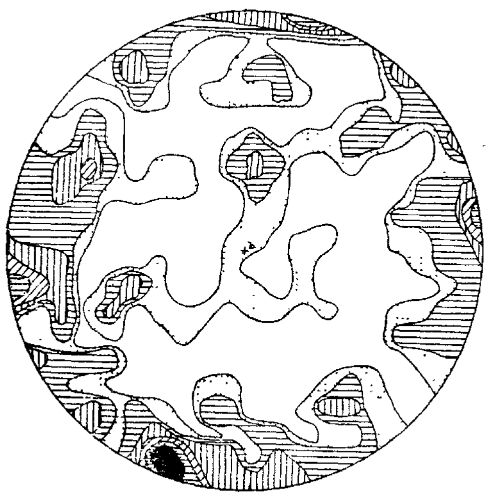


FIG. 4.

FIG. 3. Kistna (? Srisailam) quartzite (NK 30) from Gurrala Gattu (·633).
260 quartz grains; 5-4·5-4-3.5-3-2·5-2-1·5-1-0·5%.

FIG. 4. Irlakonda quartzite (9) from the band intercalated in the Lower Kistna series of rocks in the lower levels of the hill mass about 3 miles S.S.W. of Adigoppula.
200 quartz grains; 6-5-4-3-2-1%.

Fig. 5.

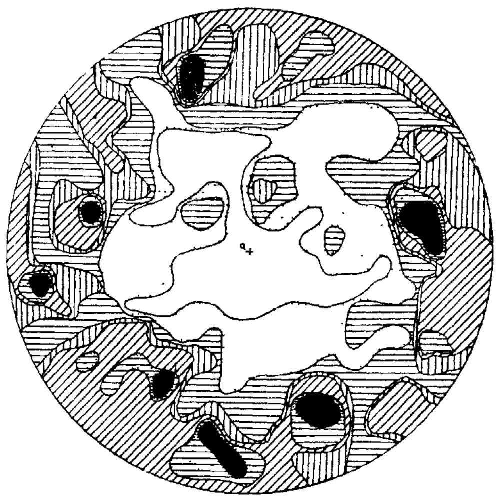


Fig. 6.

Fig. 5. Kistna (Srisailam) quartzite (K14) from the hill 1½ miles S.W. of Karempudi.
200 quartz grains; 5-4-3-2-1%.

Fig. 6. Quartzitic sandstone homotaxial with the Banganapalli sandstone from the hill ¾ mile N.W. of Durgi.
300 quartz grains; 3-2·5-2-1·5-1-0·5%.

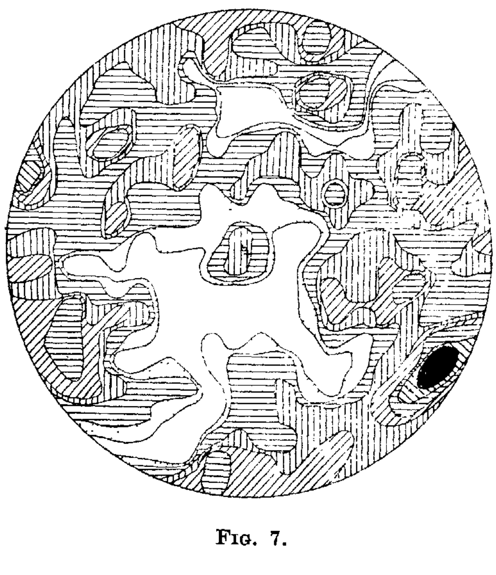


Fig. 7.

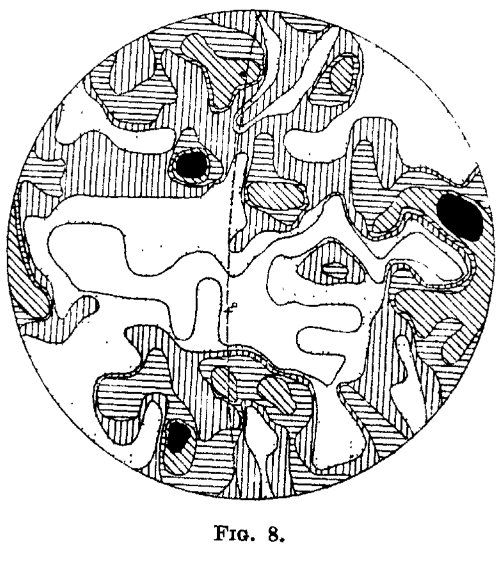


Fig. 8.

Fig. 7. Quartzitic sandstone (24) homotaxial with the Banganapalli sandstone, from Manchikallu.
325 quartz grains; 3·5-3-2·5-2-1·5-1-0·5%.

Fig. 8. Quartzitic sandstone (41) homotaxial with the Banganapalli sandstone, from the hillock S.W. of Atmakuru; ab = megascopic foliation.
150 quartz grains; 3-2·5-2-1·5-1-0·5%.

Fabric of the Quartzites.

(*a*) *Petrography.*—The quartzites are very compact and well-jointed. Two sets of jointing, each perpendicular to the other, are conspicuous. They trend E.N.E.-W.S.W. and N.N.W.-S.S.E. The quartzites are generally impregnated with vein quartz which commonly runs in north-south direction. Under the microscope in the crossed nicols position, they exhibit a typical mosaic structure. There is variation in the size of the quartz grains. The inter-spaces of the bigger grains are filled up with silica in the form of quartz. The bigger grains are irregular in form and generally exhibit undulose extinction. All the grains have undergone much compaction and granulation. The quartzites are, in general, waxy-looking and white to reddish brown in colour, though in places they are dark-coloured. Of the Kistna quartzites, the Srisailam quartzites are relatively coarse-grained.

(*b*) *Macrostructures and Microstructures*:

Macrostructures.—The structures of the quartzites which are clearly discernible megascopically either in hand specimens or in their natural setting in the field are here referred to as macrostructures. Of them, a single foliation, probably the axial-plane foliation, is the most important. It is pronounced in most of the rocks, especially in the ferruginous varieties. The orientation of this foliation is about N. 75° E. around Karempudi, tending to be about N. 60° E. in the eastern parts of the area. Shear joints are common. They are mainly in two sets. They appear to pass into the plane of foliation. Lineation is also clearly visible in the hand specimens. It is here commonly found out by the intersection of axial-plane foliation and bedding. A feature common to most of these rocks is the veining by quartz. Thus, there is ample evidence to show that the quartzites megascopically exhibit deformation.

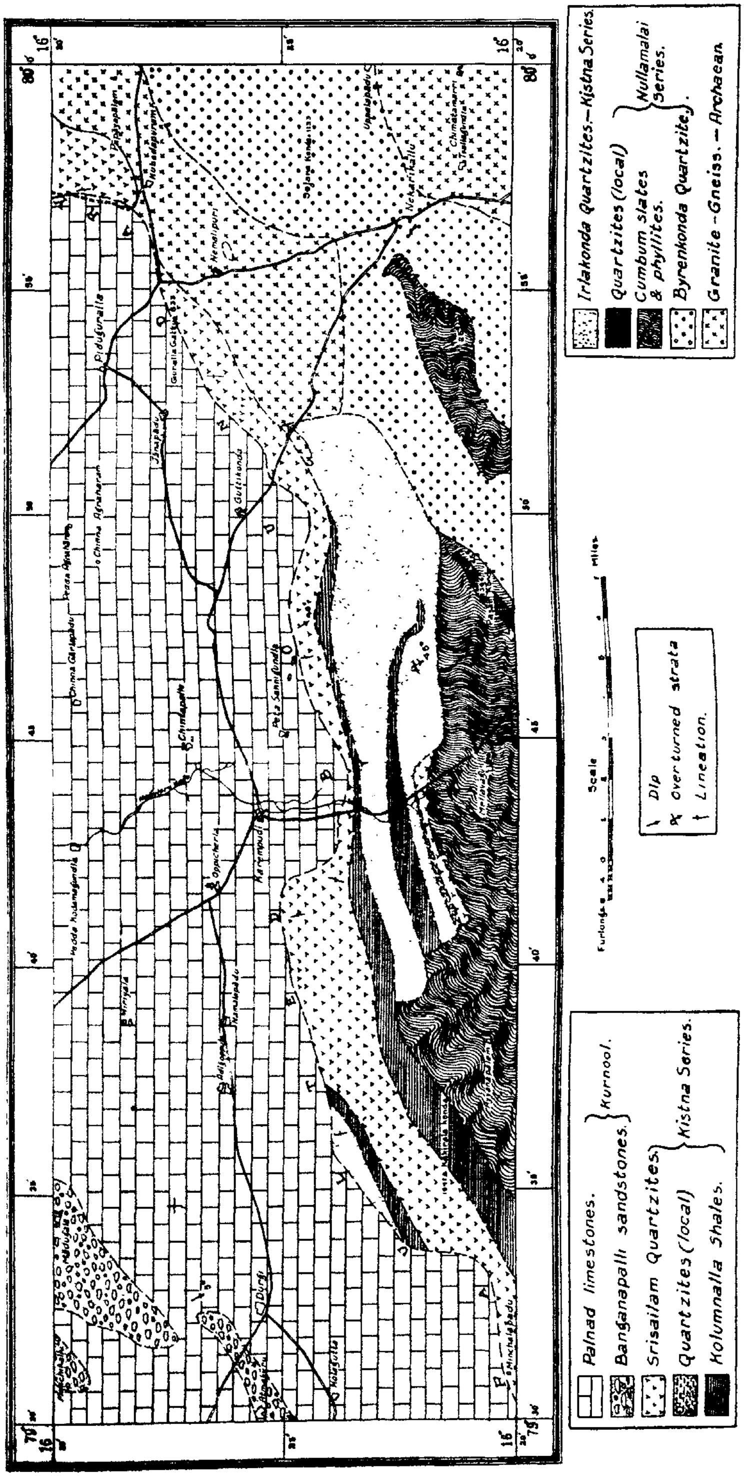
Microstructures.—The deformation of the quartzites is further evidenced by their microstructures as observed in individual quartz grains. The important microstructures include Deformation or Bohm lamellae in quite a number of the quartz grains, secondary quartz enlargement of the original grains, undulatory extinction in the mineral and also sutured boundaries between the grains. The Deformation or Bohm lamellae are very common in quartz, mostly occurring in the central portions of the grains. According to Ingerson and Tuttle (1945), they can be (1) planes of liquid inclusions, (2) healed fractures, and (3) translation glide planes. Fairbairn (loc. cit.) interprets the lamellae as translation glide planes, containing the glide line (m : r). The relation between the Deformation lamellae and the fabric of the deformed rock is indicated by Ingerson and Tuttle (1945). According to them, the angle between the optic axis and the pole of the Deformation lamellae varies with the angular distance from the optic axis of the grain to the *B* fabric axis. That secondary enlargement of the original quartz grains has occurred in many cases is proved by the incasing of a thin film of impurities at the original grain surfaces. Undulatory extinction is very commonly observed in the quartz grains. The magnitude of this change in optic orientation varies very much from grain to grain within the same sample and in different samples. The boundaries between some grains are sutured and there seems to be interpenetration of grains. Further, the big quartz grains are broken and along their boundaries are disposed small fragments of quartz which may be the result of recrystallization. In addition, the distortion in the shapes of the grains in some cases has been so much as to ultimately give rise to very elongate, nearly cylindrical shaped quartz grains. The dimensional elongation is always in a direction either very nearly parallel or perpendicular to the optic axis direction of the mineral.

Of the intergranular structures seen under the microscope, microveins of quartz are the most important. They occur as definite bands in the big quartz grains. They thus form planar structures. Another common structure, which probably represents the original sedimentary nature of the rocks, is the presence of thin laminae or streaks or lines of heavy mineral concentrates, particularly of hematite and magnetite.

(*c*) *Methods of study.*—A number of specimens of quartzite collected in the field were oriented with reference to their macrostructures and the geographic distribution. Eight of the specimens from different parts of the area but representative of the major stratigraphic horizons—Nallamalai and Kistna of Upper Cuddapah formation and Banganapalli of Kurnools—were selected for detailed study. The fabric axes were located in each case with the help of structures such as foliation and with the knowledge of the fundamental principles of structural petrology. Megascopic foliation surfaces in all examples are here designated as *S*-surfaces. The specimens were then cut in such a way that the resulting cut bits are normal to the *b* fabric axis, which again is deduced from the linear schistosity (lineation) of the rock. Only quartz, the chief and in some cases the only constituent of the quartzites, has been studied. The 4-axis Universal Stage was used during these investigations. The number of measurements made in each slide varied and was mostly from 150 to 350. The diagrams were all plotted on a Schmidt 20 cm. equal-area lower hemisphere projection, and were all counted with a one per cent circle.

(*d*) *Results of Fabric Studies.*—Preferred orientation of grains according to space-lattice structure is expressed in orientation diagrams by the presence of localized areas, called maxima, and arcuate zones, named as girdles, within which the poles of the measured optic axes are densely concentrated. Accordingly, the most striking feature of the quartz diagrams of the quartzites is a constant tendency for the plotted poles of quartz axes to lie on a more or less well-marked girdle—the girdle parallel to the *a c* plane. The quartzites are undoubtedly *B*-tectonites, including the sandstone-like facies corresponding to the Banganapalli stage of the Kurnool formation, though in the latter case, the girdle is not particularly well-defined. The *a c* girdles are a common type of deformation fabric and have been recognized and described by Schmidt (*ibid.*). Their development, according to him, is due to several processes in the course of deformation. In the initial stages, each grain tends to rotate by movement at intergranular surfaces. By rotation one of the glide planes and associated glide directions in the crystal is brought into coincidence with the plane and direction of shear imposed on the rock and thus the rotation of the crystal ceases, though it begins to yield by gliding, ultimately giving rise to a tectonite. In quartz the shear plane directions may be rhombohedra, prism or basal planes. Further, it is believed that *a c* girdles develop as a result of translatory and rotary forward movement in the tectonite perpendicular to the lineation *b*.

In general, the quartz maxima in these diagrams are peripheral lying on or near the periphery of the *a c* girdle. This is particularly seen in figures 3, 4, 5 and 8, and also to some extent in figure 7. The greatest concentrations of optic axes are usually in two directions nearly perpendicular to *b*, but inclined generally at 40° to 50° to the geographic horizontal, though in figure 4, one set of maxima is disposed at about 80° from the horizontal. In figures 2 and 6 are also seen the girdles, but the maxima which are of fairly great concentration are not peripheral, but lie on an annular area bounded by small circles of the projection sphere drawn at 50° to 55° and 72° to 75° from *b*. This cleft girdle pattern in which the *a c* great circle is a band of low concentration flanked on either side by high concentrations of quartz axes along small circles has been noted by Fairbairn (1939) in the fabrics of quartzites of Brome County, Quebec, and has been also recorded from other regions. Figure 1 which is the orientation diagram of a quartzite of Nallamalai series exhibits a distinct two-girdle pattern. This is in all probability due to partial over-printing of one *B*-tectonite fabric upon another during the course of two independent deformations governed by unrelated systems of stress. The angle of intersection of girdles in this case is nearly 90°, and hence the rock is a $B \perp B'$ tectonite. Though



TEXT-FIG. 9.—Geological and Structural Map of the Palnad Area.

the pattern of two crossed girdles could be the product either of one continuous deformation or of two distinct but closely related phases of a single deformation, here it could be taken as indicating two independent deformations, one at the end of the Cuddapah period and the other after the close of the Kurnool period. In this connection, it is interesting to note that Riley (1947) has recorded pronounced deformation in quartzites belonging to the Algonkian system which is homotaxial with the Purana system of Indian geology.

Discussion of the Results.

From the foregoing account, it is clear that the quartzites in the southern and eastern parts of Palnad Taluk, belonging to both the Upper Cuddapah and Kurnool systems, were brought to their present state of regional metamorphism by at least one and possibly two independent deformations. The movements associated with the more important and last deformation must have acted in a plane tending roughly E.N.E.-W.S.W. or N.E.-S.W. This is clearly evidenced by the general foliation strike of the rocks, which is E.N.E.-W.S.W. over a major part of the area around Karempudi, which swings to nearly N.E.-S.W. in the Janapadu and Konanki localities. The fold axes in the region seem to follow very closely the direction of tectonic transport. This feature is to be viewed in conjunction with the thrust faulting which has been brought to light by the studies of the author (*ibid.*) on the adjoining area to the north of the present one and which continues into this area as well. Even around Karempudi, where overfolding of the quartzites and shales of the Kistna series has been recorded, there is evidence of rupture of the rocks and of their constituting a mass thrust over the younger Palnad limestones. Thus, in this area, which constitutes the eastern margin of the Cuddapah-Kurnool basin and which is in a thrust zone, the transport parallel to fold axes is not a surprising feature. In fact, such parallelism is found in most thrust zones that have been studied and is well known. Further, there is proof of the quartz grains in these rocks markedly elongated in a direction more or less at right angles to the direction of transport. In other words, the lineation is N.N.W.-S.S.E. to N.W.-S.E.

The three specimens of Banganapalli quartzitic sandstone studied exhibit preferred orientation, though not to the same extent as the others. The maxima are not of relatively great concentration. This is probably to be attributed to the effects of only one deformation at the close of the Kurnool period, which was not probably of the same intensity as the one that occurred earlier. This is in conformity with the field observations that the Kurnools are much less metamorphosed than the Cuddapahs. The concentrations in figures 2 and 6 fall on or in between the circles which include maxima IV and VI of the synoptic diagram of Fairbairn (*ibid.*). This feature is significant and it is in accordance with the general findings on the distribution of sub-maxima in tectonites in connection with the proving of the hypothesis postulated by Griggs and Bell (1938) of fracture of quartz during deformation.

Summary and Conclusions.

The quartzites of Palnad are shown to be B-tectonites. The direction of predominating movement (tectonic transport) seems to be in the plane running N.N.E.-S.S.W. to N.E.-S.W. The lineation which is N.N.W.-S.S.E. is well marked. Evidence is presented in favour of two independant deformations in some of the quartzites. The Banganapalli quartzitic sandstones which exhibit a relatively lesser amount of preferred orientation of their grains and which are relatively less deformed are probably the result of only one deformation.

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