SOME EXAMPLES OF QUARTZ-GRAIN ORIENTATION IN TECTONITES AND NON-TECTONITES

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DIAGRAMS of quartz and biotite fabric of a porphyritic granite (Manbhum), prepared in this laboratory were the first of its kind in India (Sen, 1947, 1948). The petrotectonic interpretation of quartz axes fabric in tectonites and non-tectonites that have since been studied in this laboratory are presented in this paper. It discusses the quartz fabric of the wall rocks of the porphyritic granite in Manbhum (Sen, 1947, 1948, 1949), of sandstones, quartzites and arenaceous and argillaceous metamorphites of Darjeeling (Ray and Sen, 1948, 1949) and some quartzites from Chaibassa (Saha, 1949). The direct responsibility for both the fabric work and the interpretation, in case of the Darjeeling rocks, lies with the present author. The fabric of the Chaibassa quartzites was also studied under the guidance of the author and some of the interpretations were due to him.

Manbhum.—The fabric of 150 quartz axes of granite gneiss from Jhanpra $\left(73\frac{I}{11}, 22°\ 33'\ N;\ 86°31'\ E\right)$ forming the wall of the porphyritic granite shows a very high degree of axes concentration nearly that of a S tectonite, with little scattering in a zone intermediate between *ab* and *bc*, on the *ac* plane (Fig. 1c). The mean directions of the intersecting shear joints and the tension joints have been plotted on the *ac* fabric.

The *ac* quartz fabric of a specimen of quartzite, also occurring close to the porphyritic granite, from the north of Kotra (23°25′ N; 86°27′ E) shows an apparently high statistical orientation as only 50 grains were measured (Fig. 1*b*). As the specimen was not oriented in the field it cannot be compared with the first diagram (Fig. 1c): it may very well fit into the first, only the

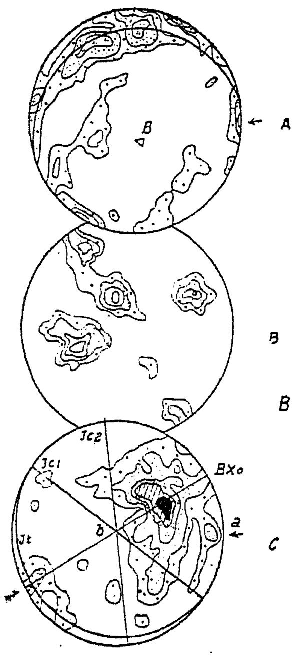

FIG. 1

Quartz Fabric (Manbhum)
A. 200 quartz axes of a quartzite from Ramchandrapur. B. Quartzite-forming wall, Kotra, 50 axes. C. 150 quartz axes of a granite-gneiss, Jhanpra.

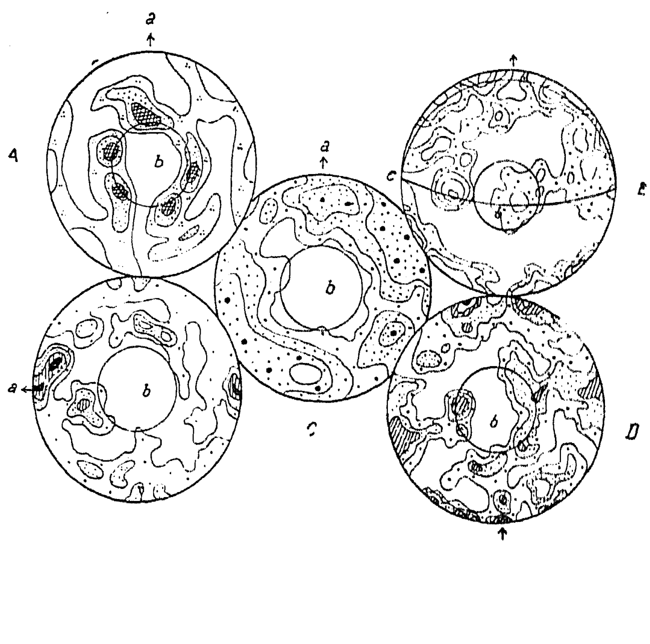

FIG. 2

Quartz Fabric (Darjeeling)
A. Gondwana sandstone, 150 axes. B. Gondwana sandstone from a shear zone, 200 axes. C. A specimen from Garnet zone 200 axes. D. Specimen 104 from Garnet zone 100 axes. E. 100 quartz axes from a kyanite-quartz rock, Kyanite zone.

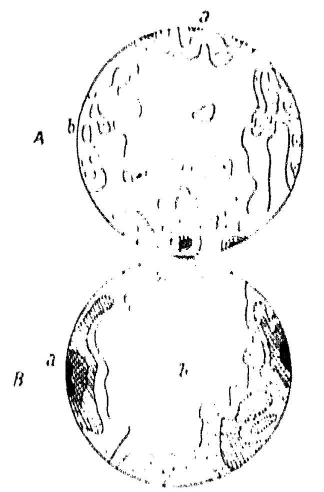

FIG. 3

Quartz Fabric (Chaibassa)
A. 60 quartz axes on *ab* of a quartzitic sandstone. B. 200 quartz axes of a quartzitic sandstone (idealised).

maximum lies closer to *b* than in the previous diagram.

The fabric of 200 quartz axes in the *ac* plane, of a quartz-sillimanite schist from near Ramchandrapur peak (23°34′ N; 86°48′ E) lying at an appreciable distance form the porphyritic granite, shows a well-developed peripheral *ac* girdle with a little spread along a plane intermediate between *ac* and *bc* (Fig. 1*a*). The specimen, coming as it does, from a region beyond an appreciable direct influence due to the intrusion of the porphyritic granite, shows the original fabric of the country rock, only slightly affected, if at all, by the intrusion.

The maximum in the first diagram lies close to the maxima VI and VII of the synoptic diagram (Fairbairn, 1944). It will be seen from the diagram (Fig. 1*c*) that the obtuse bisectrix of the intersecting shear joints, which has been recognised as the direction of compression (Sen, 1949) contains the maximum and is situated centrally about the distribution or the scattering of the axes.

The peripheral *ac* girdle is the original tectonitic fabric. The compressive force due to the intrusion of the granite, acting in the direction of the obtuse bisectrix of the conjugate shear planes, re-oriented the fabric, without, however, affecting the original *ab* plane. The fabric has been totally reconstituted, the original *ab* plane controlling the orientation. The maximum, on these premises, is really equivalent to maximum III of the synoptic diagram. The grains were ground mechanically, with the needle axes of the ruptured grains parallel to the horizontal edge (*m* : *r*) and with their unit rhombohedral bounding face lying in the original *ab* plane (Griggs and Bell, 1938). This suggestion of mechanical rupturing of the grains is not altogether conjectural or contrary to evidences. Indeed effect of cataclastation is clearly shown by mylonitic gneisses which are quite common along the wall. "With the ruptural stage predominant in the deformation (which came to an abrupt closure) the original *ab* plane remained in tact and served as the *structure control plane* for the reconstituted fabric. The grains were fractured and the axes gathered from their original disposition (a peripheral *ac* girdle) towards the *maximum* or in other words, the needle axes were rotated parallel to *a*" (Sen, 1949).

Darjeeling.—The quartz axes fabric of rocks from successive metamorphic zones, sandstones from the Tertiaries and Gondwana and specimens from the garnet and the kyanite zones were studied. The fabric of the successive stages reveal a progressive character which is significant. In a specimen from the garnet zone two *ac* girdles are found (Fig. 2*d*), one approximately 35° round *b* and the second peripheral. The first breaks up and joins with the peripheral girdle. In the higher grades the small *ac* girdle has been pushed off and only the peripheral girdle appears. The sandstones show a more perfect small *ac* girdle with only an incipient peripheral one. There is on the whole a discernible tendency for the higher grade rocks to show a more and more perfect equatorial *ac* girdle at the expense of the smaller one. The explanation put forward was that the smaller girdle is the original non-tectonitic fabric which thus appears better in the underformed Tertiaries. Ingerson and Raimisch had already found a similar small *ac* girdle in Siwalik sandstones, which they ascribe to an elongation of the clastic quartz grains parallel to (1011). This fabric was at first broken down (Fig. 2*c*) so that beyond the complete blank 30° round *b* the quartz axes were almost equally dispersed upto the periphery. Further deformation pushed forward the axes more and more to the equatorial zone as seen in the fabric of the specimen from the kyanite zone (Fig. 1*e*) which shows a perfect peripheral *ac* girdle, with a slight tendency to spread into a *bc* girdle.

A beautiful field evidence of the above explanation has been found recently from the fabric of a Gondwana sandstone (Fig. 2*b*) coming from a local shear zone. It is seen that, though the Gondwanas show a very strong small *ac* girdle, the above specimen lacks any distinct girdle in that region, the one round the periphery being prominent, though there are a good number of axes round the 35° zone giving a semblance of the original fabric. Within the peripheral *ac* girdle there are maxima closer to *a*. A careful study of the sheared quartz grains from the same specimen reveal lamellæ in the quartz which have an orientation parallel to a horizontal edge. The lamellæ have been developed in grains whose axes fall beyond 35° zone. These are seen only in highly sheared quartz grains. This may lead to the reasonable assumption that the lamellæ formed in response to the deformation, by translation along an horizontal edge, most probably $m : r$ (Fairbairn, 1939). The shifting of the girdle to the periphery has, thus, been performed by deformation gliding in a direction parallel to $m: r$, the translation might have occurred in any plane. The original fabric being interpreted as due to the needle axes of the clastic quartz grains lying parallel to c and bounded by unit rhombohedron, the presence of the *maxima* close to a (Fig. 2*b*) and the general position of the *maxima* within the small girdle, suggest a translation along a plane chiefly parallel to r.

Chaibassa.—The two specimens studied by Saha were not oriented in the field. One of these shows a normal peripheral *ac* girdle.

In the case of the second, in the small hand specimen, no distinct lineation in the *ab* plane was visible to help fixing up the *b* direction with certainty. The *b* fabric axis might have been recognized and marked out in the field, parallel to the regional tectonic strike or to some other local features like puckering and folding that might have been present, but which might have been too broad to come out in the hand specimen. Since nothing had been done in the field the interpretation has to be conjectural. In the *ab* girdle there are two *maxima* diametrically opposite. This direction has been taken to be parallel to *a*. For the girdle, I suggested an orientation by mechanical flattening in a deformation that was triaxial, causing an equivalent distribution close to *a* and *b* (Fig. 3*a*), the greater elongation parallel to *a* causing the *maxima* there. The *ab* girdle may, however, find other explanations. The somewhat cataclastic texture of the quartzites may support a suggestion of orientation by fracturing. There might have been, thus, a fracturing and rotation of the grains with their (1010) needle faces rotated parallel to *ab* and the needle axes parallel to *c* lying in any direction on *ab*. The explanation for the *maxima* near *a* is as above. The explanation may also lie in the manner of fracturing, with the needle axes parallel to *c* and also to the horizontal edge $m : r$ with the larger percentage having the former orientation. The distribution of axes round four zones as seen in the Figure (3*a*) may support this suggestion. Since, however, only 60 axes were measured, the distribution may give a false picture and the true fabric may be more or less a complete *ab* girdle. In such a case as the last mechanism does not explain the girdling, the former explanations seem more plausible. Whether the orientation was by fracturing and subsequent rotation, or by mechanical flattening, perhaps by translation, is difficult to be sure of, and a more detailed work is necessary.

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CARBON DIOXIDE ISOTOPES

Infra-red spectra of the sun studied at the McMath-Hulbert Observatory, University of Michigan, have revealed the presence in the earth's atmosphere of carbon dioxide made up of the less common isotopes of carbon and oxygen. These are carbon of atomic weight 13 (C^{13}) and oxygen of atomic weight 18 (O^{18}).

The isotopes of carbon dioxide, found by Drs. Leo Goldberg, Orren C. Mohler and Robert R. McMath, are $C^{13}O^{16}O^{16}$ and $C^{12}O^{16}O^{18}$, detected in several relatively faint band structures.

In view of the difficulties that arise in the comparison of the intensities of very strong and very weak absorption lines, it is not possible at present to derive accurate isotope abundances from the line intensities. But the relative intensities of these carbon dioxide isotopes appear to be consistent with the generally accepted abundances of C^{13} and O^{18}, which are respectively 1·1 per cent. and 0·20 per cent. of the more abundant isotopes of these two elements.—(By courtesy of *Sky and Telescope*, 1949, VIII, p. 124).