THE DEFORMATION OF DHARHARA CONGLOMERATE IN MONGHYR DISTRICT, INDIA

BY

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Abstract. Deformational features of Dharhara Conglomerate occurring at the base of the Monghyr Series are described. The main effect of deformation is observed as flattening of pebbles in steep NW striking cleavage planes parallel to the axial plane (S_3) of B′-folds. Quartz c-axes orientations in pebbles and in the matrix exhibit concentric cleft and peripheral girdles around subhorizontal axes on S_3. The mesoscopic fabric in the conglomerate has orthorhombic symmetry developed by the main compressional stress normal to S_3 during the second phase of the Monghyr Orogeny, while the monoclinic quartz fabric on microscopic scale seems to have been caused by slight rotational movement at the closing stage of the same compressional stress.

Introduction

The Dharhara Conglomerate occurs as impersistent bands at the base of the Precambrian Monghyr Series. It is exposed near the latitude N 25°19′30″ and the longitude E 86°24′30″ at the nose of a synclinal fold near Dharhara in Monghyr district of Bihar province (Fig. 1). Evidence of the existence of a structural fabric in this conglomerate has been found on both mesoscopic and microscopic scales. The nature of the stresses responsible for this fabric is considered in the light of the observed relationships between cleavage, pebble deformation, and quartz lattice orientation within the conglomerate.

Geological environment

On the basis of detailed structural and stratigraphic studies in the Monghyr district, we have established a sequence of interbedded quartzite and shale formations constituting the upper part of the

'Monghyr Series' (HASAN 1965a & b, HASAN & SARKAR 1965). This upper part of the series (2,700 m thick) is underlain by a bed of gritty quartzite formation (1,550 m) with an angular unconformity between. The conglomerate, occurring as impersistent bands in the basal part of the gritty quartzite formation (see Fig. 1), has been named Dharhara Conglomerate. There are two conglomerate bands, one 20 m thick at the base and the other 5 m thick about 100 m higher in stratigraphic level within the gritty quartzite bed. These conglomerate bands are identical in character, and their outcrops extend about 50 to 70 m along the strike.

Structurally, the rocks of the Monghyr Series form a synclinorium consisting of a major southward plunging, nearly isoclinal syncline (B-fold) with NNE–SSW trending eastward dipping axial surface ($=S_2$). The primary bedding surface is here termed S. Another set of smaller folds, consisting of SE to eastward plunging synclines and anticlines (B′-folds) with axial planes dipping steeply towards the SW, are developed on the western limb of the B-fold. On the eastern limb of the B-fold, however, the B′-folding is represented by a SW facing antiformal flexural bend (Fig. 1). Tectonic analysis of these fold systems shows that they were developed during two distinct phases of deformation which occurred during the Monghyr Orogeny (HASAN & SARKAR 1965).

The synclinal fold near Dharhara (Fig. 1) is developed by folding of the gritty quartzite beds along a NNE–SSW trending axis plunging at 50° towards the SSW. In view of its axial trend and attitude, this syncline is probably contemporaneous with the main B-fold. The effect of B′-folding on the gritty quartzite and underlying Dharhara Conglomerate, however, is seen as a pronounced cleavage developed parallel to the axial plane of B′-folds ($=S_3$).

Mesoscopic and microscopic features

Outcrops of both the conglomerate bands were examined and data regarding the attitude of bedding, cleavage planes, and pebble dimensions were recorded along the full length of their exposures. The samples of pebbles and matrix for quartz lattice orientation study were collected only from the lower 20-m-thick conglomerate band, distributed unevenly over its strike length of 70 m.

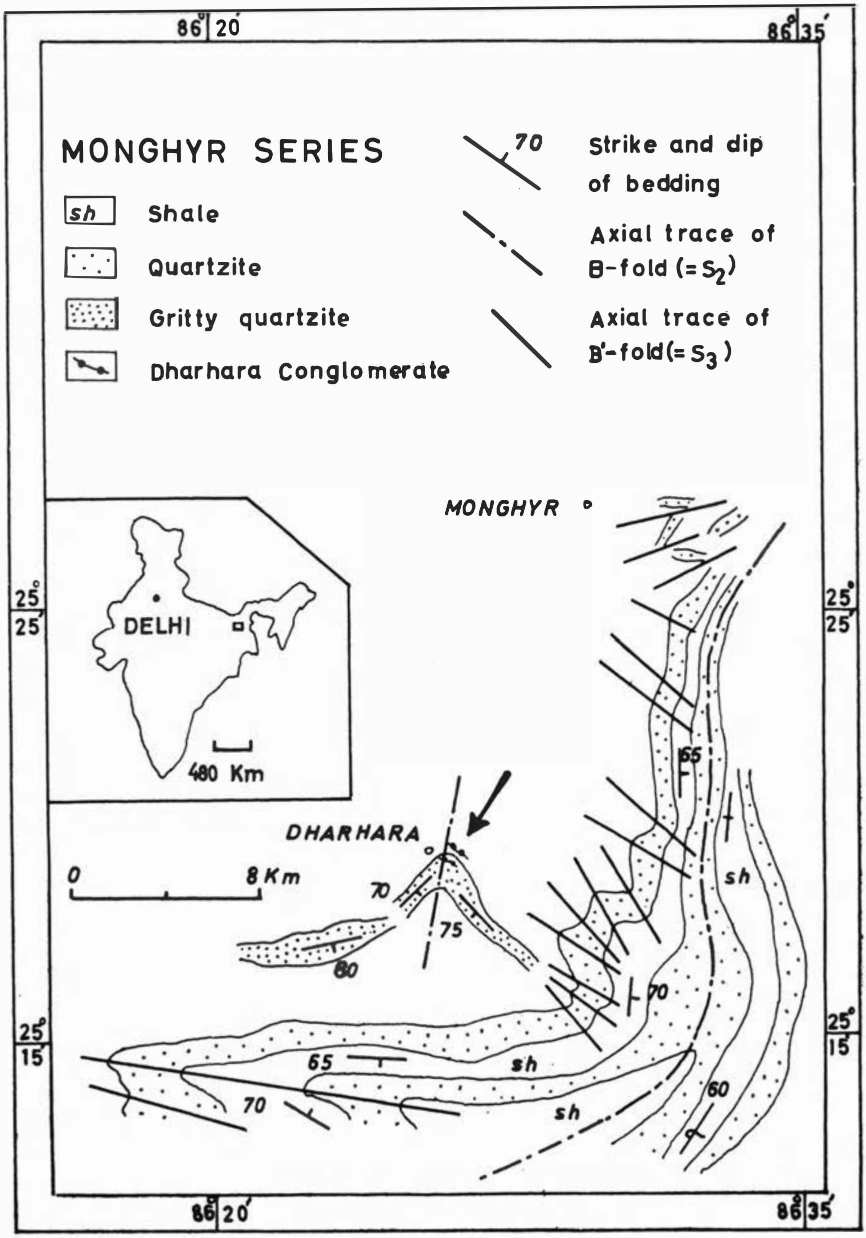
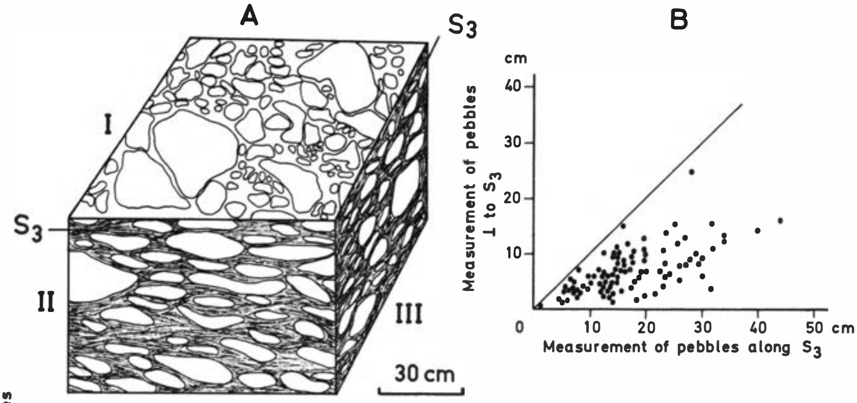


Fig. 1. Geological map of Monghyr district.

The conglomerate consists of various kinds of pebbles; the majority are of grey-white quartzite, gritty quartzite, and milky vein-quartz, but shale and altered rhyolite pebbles are also found, all embedded in a fine-grained shaly to quartzose matrix. The size of pebbles varies from a few mm to 50 cm, and, where the shaly matrix is extremely fine, quartz grains measuring down to 1 mm in diameter give the rock the character of a grit. Primary bedding surfaces can be recognized at a few places, marked by gradation in size of the pebbles and variation in the quartz content of the shaly matrix. Bedding planes generally dip at 40° to 50° towards the SW and their oblique relation to the steeply dipping cleavage and the longer dimensions of the pebbles is clearly seen on surfaces normal to the strike.

There is a distinct phyllitic cleavage visible in the matrix of the conglomerate generally striking N 125° and either dipping 75° towards the SW or standing vertical. A silky sheen is visible on cleavage surfaces on which at times a faint down-dip micro-corrugation lineation can also be seen. A good development of cleavage parallel to that of the matrix is quite often seen in the shaly pebbles and occasionally in those composed of impure quartzite. This cleavage is structurally concordant with the axial plane of B′-folds ($=S_3$) and, therefore, will subsequently be referred to here as S_3. The S_3 cleavage was developed in the conglomerate by NE–SW compressional movement during the second phase of the Monghyr Orogeny as the axial plane-cleavage of B′-folds.

The conglomerate fractures easily along the S_3 cleavage. The outline of pebbles on this plane varies considerably from squarish to rounded or oval (Fig. 2A). The majority of pebbles, however, are lensoid with their shortest dimension lying normal to the S_3-plane. There does not seem to have been stretching of pebbles in any particular direction on the cleavage plane as can be seen in Fig. 2A. Due to the absence of any uniformity in the outline of pebbles or their dimensional elongation on the S_3-plane, a procedure to assess the amount of deformation (if any) along the larger and intermediate dimensions of pebbles cannot be followed. As stated earlier, the shortest dimension of the pebbles lies perpendicular to the S_3 cleavage, and their outlines are quite regular in being lens-shaped on surfaces normal to S_3 (Fig. 2A, II & III). Correlation of pebble dimensions measured parallel and perpendicular to S_3 cleavage is shown in plots in Fig.



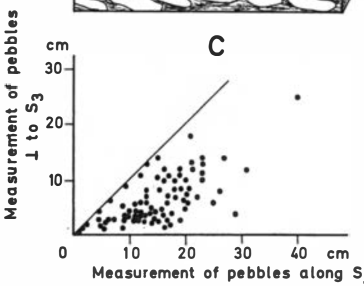


Fig. 2. **A.** Showing different faces of Dharhara Conglomerate drawn from photographs. Face I is parallel to the S_3 plane and shows outline of the pebbles as seen on the S_3. Faces II and III are sections normal to the S_3-plane as seen on the joint surfaces. These three faces (I, II, and III) belong to the same outcrop. **B.** Plots of pebble measurements made on face III of A and also on similar sections at various spots on the two bands of the conglomerate. **C.** Plots of pebble measurements made on face II of A and also on similar sections at various spots on the two bands of the conglomerate.

2B & C. These plots, from two different surfaces vertical to S_3, clearly show that the shortest dimensions of the pebbles lie normal to S_3 except in a few cases (Fig. 2C) where the pebbles are subrounded and the two measurements are equal. This obviously indicates flattening of pebbles in a plane parallel to the S_3 cleavage (cf. Plättung-S of SANDER 1948). If this shortest axis of the pebbles be assumed now to represent the *C* axis of a strain ellipsoid, the S_3-plane could then be correlated to the *AB*-plane of the ellipsoid. It has been stated by BILLINGS (1954) that the *AB*-plane of a strain ellipsoid conforms with the axial plane of a fold. The flattening of pebbles in the Dharhara Conglomerate along the axial plane-cleavage (S_3) of B′-folds may be another illustration of a similar type of fabric.

Identical flattening deformation of pebbles with their long and intermediate axes lying in an axial plane-foliation has been described by FAIRBAIRN (1936), CLOOS (1947), and BRACE (1955). In contrast to

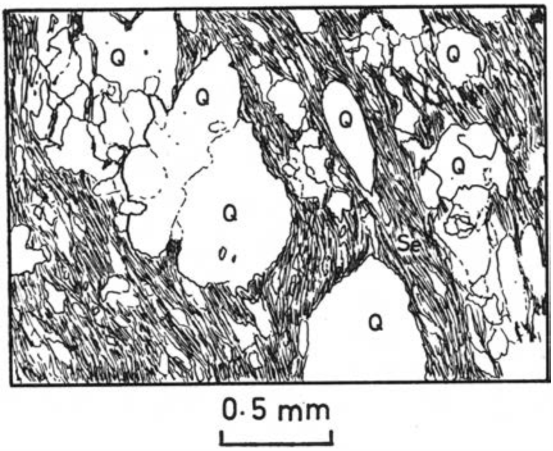


Fig. 3. Sketch drawn from the photomicrograph of fine-grained gritty matrix of the conglomerate, showing small quartz pebbles in shaly groundmass and preferred orientation of grains along S_3 cleavage: Q — quartz, Se — sericite.

the present case, elongation or stretching of pebbles in conglomerate along fold axis or *a*-fabric axis has been reported by many workers from different parts of the world such as FAIRBAIRN (1939), STRAND (1944), KVALE (1947), OFTEDAHL (1948), and FLINN (1956). In the present case, however, compression normal to the S_3 cleavage seems to have caused flattening of pebbles in the conglomerate without stretching in any particular direction.

Under the microscope, quartz and sericite seem to constitute the bulk of pebbles as well as of matrix. The minerals are seen at various stages of deformation and invariably show a strong preferred orientation defining the S_3 cleavage. The shaly matrix appears to flow round the lens-shaped quartzose pebbles (Fig. 3). The matrix is often so fine grained that it could not be resolved for a detailed microscopic examination. The rhyolite pebbles have completely altered, showing relicts of rectangular to subrounded crystalloblasts of quartz embedded in an extremely fine matrix composed mainly of sericite and exhibiting a good cleavage. Shreds of chlorite and minor amounts of tourmaline and iron ore are the common accessory minerals.

Quartz fabric

Lattice orientation of quartz grains in seven samples of different pebbles and four samples of quartzose matrix from the lower conglomerate band was studied and is presented here. Due to the absence of any pronounced lineation in the conglomerate, thin sections were prepared along the vertical plane normal to S_3 cleavage available in the hand specimen. Two hundred c-axes of quartz grains were measured in each case, and orientation data were plotted on the lower hemisphere of a Schmidt net and contoured. The strike of the plane of projection is given in each diagram with its bearing written in the whole circle (360°) compass reading. Brief microscopic structural features and orientation patterns of quartz c-axes in different cases are given in the descriptions of Figs. 4 to 14.

From a critical study of the above microfabric diagrams (Figs. 4–14) and the synoptic diagram of maxima (Fig. 15), it is evident that the quartz c-axes mostly form concentric annular and/or peripheral girdles (cf. FAIRBAIRN 1939) with horizontal girdle axes exhibiting monoclinic symmetry. Maxima close to S_3 or oblique girdles occur in only a few cases.

Conclusions

On the basis of all available evidence, it may be concluded that the Dharhara Conglomerate was mainly affected by compressional stress perpendicular to S_3 during the second phase of Monghyr Orogeny which generated B′-folds and S_3 cleavage in the rocks of Monghyr Series. The deformation in the conglomerate was essentially of 'Plättung-S' type (SANDER 1948), and stretching of pebbles followed no preferred direction in the cleavage plane, which has been tentatively correlated with the *AB*-plane of the strain ellipsoid. Megascopic fabric of the conglomerate shows mainly orthorhombic symmetry.

Quartz lattice orientations, however, mostly exhibit monoclinic symmetry with a vertical symmetry plane (perpendicular to S_3) and a subhorizontal symmetry axis on S_3. Assuming fabric symmetry to be a reflection of the symmetry of movement (cf. SANDER 1948), slight rotational monoclinic movement in a vertical plane perpendicular to S_3 at the closing stage of the second phase of Monghyr Orogeny seems to have developed girdles of quartz c-axes around subhorizontal girdle axes. Quartz, which is very sensitive to deformation, reacted sympathetically to this last phase of mild movement, while the mesoscopic fabric retained the orthorhombic symmetry

PEBBLES

Fig. 4. Projection diagram of 200 quartz c-axes measured in gritty quartzite pebble (Z 576), contours 2–3–4–5% per 1% area, looking N 115°. The Figure shows an incipient oblique girdle with a partial small circle annular girdle to a horizontal axis. A strong 5% maximum lies on the trace of S_3. The fabric approaches monoclinic symmetry. In thin section, elongated to subrounded quartz grains (0.2 to 1.5 mm across) are embedded in a quartz-sericite matrix showing some recrystallization. Their preferred dimensional orientation marks the S_3 cleavage.

Fig. 5. Projection diagram of 200 quartz c-axes measured in quartzose shale pebble (Z 581), contours 3–4–5% per 1% area, looking N 124°. The Figure shows an incomplete peripheral girdle and also a tendency to form an incipient annular girdle with two 5% maxima. In thin section, angular to subangular (0.1 to 0.3 mm across) quartz grains are embedded in a fine-grained matrix of quartz and sericite showing preferred alignment parallel to S_3.

Fig. 6. Projection diagram of 200 quartz c-axes measured in altered rhyolite pebble (Z 584), contours 2–3–4% per 1% area, looking N 140°. The Figure shows two concentric girdles, one peripheral, with three 4% maxima, one of which lies very close to S_3, and the other an inner cleft girdle with a single 4% maximum and several submaxima. Symmetry of the fabric is monoclinic. In thin section, subrounded to oval quartz grains measure 0.1 to 0.6 mm across. The S_3 is marked by preferred orientation of quartz grains of different sizes and of sericite flakes.

Fig. 7. Projection diagram of 200 quartz c-axes measured in a quartzite pebble (Z 557), contours 2–3–4% per 1% area, looking N 120°. The Figure shows an incipient annular girdle having two 4% maxima on either side of the S_3-plane. A very incipient peripheral girdle is also developed. In thin section, the rock is fine-grained with elongated quartz grains and sericite flakes (0.06 to 0.2 mm) aligned parallel to S_3 cleavage. Wavy extinction is observed in most of the quartz grains.

Fig. 8. Projection diagram of 200 quartz c-axes measured in a quartzite pebble (Z 565), contours 2–3–4% per 1% area, looking N 130°. The Figure shows two concentric incipient girdles having two 4% maxima. One is peripheral and the other is annular exhibiting monoclinic symmetry. In thin section, elongated to subrounded quartz grains (0.2 to 0.9 mm long) with elongation index 1.5 to 2.0 show preferred orientation along S_3 and are surrounded by fine quartz-sericite mass. Nearly 50% of the quartz grains show wavy extinction.

Fig. 9. Projection diagram of 200 quartz c-axes measured in a quartzite pebble (Z 567), contours 2–3–4% per 1% area, looking N 114°. The Figure shows one cleft girdle within an incipient peripheral girdle. A single 5% peripheral maximum occurs in the plane of the peripheral girdle and many submaxima in the cleft girdle. In thin section, the S_3 is marked by the preferred orientation of elongated to subrounded quartz grains (0.06 to 0.5 mm long) and sericite flakes. The elongation index of the quartz grains is 1.2 to 2.0 and nearly 30% of the quartz grains show wavy extinction.

Fig. 4.

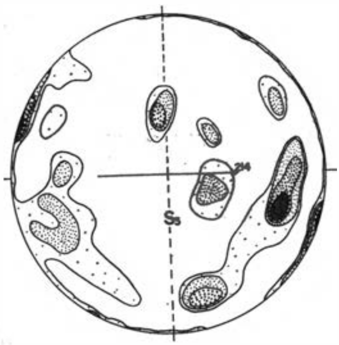


Fig. 5.

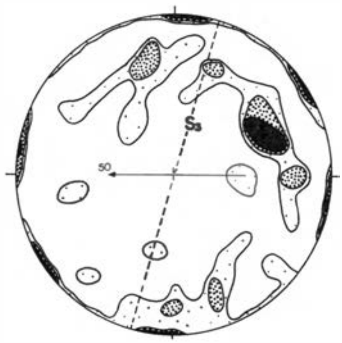


Fig. 6.

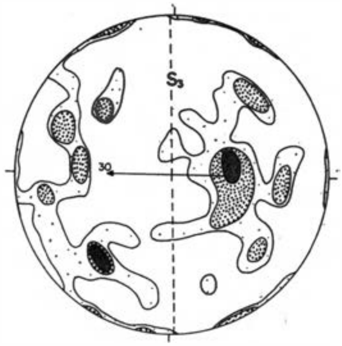


Fig. 7.

Fig. 8.

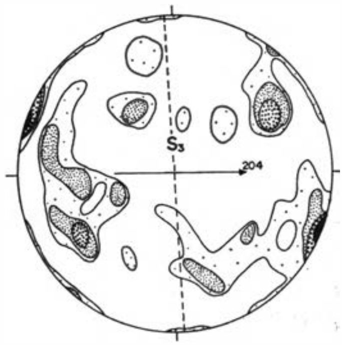


Fig. 9.

PEBBLES (continued)

Fig. 10. Projection diagram of 200 quartz c-axes measured in a shale pebble (Z 553), contours 2–3–4% per 1% area, looking N 120°. The Figure shows an incipient annular girdle and a peripheral girdle having a strong 5% maximum. In thin section, the pebble contains fine aggregate (less than 0.2 mm across) of quartz and sericite in nearly equal proportions showing preferred orientation along S_3 cleavage.

MATRIX

Fig. 11. Projection diagram of 200 quartz c-axes measured in quartzose matrix (Z 591), contours 2–3–4–7% per 1% area, looking N 110°. The Figure shows an oblique girdle with partial annular and peripheral girdles having a single strong 7% maximum and a few submaxima. In thin section, quartz grains (0.06 to 0.2 mm long) are elongated to subrounded showing weak preferred orientation. Wavy extinction is commonly seen in bigger grains.

Fig. 12. Projection diagram of 200 quartz c-axes measured in semi-quartzose matrix (Z 545), contours 2–3–4–5% per 1% area, looking N 120°. The Figure shows a well-developed annular girdle and a peripheral girdle with horizontal axis. One strong 5% maximum occurs at the periphery and several submaxima in the plane of the annular girdle. In thin section, a few subrounded to angular big quartz grains (0.3 to 0.6 mm long) occur in a fine-grained mesh of sericite and quartz grains which are less than 0.1 mm in length and are aligned parallel to S_3 cleavage.

Fig. 13. Projection diagram of 200 quartz c-axes measured in gritty matrix (Z 597), contours 2–3–4–5% per 1% area, looking N 95°. The Figure shows an oblique girdle with an incipient annular girdle to a nearly horizontal axis. Two 5% maxima occur in the plane of the girdle along with several submaxima. In thin section, it is gritty in nature. The bigger quartz grains are elongated to subrounded (0.6 to 5.4 mm in length). Some of them appear to have grown from the matrix by recrystallization enclosing partially recrystallized portions of matrix within them. A few quartz grains show deformation lamellae. The matrix around these big grains contains small quartz and sericite grains (less than 0.2 mm) showing preferred orientation parallel to S_3.

Fig. 14. Projection diagram of 200 quartz c-axes measured in gritty matrix (Z 602), contours 2–3–4–5% per 1% area, looking N 105°. The Figure shows a broad incomplete cleft girdle with two 5% maxima occurring within a faint peripheral girdle. The fabric has a monoclinic symmetry. In thin section, elongated quartz grains having elongation index 2.2 to 3.2 are seen surrounded by fine quartz and sericite mass showing preferred orientation along S_3.

Fig. 15. Synoptic projection diagram of pronounced maxima of quartz c-axes from Figs. 4 to 14 (maxima are numbered accordingly) with the trace of S_3. All sections are vertical and perpendicular to S_3 and data are shown on the lower hemisphere equal area projection.

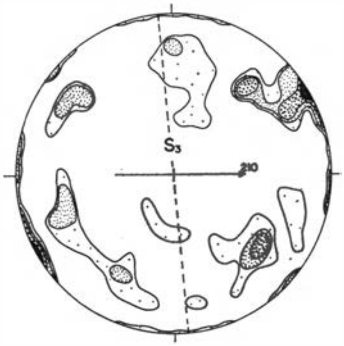


Fig. 10.

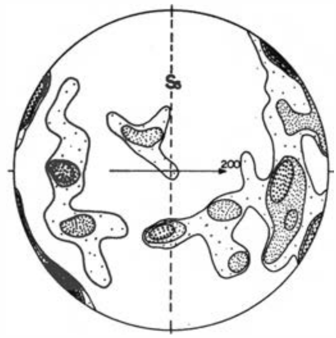


Fig. 11.

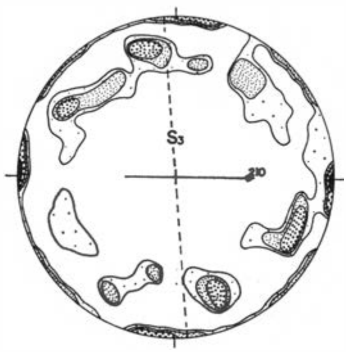


Fig. 12.

Fig. 13.

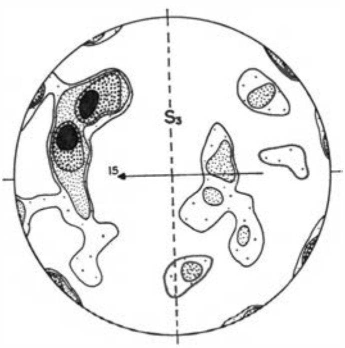


Fig. 14.

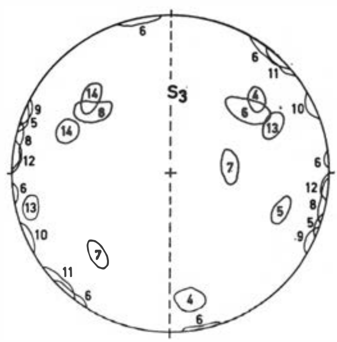


Fig. 15.

developed by the main compressional stress normal to S_3 during the second phase of the orogeny. In the macroscopic scale, however, B'-folds exhibit monoclinic symmetry in individual domains.

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