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FABRIC ANALYSIS OF A TRICLINIC TECTONITE AND ITS BEARING ON THE GEOMETRY OF FLOW IN ROCKS

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ABSTRACT. A triclinic tectonite from Anglesey showing asymmetrically oriented quartz and mica girdles is analyzed geometrically and kinematically. Some important features of the geometry of plane deformations with monoclinic symmetry are emphasized and discussed; and on the basis of these principles the fabric of the triclinic tectonite is interpreted in terms of one monoclinic deformation involving solid flow. It is concluded that a descriptive geometrical analysis on all scales must precede kinematic interpretation of fabric data.

INTRODUCTION

Fabric analysis of *B*-tectonites has demonstrated the existence of a commonly occurring type of fabric in which a single girdle of {001}-poles of mica, agreeing in symmetry with the main features of the megascopic fabric, is oriented asymmetrically with respect to an accompanying single girdle of [0001]-axes of quartz (Sahama, 1936; Turner, 1940; Wenk, 1943; Phillips, 1945; Kvale, 1953). With the possible exception of the granulite described by Sahama—in which the symmetry is dominantly orthorhombic—in these fabrics, generally, an apparent monoclinic symmetry defined by the megascopic fabric and the preferred orientation of mica is lowered to triclinic symmetry by the preferred orientation of quartz. The non-coincidence of the axes of the girdles has been universally interpreted to mean that the preferred orientation of mica and quartz has been effected by differently directed movements. Phillips (1945, p. 216) writes, with reference to the microfabric of the Moine schists: "Study of geographically oriented diagrams, however, shows that there is frequently a slight discordance between the attitude of the mica girdles on the one hand and the quartz girdles on the other in diagrams for the same section." Phillips goes on to suggest that this anomaly may indicate the effects of later movements upon an already existent preferred orientation of quartz. Kvale (1953, p. 60) likewise records discrepancies: "In some rocks, if the megascopic lineation deviates from the principal direction of movement (east-south-east) the micas form a girdle with the megascopic lineation as the *b*-axis, while the quartz axes form a girdle around an axis trending about east-south-east. This seems to indicate that the quartz grains reflect a later stage of deformation than do the micas." Neglecting Kvale's interpretation of the girdles and his views on the importance of fabric symmetry, it should be noted that he records quartz girdles more constant in orientation than either the associated megascopic fabric or the mica girdles. The writer has observed a similar phenomenon in southern Anglesey, a possible explanation of which will be outlined later in the paper.

In general, in such fabrics, each girdle is symmetrologically an *ac*-girdle for the fabric component concerned; and associated lineations lying in the foliation are symmetrologically *B*-lineations. The rocks are generally interpreted as $B \wedge B'$-tectonites, with one *B*-axis (*B*) parallel to the main lineation and axis of the mica girdle, and the other, later *B*-axis (B'), parallel to the axis of the quartz girdle. Movements about B', it has been argued, were insufficiently strong to reorient the mica fabric and destroy the symmetry of its megascopic manifestation (foliation, lineation and folds). The interpretation implies that quartz can acquire a marked preferred orientation in response to deformation with little or no movement in the fabric; and this view has become generally held in spite of the absence of supporting evidence of any kind.

This paper presents the results of fabric analysis of one such "$B \wedge B'$-tectonite" from near Gaerwen in Anglesey (N. Wales), analyzed during a regional study of the fabrics of the Penmynydd schists. The orientation data are interpreted by the writer in terms of a single symmetry-constant movement involving solid flow. Similar interpretations may be possible for some, but not necessarily all, similar triclinic $B \wedge B'$-fabrics referred to in the opening paragraph.

PRELIMINARY DISCUSSION

Monoclinic flow in rocks.—For the purpose of this paper we consider only the type of deformation which has been called rotational strain (Becker, 1893) and which is referred to more generally as slip upon one set of parallel *s*-surfaces (Knopf and Ingerson, 1938, p. 75-77; Turner, 1948, p. 164-166).[1] This is a plane deformation with monoclinic symmetry of movement. The deformation plane is the symmetry plane of the movements and is also the symmetry plane of the structures *newly* produced by the movements.

For rotational strain to occur, the resolved shear stress on the slip plane must exceed the resistance to shear (shear strength) on that plane. Since pre-existing *s*-surfaces of many sedimentary and metamorphic rocks are planes of relatively low shear strength, it is to be expected that they will commonly function as initial slip surfaces, even when the resolved shear stress acting upon them is somewhat less than the maximum possible value. In other cases, the pre-existing *s*-surfaces are so oriented in the field of stress that resolved shear stress upon them is too low for slip to occur. Slip must therefore take place upon some other plane upon which the resolved shear stress is high. The mode of development of this newly induced slip plane lies somewhere between two extremes:

1. Slip is concentrated upon parallel discrete surfaces separating layers of relatively undeformed material, as in displacement of a pack of cards. The slip surfaces are visibly expressed as strain-slip or fracture cleavage.

2. Slip is more or less evenly dispersed throughout the deformed rock even on a microscopic scale. Intragranular gliding and recrystallization are important componental movements, and the rock behaves "plastically."[2] Although no discrete individual surfaces of slip develop, the deformation still can be pictured in terms of slip upon a definite plane, or of slip upon surfaces spaced infinitesimal distance apart. The geometry of the deformation ap-

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[1] Nonplanar deformations involving solid flow with triclinic symmetry are beyond the scope of this paper.

[2] For a discussion of this usage of the term *plastic* see Knopf and Ingerson, 1938, p. 179-189; Turner, 1948, p. 225-237; and Fairbairn, 1949, p. 96-115.

proximates to that of plastic flow in a crystal or laminar flow in a fluid (Knopf and Ingerson, 1938, p. 33-36).

s-surfaces and s-planes.—The planar elements that are so characteristic of the fabrics of rocks have been termed *s-surfaces* (*s-flachen*) by Sander (1948, p. 105-107). Those produced by deformation are, as we have just seen, of two extreme types which, although grading one into the other, may conveniently be distinguished. In this paper they are respectively designated *s*-surfaces and *s*-planes.

1. *s*-surfaces are discrete, visible, more or less continuous surfaces exemplified by structures such as bedding foliation, strain-slip cleavage, segregation banding, and so on.

2. *s*-planes are defined statistically by preferred orientation of one or more constituent minerals. Thus, in the rock from Anglesey which forms the subject of this paper, sharply crystallized flakes of mica tend to be oriented with {001} inclined at a statistically constant angle to the foliation, but show no tendency to be positioned in discrete layers. This plane of preferred orientation of mica although not megascopically visible is an *s*-plane of the fabric.

In general, plastic deformation as defined above favors development of *s*-planes, whereas discontinuous deformation favors appearance or accentuation of *s*-surfaces. In rocks which have suffered flow, the degree of arrangement into surfaces of elements such as mica flakes or grains of quartz with a preferred orientation is a guide to the nature of the deformation. If deformation is continuous, that is, if each grain behaves as a deforming unit regardless of the behavior of the fabric as a whole, then no inhomogeneities (*s*-surfaces) are induced by the movements. On the other hand, if movement is not continuous on the scale considered, then inhomogeneities appear transgressing the whole fabric. Such slip surfaces can be on all scales, from microscopic *s*-surfaces separating layers of the thickness of a single grain or group of grains, to great movement horizons penetrating the largest of rock bodies.

Affine and non-affine deformation by slip.—A monoclinic deformation involving penetrative slip upon one plane is said to be affine if straight lines and planar surfaces within the deformed body before deformation remain straight lines and planar surfaces, respectively, after the deformation. A sphere becomes a triaxial ellipsoid with the mean axis (the axis of slip) as an axis of no change.[3] If, on the other hand, what were straight lines and planar surfaces before deformation, respectively become curved lines (lying in one plane) and curved surfaces after the deformation, then slip is said to be non-affine (Knopf and Ingerson, 1938, p. 75-77; Turner, 1948, p. 164-166). Both affine and non-affine deformation by slip are movements with monoclinic symmetry. Non-affine slip is probably more important than affine slip in the evolution of rock fabrics.

External and internal rotation.—In one type of non-affine deformation there is flexure of the slip plane giving flexural slip folding so that there is

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[3] In rocks this axis is not always an axis of no change. It is commonly an axis of elongation or axial flow (Weiss, 1954, p. 76), and under some conditions of deformation it may be an axis of shortening. But so long as there is no laminar slip along this axis, that is, so long as the symmetry of the deformation remains monoclinic, the deformation remains plane and its geometry is essentially unchanged.

an *external rotation* of one part of the slip plane with respect to another, and of both with respect to coordinates external to the deformed body (Turner, Griggs, and Heard, 1954, p. 898). The deformation remains plane during external rotation; and the axis of external rotation of all elements of the fabric is normal to the deformation plane.

During plane deformation by slip, inactive pre-existing planes (or surfaces) and lines (or lineations) in the fabric undergo *internal rotation*; that is, they are rotated through the fabric by componental movement, with reference to coordinates within the deformed body, in a manner and amount decided by their initial orientation and the degree of deformation. The geometrical principles underlying the internal rotation of one plane by gliding on another have been used by Turner, Griggs, and Heard (1954) in detailed analyses of structures produced in single crystals of calcite by experimental deformation. The axis of internal rotation of one plane by slip upon another is given by the line of intersection of the two planes, regardless of the direction of slip (Borg and Turner, 1953, p. 1348, fig. 3).

Surfaces undergoing internal rotation in rocks may contain one or more lineations. It is important therefore to determine also the axis of internal

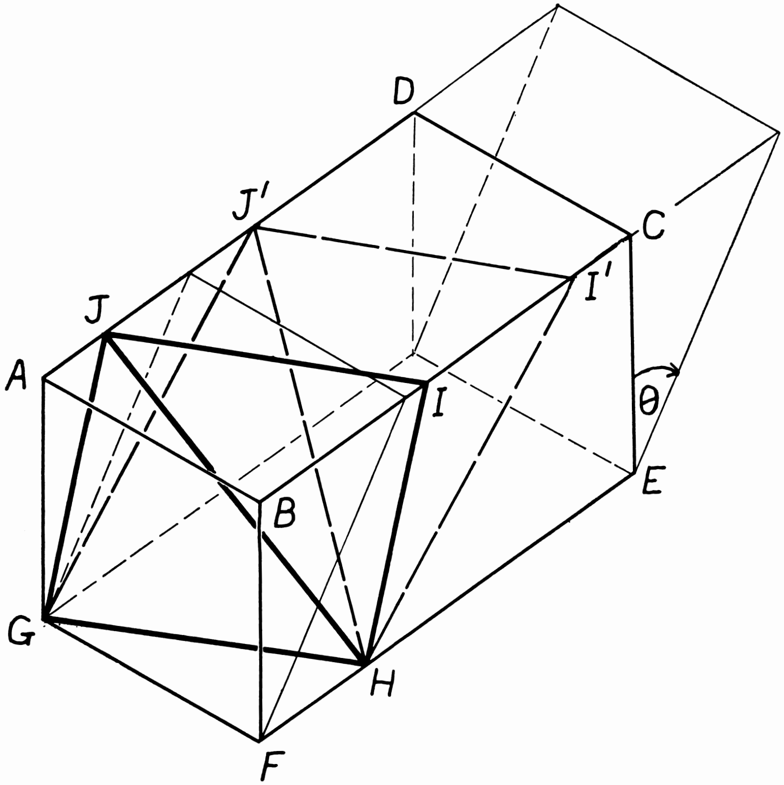

Fig. 1. Geometry of internal rotation of a plane *GHIJ* and a line *HJ* by affine slip upon the plane *ABCD*.

rotation of a line relative to that of a plane which contains it. In figure 1 a rectangular prism *ABCDEFG* contains a randomly oriented plane *GHIJ*, which in turn contains a line *HJ*. The prism is deformed by affine slip in direction *AD* on a plane *ADCB*, the angle of shear being Θ. The plane *GHIJ* is internally rotated about the axis *GH* to the position *GHI'J'*, and the line *HJ* is internally rotated to *HJ'*. No matter how great the amount of deformation, *J'* will always lie on *AD* (the direction of slip), and *HJ* will be internally rotated so that it always lies in a unique plane containing the direction of slip. The axis of internal rotation of any line is thus the normal to the plane containing the line and the direction of slip.

B-axes.—There is still, in structural geology, some confusion surrounding the recognition and significance of fabric axes in general and of *B*-axes in particular. It is beyond the scope of this work to trace the evolution of the concept of a *B*-axis; but it is necessary for what follows to define this axis for fabrics with monoclinic symmetry. For the moment we shall not consider *B*-axes in fabrics with either orthorhombic symmetry or triclinic symmetry resulting from the effects of one non-planar deformation.

One purpose of fabric axes is to facilitate description of rock fabrics in a fashion similar to that in which crystallographic axes are used in descriptions of crystals. This purpose may be termed *geometrical*, or, more properly, "*symmetrological*" (*symmetrologisch;* Sander, 1948, p. 132). There is, however, another and more important purpose in defining fabric axes, and that is to describe the movements responsible for the fabric in its present form. In this sense the axes are *kinematic*. It has been necessary, therefore, to define two distinct systems of axes which for ideal rock fabrics are identical. Each system of three orthogonal axes, *a*, *b*, and *c*, can be defined in terms of monoclinic symmetry—the first in terms of monoclinic fabric, the second in terms of monoclinic movement.

1. In the symmetrological system *ab* is the principal fabric plane. This is the most prominent surface in the fabric, that is, the foliation. The symmetry plane (which, since the symmetry is monoclinic, must be normal to *ab*) is *ac;* and *the normal to the plane of symmetry is b.* In many deformed rocks *ab* is folded with *b* as fold axis. Since *b* is therefore a direction of maximum continuity in the fabric (as well as the axis of symmetry), it is designated *B*.

2. The kinematic axes are defined for rotational strain involving slip upon one *s*-plane. The slip plane is *ab*, the deformation plane is *ac*, and *the normal to the plane of deformation is b.* The direction of slip is *a*. Deformation is commonly by flexural slip of *ab*; and *b*, as the axis of external rotation is again a direction of maximum continuity, designated *B*.

The relationships of these axes are summarized in table 1.[4]

The most fundamental principle of structural petrology—that upon which the kinematic analysis of fabrics is based—states that the symmetry of a deformed fabric preserves the symmetry of the movements which have produced

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[4] The two systems of axes as here defined have one fundamental difference. The symmetrological axes are *descriptive* in that they are applied directly to visible structures, whereas the kinematic axes are *genetic*, applying to the movements which have produced the structures.

TABLE 1

Axis	"Symmetrological" (descriptive)	Kinematic (genetic
b	Normal to plane of symmetry (*ac*).	Normal to plane of deformation (*ac*).
B=*b*	Axis of flexural slip folds of *ab*.	Axis of flexural slip movements.
	Axis of symmetry.	Axis of external rotation.
a	Normal to *B* in the foliation (*ab*).	Normal to *B* in the slip plane = direction of slip.
c	Normal to foliation (*ab*).	Normal to slip plane (*ab*).

that fabric (Sander, 1948, p. 81-83; Griggs, Turner et al., 1951, p. 905). For any rock deformed by slip or flexural slip upon a single foliation, the symmetry plane of the fabric is the deformation plane of the movements which have produced the fabric, and the symmetrological and kinematic axes are the same. This relationship, which is the basis of Sander's methods of fabric analysis, admits of no exception so long as the symmetry of the fabric is truly monoclinic.

Modification of pre-deformational s-surface and s-planes.—Monoclinic movements will give rise to monoclinic movements under three conditions only:

1 If the deformed fabric was statistically isotropic before deformation.

2. If the deformation was sufficiently prolonged or intense to remove by transposition all traces of structures in the original fabric.

3. If structures inherent in the fabric before deformation agreed in symmetry with the deforming movements.

Under all three conditions the *B*-axes defined symmetrologically coincide with those defined in terms of movement.

Conditions 1 and 2 do not concern us. The first is a special case of limited importance; and the second gives rise to fabrics the full structural history of which cannot be determined by fabric analysis. Much more commonly a monoclinic deformation acts upon an initially anisotropic fabric in which there is a single set of *s*-surfaces that may be designated *S*; for example, the bedding of a sediment, the flow banding of a rhyolite, or the foliation of a schist. Three cases may be recognized:

(a) *S* is planar and normal to the deformation plane. This condition is generally statistically fulfilled, at least in the early stages of deformation, during the primary deformation of horizontally bedded sediments and sedimentary rocks by slip on and flexural slip folding of the bedding in response to tangential stresses in the Earth's crust. The initially horizontal bedding is folded by movements with a vertical deformation plane; and the horizontal fold axis can be demonstrated on symmetrological grounds to parallel the kinematic *B*-axis. Condition 3 (above) is fulfilled, and the resultant fabric is monoclinic. But this is a special case reflecting special conditions of deformation.

(b) S is already folded, but the fold axis is normal to the deformation plane of the subsequent movements. Here too the resultant fabric is monoclinic (condition 3).

(c) The general case is that in which the deformation plane intersects S (whether this is planar or already folded generally depends on the scale of the field considered) at angles other than 90°. The foliation is generally unsuitably oriented to act as the slip plane of the deformation, and, under conditions of solid flow, a plane of affine or non-affine slip—again depending on the scale of the field considered—intersects and internally rotates S about axes which vary in orientation with the variation in the initial attitude of S. If this slip plane does not develop as a visible set of surfaces, then S remains the most conspicuous set of s-surfaces in the fabric. The symmetry of the fabric is triclinic.

Significance of triclinic symmetry.—It is normal procedure in fabric analysis (on all scales) to select the foliation of a deformed rock as the *ab*-plane and the main lineation or fold axis as the B-axis (Knopf and Ingerson, 1938, p. 213; Turner, 1948, p. 177; Fairbairn, 1949, p. 6). Triclinic fabrics (other than those produced by proved triclinic strain) are generally interpreted in terms of two or more B-axes lying in the foliation. It has been stressed by Sander that this is a tentative identification to await full analysis of the fabric for confirmation; nevertheless, it has given rise to fundamental misconceptions of the geometry of tectonites as illustrated by Fairbairn's (1949, p. 6) statement: "If foliation is developed, as is commonly the case, b lies in the foliation surface." This statement holds without exception *only for fabrics with undoubted monoclinic symmetry on all scales.* The fabrics of most tectonites, when all structural elements are taken into consideration, have slightly triclinic symmetry. By selecting a planar foliation in these rocks as *ab* we are limiting the orientation of B to a single plane, without proper regard for the symmetry of the fabric. Likewise, the unqualified equation of B with the fold axis in folded rocks with any degree of triclinic symmetry, however small, can be an oversimplification of the true geometrical facts. Folds with triclinic symmetry can be associated with monoclinic movements in at least two ways:

1. Folds of a set of s-surfaces (S_1) inherent in the fabric before deformation on an intersecting s-plane (S_2) can survive a certain degree of internal rotation, and retain their identity as folds, although not their orientation or direct kinematic significance.

2. Slip or flow folds of a set of inherent planar s-surfaces (S_1) can form by internal rotation in response to non-affine slip on an obliquely intersecting s-plane (S_2).

Although both of the above types of fold can have well-defined fold axes, these axes are not as a general rule parallel to the kinematic B-axes of the monoclinic deforming movements. The fabrics concerned show, on all scales, a tendency toward triclinic symmetry which expresses an equivalent tendency for the kinematic B-axis to depart from parallelism with the foliation. Even fabrics in which on a large scale there is statistical monoclinic symmetry can possess, on a small scale, some degree of triclinic symmetry. A genuinely monoclinic fabric, on the scale of one hand specimen, is very rare. In most tectonites a combination of lineations, folds, *s*-planes, *s*-surfaces and patterns of preferred orientation of minerals collectively defines triclinic symmetry of fabric.

To summarize; as a general rule, layered rocks that undergo monoclinic deformation by solid flow which does not agree exactly in symmetry with structures inherent in the predeformational fabric develop fabrics having overall triclinic symmetry. In such fabrics the kinematic *B*-axis commonly does not lie in the foliation, and its orientation must be determined by geometrical analysis of all orientation data. Common procedure of accepting foliation as *ab* and explaining triclinic symmetry in terms of superposed symmetrological *B*-axes, both lying in the foliation, leaves the way open for fundamental errors in interpretation of structural data. None of the *B*-axes determined symmetrologically, in effect, may be parallel to the kinematic *B*-axis. The tectonite now to be described will serve to illustrate these points.

THE TRICLINIC TECTONITE FROM ANGLESEY

Petrofabric analysis.—The rock is a dark brown quartz-albite-mica schist with a well-marked foliation defined by layers alternately richer in muscovite and deep brown biotite. The grain size is small (average mean grain dimension about 0.2 mm) and approximately uniform. In thin section the rock consists of a mosaic of equidimensional quartz grains, enclosing scattered non-twinned porphyroblasts of albite full of minute inclusions, small undeformed flakes of muscovite and biotite and small rounded granules of clinozoisite.

In the foliation (S_1) two lineations can be seen:

1. A very fine regular parallel ribbing (L_1).
2. A weaker more imperfectly developed lineation (L_2) inclined at 32° to L_1.

From several thin sections the preferred orientation of the poles of {001}-planes in muscovite and biotite and the [0001]-axes in quartz were measured and plotted on the lower hemisphere of an equal area projection. The preferred orientations of these directions are surprisingly homogeneous throughout the hand specimen, and the data for mica and quartz were rotated into the plane normal to L_1 and combined to give two synoptic diagrams (figs. 2a and 2b, respectively).

The poles of {001}-planes of the mica flakes are arranged in a strong maximum, actually a double maximum (fig. 2a), inclined to the pole of S_1, and spreading into a perfectly developed girdle about L_1. The plane (S_2), statistically defined by the weighted maximum of {001}-poles, intersects S_1 in L_1. The quartz diagram (fig. 2b) shows a preferred orientation of [0001]-axes in a broad girdle asymmetrically oriented with respect to L_1 and the mica girdle. An area of maximal concentration of axes is situated close to, but not in S_1. The axis of the girdle similarly is close to, but does not coincide with, L_2. Although no A.V.A. (Ramsauer, 1941; Weiss, 1954, p. 63-70) has been made, investigation with a gypsum-plate suggests that the preferred orientation of quartz is essentially homogeneous, that is, unrelated to slip surfaces in the fabric. The crystallization of quartz and mica is postkinematic.

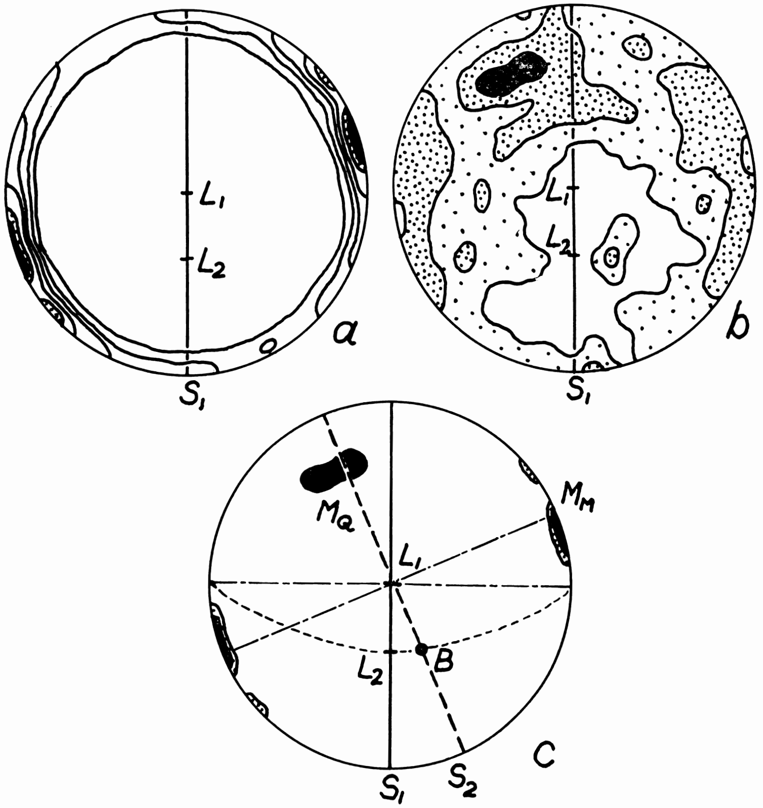

Fig. 2. Preferred orientation data from a triclinic tectonite from Anglesey.

a. 761 {001}-poles of muscovite and biotite. Contours: 2-4-6-8-10-12% per 1% area.

b. 600 [0001]-axes of quartz. Contours: 1-2-3% per 1% area.

c. Synoptic diagram to show the geometry of the fabric.

S_1—foliation.

S_2—*s*-plane statistically defined by the preferred orientation of mica.

L_1, L_2—lineation lying in the foliation.

M_Q—quartz maximum.

M_M—mica maximum.

B—axis of quartz girdle.

L_1 is horizontal, trending northeast—southwest: it is viewed in the southwest sense. S_1 dips 76° to the northwest.

Interpretation of fabric data.—The symmetry of the fabric is obviously triclinic. Two alternative interpretations of the data are given below. The first is consistent with normal procedure in fabric analysis as outlined in various reference books (Knopf and Ingerson, 1938, p. 213; Turner, 1948, p. 217; Fairbairn, 1949, p. 5-6). The second is based on the geometrical considerations outlined above and is that preferred by the present writer.

1. According to normal procedure, S_1 would be selected as *ab*, L_1 as one symmetrological *B*-axis, and L_2 as another. L_1 would be interpreted as

the earlier axis associated with the more intense movements responsible for the preferred orientation of mica, and L_2 would be attributed to later much weaker movements sufficiently strong only to reorient the quartz and leave a faint lineation. Each symmetrological B-axis would be considered to coincide with a corresponding kinematic B-axis, and the tectonite would be interpreted as a $B \wedge B'$-tectonite in terms of two monoclinic deformations.

2. A completely different interpretation of these same fabric data, based on geometrical analysis, is more satisfactory in that it explains several features of the quartz fabric that otherwise appear merely coincidental. First, the girdle of [0001]-axes is more nearly normal to B (fig. 2c) than to L_2 (fig. 2b). Second, as seen in figure 2c, B lies in the statistically defined plane S_2. Third, the maximum concentration of [0001]-axes also lies in S_2 and is roughly normal to B. All these features can be correlated with deformation by slip normal to B in a slip plane S_2, in which case the main quartz axis maximum would be equivalent kinematically to the familiar Maximum I of Sander's synoptic diagram (Turner, 1948, p. 260). Moreover, S_2 intersects S_1 in L_1, the axis of the mica girdle, and it is the plane of preferred orientation of {001}-planes of mica. In other words, the movements upon S_2 are responsible for the preferred orientation of both mica and quartz. Non-coincidence of mica and quartz girdles can be explained by assuming that mica in the initial fabric was oriented parallel to S_1 and that S_1 was internally rotated during the subsequent deformation by slip on S_2 normal to B. We know that this slip was affine on the scale of one hand specimen; otherwise S_1 would be slip folded about L_1 as fold axis. The mica flakes rotated from S_1 toward S_2 have assumed a pattern of preferred orientation in a girdle whose axis is L_1—the intersection of S_1 and S_2—although *this axis is not the kinematic B-axis of the deforming movements*. The only kinematic B-axis recognizable in the fabric is B, the axis of the quartz girdle, which does not lie in the foliation (S_1). The lineation L_2 is the projection or trace on S_1 of a linear structure (most probably an elongation of quartz grains) lying in S_2 parallel to B. The geometry of this trace is shown in figure 2c—the plane normal to S_1 containing B intersects S_1 in L_2 (Clark and McIntyre, 1951, p. 757).

The evolutionary history of the fabric may be summarized as follows: a rock with either a sedimentary or metamorphic layering (S_1) was deformed by continuous plane deformation involving affine slip upon a mechanically induced slip plane (S_2). The deformation was sufficiently homogeneous to prevent the development of discrete microscopically visible *s*-surfaces of slip. The kinematic B-axis lay not in the initial foliation (S_1) but in the mechanically induced plane of slip (S_2). The mica flakes initially lying in the foliation were rotated about L_1 toward the slip plane S_2. The preferred orientation of quartz suggests that there was an incipient alignment of [0001]-axes in the slip direction (the kinematic *a*-axis), accompanied, perhaps, by fracture and granulation of the previously existing quartz grains. Such a cataclastic history of the quartz would be concealed by the complete postkinematic crystallization which has affected the fabric, although the preferred orientation would be preserved. The mica flakes may have recrystallized more nearly parallel to the actual plane of slip than they were brought by rotation during the deformation.

The quartz and mica girdles, although not coaxial, have thus been produced during a single phase of movement. The kinematic *B*-axis of this movement is most clearly defined by the preferred orientation of quartz; whereas the slip plane S_2 is defined by the preferred orientation of mica and to a lesser extent quartz. The megascopic fabric considered alone gives no guide to the orientation and significance of the kinematic *B*-axis. Neither of the two lineations visible in the foliation is parallel to *B*, although movements normal to it have produced them both.

GENERAL CONCLUSIONS

1. Not all visible lineations in tectonites represent *B*- or *a*-axes. Nor are all triclinic fabrics produced by two superposed non-coaxial deformations. On the contrary, many triclinic fabrics are products of monoclinic deformations acting upon initially layered fabrics which do not agree in symmetry with the deforming movements. Lineations in these fabrics commonly parallel the intersection of the initial lamination with the slip plane (axis of internal rotation), and do not have constant orientation although the kinematic *B*-axis lying in the slip plane does. This concept may be stated in a different manner. It is commonly assumed that the *B*-axis of a deformed fabric lies in the foliation. This may be a general rule for rocks deformed by proved slip upon the foliation; but it cannot apply to many rocks which have suffered solid flow during plane deformations in which the *B*-axis transects structures inherent in the initial fabric.

2. For this reason current procedure of selecting tentatively the most prominent surface in the rock as *ab*, and the most prominent lineation as *B*, is liable to give rise to a basically two dimensional interpretation of the orientation data, governed by the foliation. A more descriptive primary nomenclature is advised: S_1, S_2 and so on for surfaces and planes, L_1, L_2 and so on for lineations, and F_1, F_2 and so on for the axes of folds. Complete fabric analysis, on all scales, of selected specimens and areas should follow, with particular attention paid to geometry and symmetry of fabric.

3. Microscopic fabric analysis is of great importance in structural geology as a means of evaluating the significance of megascopically visible lineations, folds and so on, and of demonstrating the existence of statistically defined *s*-planes. The constant orientation of quartz girdles, regardless of the megascopic fabric, recorded in Bergsdalen by Kvale and in Anglesey by the writer, suggests the presence of a constantly oriented kinematic *B*-axis in these two areas. The importance of mica as a guide to the kinematics of a fabric lies in its tendency to become oriented with {001} lying in planes and surfaces. The {001}-poles of mica define not only axes of external rotation of surfaces but also axes of internal rotation which are not always *B*-axes. The non-equidimensional habit of mica means that its initial orientation will exert an influence upon its final orientation during movement in a fabric. This property it shares with all surfaces in rocks, together with which it may be classed as a *dependent* fabric element. Quartz, on the other hand, with no tabular habit,

is more free from influence of an initial orientation; and it tends to reflect more nearly in its orientation the geometry and symmetry of the movements by which the orientation is produced. Quartz may be classed as an *independent* fabric element.

4. Non-coaxial quartz and mica girdles have hitherto been considered evidence in favor of the view that quartz can acquire a preferred orientation, by some unknown mechanism. without appreciable penetrative movement in a fabric. Therefore. fabrics showing such girdles should be subjected to the most thorough geometrical and kinematic analysis in order to confirm that the differently oriented girdles do not merely record different axes of rotation of the same movements.

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