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DYNAMIC INTERPRETATION OF THE FABRIC OF A DOLOMITE FROM THE MOINE THRUST-ZONE IN NORTH-WEST SCOTLAND

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ABSTRACT. Petrofabric studies on naturally and experimentally deformed dolomite indicate that the main mechanisms of plastic deformation of dolomite, under most conditions, are twin-gliding on $\{02\bar{2}1\}$ and translation-gliding on $\{0001\}$. The fabric of a dolomite with mylonitic textures is analysed and interpreted in dynamic terms. The grains in the rock contain numerous $\{02\bar{2}1\}$ twin lamellae and also internally rotated lamellae of the type observed in experimentally deformed dolomite and designated L_{θ}. Compression and tension axes inferred from twinned $\{02\bar{2}1\}$ lamellae are statistically parallel to those inferred from L_{θ} lamellae. The strain calculated from the amount of rotation of L_{θ} lamellae varies from 5 to 18 percent for individual grains; it is concluded that these figures are probably less than the total post-crystalline strain in the rock.

INTRODUCTION

Recent fabric studies of experimentally deformed dolomite rock (Turner, Griggs, Heard, and Weiss, 1954; Handin and Fairbairn, 1955) and of single crystals of dolomite (Higgs and Handin, 1954) have elucidated the mechanisms of plastic deformation of dolomite at temperatures below 400°C. The present paper describes the fabric of a dolomite tectonite from the Moine Thrust-zone in the Assynt district of Sutherland, Scotland.[1] The fabric of this specimen is of particular interest as some of its constituent grains contain internally rotated lamellae of the type recorded in experimentally deformed dolomite but not hitherto described in naturally deformed rocks. A dynamic interpretation of the $\{02\bar{2}1\}$ twin lamellae and rotated lamellae is made in the light of the experimentally established data, and the mechanism of deformation of the rock is tentatively discussed.

INTRAGRANULAR DEFORMATION OF DOLOMITE

Inferred from Natural Fabrics.—The first detailed study of dolomite orientation in deformed rocks was made by Fairbairn and Hawkes (1941). Analyses of the orientation of the lattice and twin lamellae in a number of specimens from Montana, Vermont and Ontario were recorded and a possible mechanism of deformation was inferred from the data. The authors found that $\{02\bar{2}1\}$ twin lamellae were extensively developed in all the specimens, and the orientation of the lamellae in the fabric of the rocks led them to conclude that the sense of gliding in twinning on $\{02\bar{2}1\}$ was opposite to that for twinning on $\{01\bar{1}2\}$ in associated calcite. They considered that translation-gliding on $\{0001\}$, which had been produced experimentally by Johnsen (1902), might also be of some importance as an orienting mechanism, though this would be difficult to prove in view of the difficulty of identifying the process by optical means.

In a comprehensive study of Alpine dolomite-tectonites, Ladurner (1953)

[1] The specimen (M14) was collected from a body of crystalline dolomite underlying the Moine Thrust at Benmore Lodge near Loch Ailsh. It is one of five similar specimens analyzed as part of a detailed structural study of the area. The fabrics of the remaining four specimens are described elsewhere (Christie, 1956) and related to the visible megascopic structures in the rocks of the thrust-zone.

recorded the orientation of [0001]-axes in more than 40 specimens from various parts of the Alps. On the basis of the preferred orientation of [0001]-axes he classified the rocks into *S*-tectonites and three types of *B*-tectonite, according to the number of *s*-planes and symmetry planes which he recognized in the fabrics. The similarity between synoptic diagrams showing maxima of [0001]-axes in dolomite-tectonites and analogous diagrams for calcite-tectonites led Ladurner (1953, p. 290, 296) to assume that the same mechanism was responsible for producing the preferred orientation in dolomites as was postulated by Felkel (1929) for calcite: namely, gliding on $\{01\bar{1}2\}$, combined with rotation of the $\{01\bar{1}2\}$ planes about the *B*-axis of the fabric. This conclusion is invalidated by the experimental work of Turner, Griggs and Heard (1954), who have shown that translation-gliding in calcite occurs, not on $\{01\bar{1}2\}$, as thought by Felkel, but on $\{10\bar{1}1\}$, and at room temperatures on $\{02\bar{2}1\}$. Moreover, experimental work on dolomite up to the present time (see below) gives no indication that gliding on $\{01\bar{1}2\}$ occurs in dolomite, nor is such a mechanism compatible with the geometry of the dolomite lattice.

Determined by Experimental Deformation of Dolomite.—Early attempts to produce twinning experimentally in dolomite were unsuccessful but Johnsen (1902) recorded translation-gliding in deformed crystals with {0001} as the glide plane and one of the *a* crystal axes as the glide line. More recently two glide mechanisms were demonstrated for dolomite (Dover Plains dolomite rock) compressed 9.4 percent at 380°C and 3,000 atmospheres confining pressure (Turner, Griggs, Heard and Weiss, 1954):

1. "twin-gliding on $\{02\bar{2}1\}$, the sense of shear being such that the upper layers of the crystal lattice are displaced downwards from the upper end of the *c*-axis," that is, with a *negative* sense of shear (Turner, Griggs and Heard, 1954, p. 897);
2. "translation-gliding on {0001}, with the *a*-axes as probable glide directions."

Deformation of single crystals of dolomite at room temperature and at 300°C (Higgs and Handin, 1954) confirms the above conclusions: the crystals deformed at 300°C by translation-gliding on {0001} and by twin-gliding on $\{02\bar{2}1\}$ with a negative sense of shear; the latter mechanism was not identified in crystals deformed at room temperature. Twin-gliding on $\{02\bar{2}1\}$ was also found by Handin and Fairbairn (1955) in their experiments on Hasmark dolomite rock. Bradley, Burst and Graf (1953) have shown, moreover, that these two glide mechanisms would account for the progressive changes observed in the lattice of dolomite after prolonged grinding.

DYNAMIC INTERPRETATION OF LAMELLAE IN NATURALLY DEFORMED DOLOMITE ROCK

Inferences of two independent kinds, concerning the dynamics of deformation, may be drawn from $\{02\bar{2}1\}$ lamellae in naturally deformed dolomite rocks:

The first is analogous to the dynamic interpretation of twin lamellae in calcite marbles, described by Turner (1953). Figure 1a shows the orientation of $\{02\bar{2}1\}$ twin lamellae in relation to the [0001]-axis in dolomite twinned on

$\{02\bar{2}1\}$. The angle between [0001] and the pole of the lamellae, $\{02\bar{2}1\}$, is 62½°. The applied stresses which would be most effective in causing twin-gliding on $\{02\bar{2}1\}$ with a negative sense are also shown in figure 1a: a compression applied in a direction designated C, or a tension in a direction T. For either, the coefficient of resolved shear stress on $\{02\bar{2}1\}$ would have the maximum possible value, 0.5.

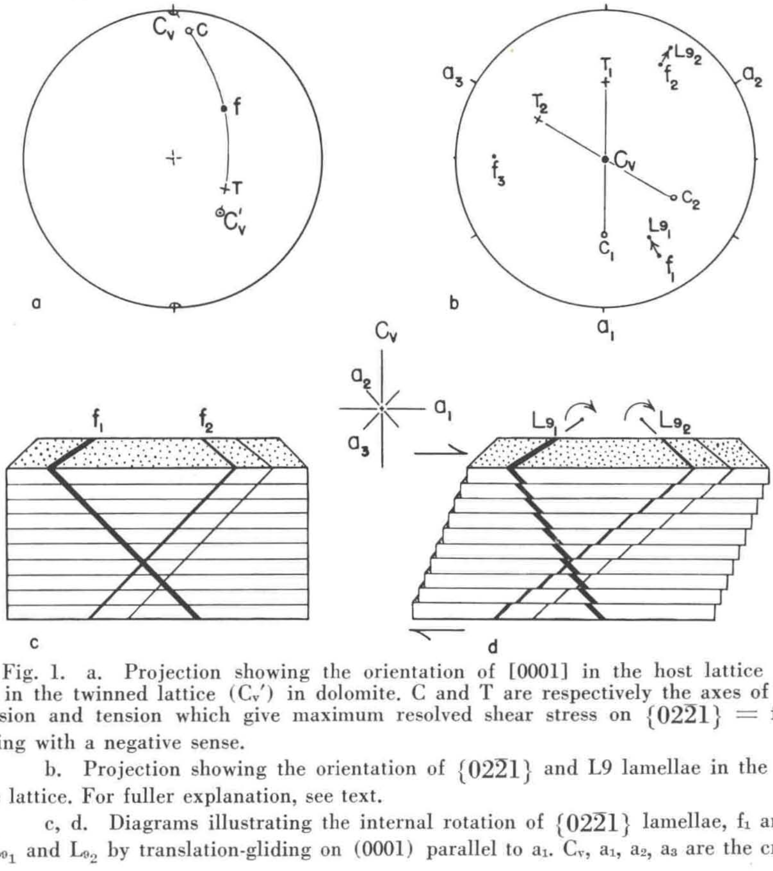


Fig. 1. a. Projection showing the orientation of [0001] in the host lattice (C_v) and in the twinned lattice (C_v') in dolomite. C and T are respectively the axes of compression and tension which give maximum resolved shear stress on $\{02\bar{2}1\}$ = f, for gliding with a negative sense.

b. Projection showing the orientation of $\{02\bar{2}1\}$ and L9 lamellae in the dolomite lattice. For fuller explanation, see text.

c, d. Diagrams illustrating the internal rotation of $\{02\bar{2}1\}$ lamellae, f_1 and f_2, to L_{9_1} and L_{9_2} by translation-gliding on (0001) parallel to a_1. C_v, a_1, a_2, a_3 are the crystal axes.

The second kind of inference is drawn from internally rotated $\{02\bar{2}1\}$ lamellae of the type designated L_9 by Turner, Griggs, Heard and Weiss (1954). Following Turner, et al., it is assumed that these have been rotated by translation on {0001} parallel to one of the *a* crystallographic axes. In the experimentally deformed Dover Plains rock only one set of L_9 lamellae were found in any grain; but in the specimen here described two sets of L_9 lamellae are present in several grains, allowing unique identification of the active glide direction. The orientation of these two sets of lamellae in the dolomite lattice is shown in figure 1b. Figures 1c and d illustrate diagrammatically the phenomenon of translation-gliding on {0001} in dolomite. The lattice orientation (C_v, a_1, a_2, a_3) is unchanged by gliding. Pre-existing $\{02\bar{2}1\}$ lamellae, f_1 and f_2, are internally rotated about axes which are the intersections of the lamellae $\{02\bar{2}1\}$ with the glide plane $\{0001\}$, that is, the *a* crystal axes. The sense of internal rotation about the axes of internal rotation is the same as the sense of shear on the glide plane. Following gliding parallel to a_1 the lamellae f_1 and f_2 are rotated about a_3 and a_2 respectively and so assume the new orientations $L_{\theta 1}$ and $L_{\theta 2}$. If three sets of $\{02\bar{2}1\}$ lamellae are present in a grain before the inception of translation-gliding on $\{0001\}$, the axes of potential internal rotation are parallel to the three *a*-axes of the lattice. But it is evident that only two sets of lamellae can undergo rotation by gliding, since the axis of potential rotation for the third set is parallel to the glide line. Since a_2 and a_3 are the axes of internal rotation of $L_{\theta 1}$ and $L_{\theta 2}$, the only possible glide direction is a_1 and the sense of slip on the glide plane is given by the sense of rotation of the L_9 lamellae. Optimum directions of compression and tension which would give maximum resolved shear stress on the $\{0001\}$ glide system so deduced are C_1 and T_1. Such axes of compression and tension may be determined for all grains in which two sets of L_9 lamellae are recorded. For grains in which only one set of L_9 lamellae is present or is accessible for measurement, there is a choice of two possible glide directions and there are two alternative orientations of both C and T. For example, if only $L_{\theta 1}$ lamellae are present (fig. 1b), the axis of internal rotation of $L_{\theta 1}$ is a_2 and the active glide line may be either a_1 or a_3; the inferred directions of applied stress are C_1 and T_1 or C_2 and T_2.

THE LOCH AILSH DOLOMITE

Description of the Fabric.—The specimen (M14) described below is a pure, massive crystalline dolomite with no trace of foliation or lineation. The only impurity in the rock is quartz, in the form of small, isolated grains making up considerably less than 1 percent of the rock. The dolomite grains, which are more or less uniform in size (average mean grain diameter = 0.54 mms.), show a high degree of post-crystalline strain: all contain well-developed $\{02\bar{2}1\}$ twin lamellae, and a few show undulose extinction. There is considerable granulation along grain boundaries, the minute interstitial granules comprising approximately 27 percent of the rock (measured by means of a point counter in 3 mutually perpendicular sections). There is a weak dimensional orientation of the main grains: the majority of the grain sections in all three sections are equidimensional, but a limited number in each section are slightly elongate parallel to a common direction in the fabric.

To overcome limitations due to orientation of any single section relative to the fabric, the analysis was carried out on three mutually perpendicular sections cut from the specimen. Lamellae which are inclined at low angles (less than 35°) to a section are not accessible for measurement with the universal stage, so that there is a corresponding central "blind spot" in every fabric diagram. Since the three $\{02\bar{2}1\}$ planes in dolomite are inclined to each other at approximately 80°, one set of lamellae is inaccessible in most grains. It should be noted that L_9 lamellae can be recorded satisfactorily only if the intersection $[L_9: 02\bar{2}1]$ can be rotated into parallelism with the microscope axis. Consequently, in any section, L_9 lamellae can be measured only in grains with a limited range of orientation. The range of orientation of grains in which two sets of L_9 lamellae can be measured is obviously further restricted. Thus, in order to obtain a reliable statistical estimate of the orientation of L_9 lamellae in a rock it is necessary to examine at least three sections with different orientation.

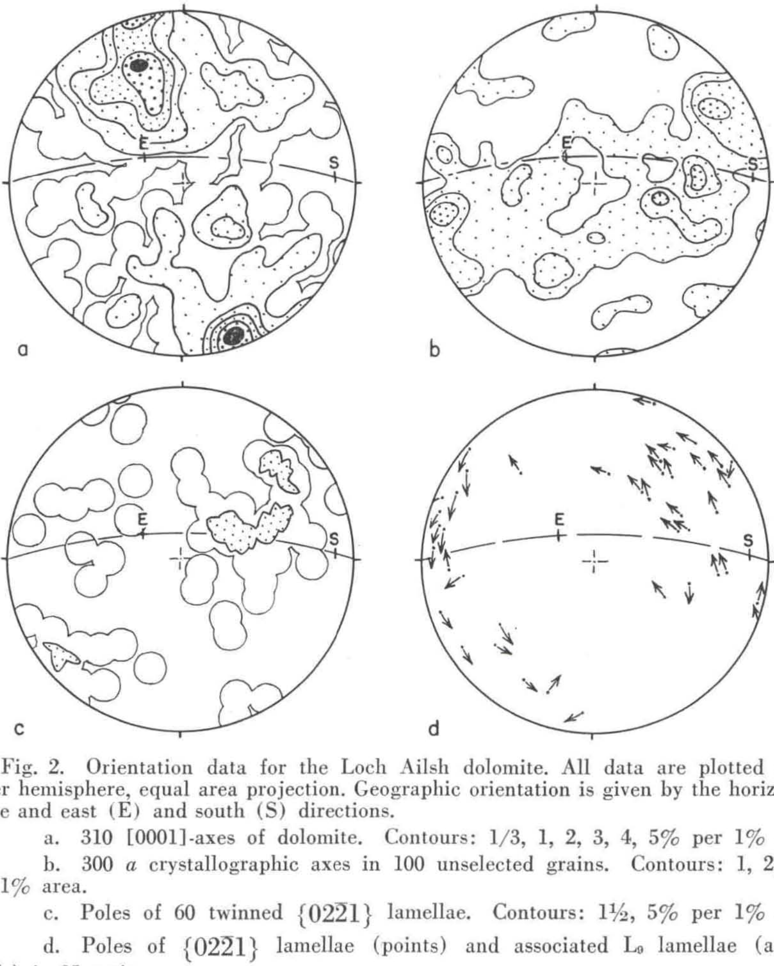


Fig. 2. Orientation data for the Loch Ailsh dolomite. All data are plotted on a lower hemisphere, equal area projection. Geographic orientation is given by the horizontal plane and east (E) and south (S) directions.

a. 310 [0001]-axes of dolomite. Contours: 1/3, 1, 2, 3, 4, 5% per 1% area.

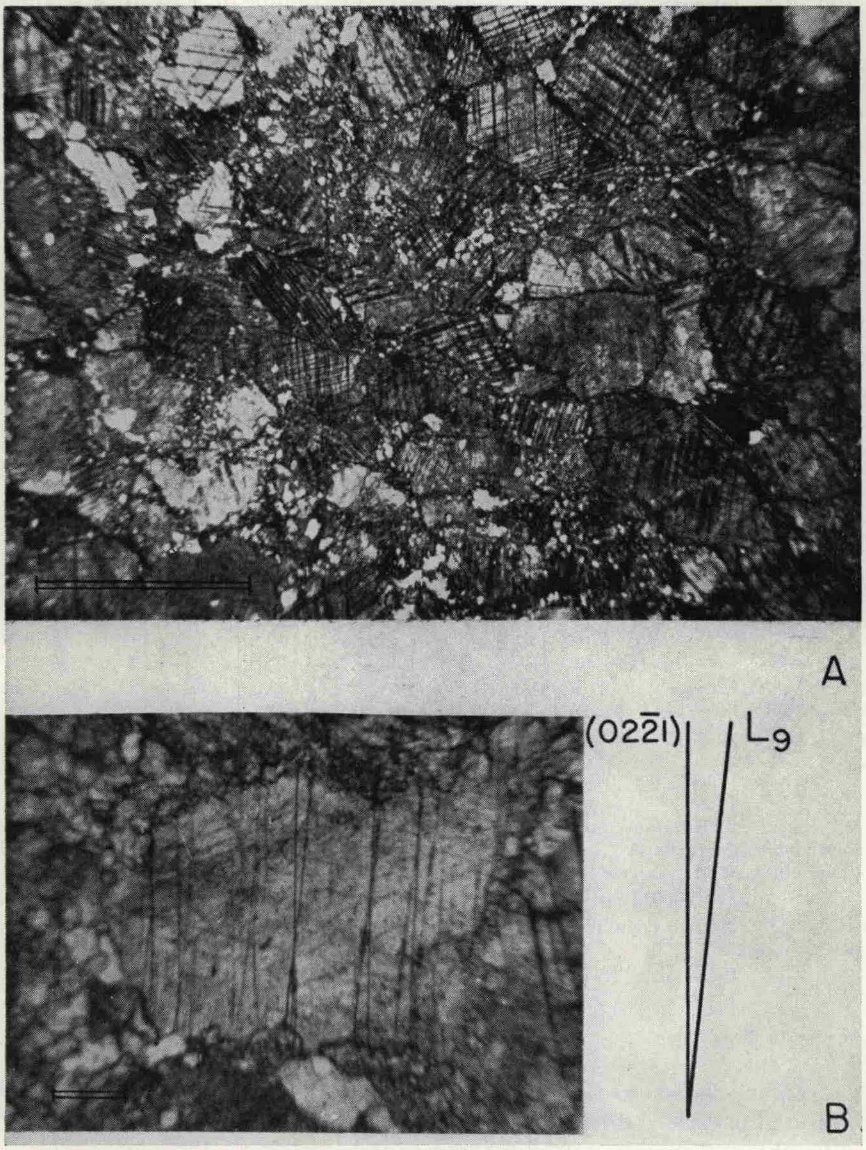
b. 300 *a* crystallographic axes in 100 unselected grains. Contours: 1, 2, 3% per 1% area.

c. Poles of 60 twinned $\{02\bar{2}1\}$ lamellae. Contours: 1½, 5% per 1% area.

d. Poles of $\{02\bar{2}1\}$ lamellae (points) and associated L_9 lamellae (arrowheads) in 35 grains.

Figure 2a shows the preferred orientation of 300 [0001]-axes, 100 measured in each of three mutually perpendicular sections. A strong similarity in the three component partial diagrams (each containing 100 axes) indicates a high degree of homogeneity within the field of the specimen. There is a single area of concentration, containing two maxima of equal intensity approximately 30° apart, and there is some suggestion of a girdle, the axis of which is nearly horizontal in figure 2a. The orientation of the *a* crystallographic axes (figure 2b) is restricted by the strong preferred orientation of the [0001]-axes: they are disposed in a broad zone normal to the maximum

PLATE 1



A. Photomicrograph showing the texture of the Loch Ailsh dolomite. Scale line represents 1mm.

B. Single grain showing L_9 lamellae intersected by later $\{02\bar{2}1\}$ lamellae. The intersection of the two sets of lamellae is vertical. Scale line represents .1mm.

of [0001]-axes, and there is a concentration near the periphery of the diagram (i.e. parallel to the girdle axis of the [0001] diagram).

As shown in plate 1A $\{02\bar{2}1\}$ lamellae are strongly developed in all the grains. An analysis of the lamellae is given in tables 1 and 2. The majority of the grains contain three sets of $\{02\bar{2}1\}$ lamellae; but it is remarkable that there is optically recognizable twinning in only 20 percent of the grains, and in these it is generally present on only one set of lamellae. The orientation of recognizably twinned lamellae (60 lamellae in 58 grains) is shown in figure 2c. The poles of the lamellae define a single maximum.

TABLE 1*

Percentage of Grains Showing Twinned and Non-twinned $\{02\bar{2}1\}$ Lamellae

Number of sets of lamellae per grain	Percentage of grains
3 sets	71%
2 sets	25%
1 set	4%
No sets	0%

Rotated L_9 lamellae were recorded in 35 of the grains examined. These lamellae (plate 1B) differ from $\{02\bar{2}1\}$ lamellae in being less sharply defined; they have a discontinuous, granular appearance and their orientation is consequently more difficult to measure accurately than that of twin lamellae and cleavages. The L_9 lamellae may frequently be recognized by this characteristic appearance; but as this is not invariably so, and to avoid errors of identification, they were recorded only where associated with later lamellae having rational $\{0221\}$ orientation (plate 1B). Turner, Griggs, Heard and Weiss (1954) record only one set of L9 lamellae per grain in their experimentally deformed dolomite rock, but two sets of L_9 lamellae are present in four of the grains analyzed in the Loch Ailsh rock. Figure 2d shows the orientation of the L_9 and associated $\{0221\}$ lamellae in the specimen; all but two of these sets of L_9 lamellae were measured in the section with the same orientation as the diagram. The angle between L_9 and $\{02\bar{2}1\}$ varies between 5° and 12°,

TABLE 2*

Percentage of Grains Showing Twinned $\{02\bar{2}1\}$ Lamellae

Number of sets of lamellae per grain	Percentage of grains
3 sets	0%
2 sets	1%
1 set	19%
No sets	80%

* The above analyses are based only on grains in which all three planes were accessible for measurement with the U-stage. Lamellae parallel to $\{02\bar{2}1\}$ which are not recognizable as twin lamellae are described as "non-twinned" to distinguish them from lamellae in which the orientation is visibly different from that of the host grain ("twinned lamellae"), as in Borg & Turner, 1953.

with a mean value of 8½°, a figure which is comparable with that obtained in the dolomite deformed by Turner et al. The sense of rotation of $\{02\bar{2}1\}$ to L_9 is statistically constant.

Dynamic Interpretation of the Fabric.—The axes of compression and tension which would be most effective in causing the observed twinning are shown in figure 3a. It is clear that a strong compression parallel to the direction C, or a tension parallel to the direction T could account for all the observed twinning. Figure 3b shows the glide lines (a) and axes of compression (C) and tension (T) deduced for the four grains in which two sets of L_9 lamellae were recorded. For the 31 grains with one set of visible L_9 lamellae the 62 *possible* glide lines are shown contoured in figure 3c (unshaded

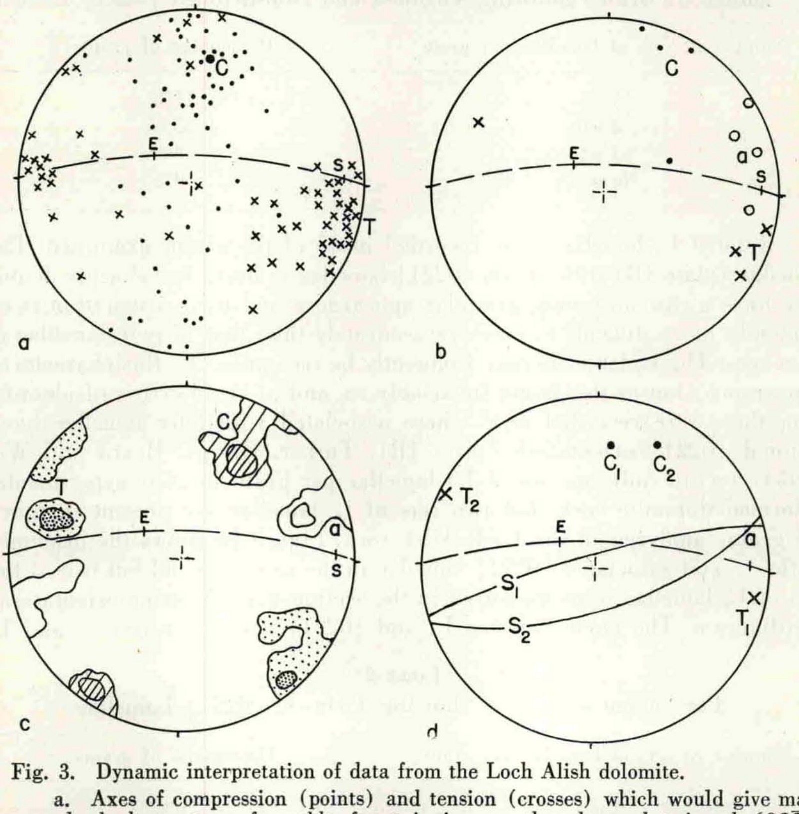


Fig. 3. Dynamic interpretation of data from the Loch Alish dolomite.

a. Axes of compression (points) and tension (crosses) which would give maximum resolved shear stress favorable for twinning on the observed twinned $\{02\bar{2}1\}$ lamellae.

b. Active glide lines (circles) and axes of compression (points) and tension (crosses) which would give maximum resolved shear stress favorable for translation-gliding on $\{0001\}$ in grains containing two sets of L_9 lamellae.

c. Synoptic diagram showing maxima of *possible* glide-lines (a), tension axes (T) and compression axes (C) inferred for 31 grains containing one set of L_9 lamellae.

d. Kinematic and dynamic interpretation of the data for the specimen. S_1 and S_2 are planes defined statistically by $\{0001\}$. C_1, T_1 and C_2, T_2 are stress axes inferred from twinned $\{02\bar{2}1\}$ lamellae and L_9 lamellae respectively.

contours). The *possible* axes of compression (shaded contours) and tension (stippled contours) deduced for the 31 grains are also shown in the figure (3c). Maxima for possible glide lines (a) and for axes of compression (C) and tension (T) in figure 3c have orientations close to the glide lines and axes of compression and tension inferred for grains with two sets of L_9 lamellae (fig. 3b). The axes of compression and tension deduced from twinning (C_1 and T_1, fig. 3d) are also subparallel to those inferred from the L_9 lamellae (C_2 and T_2, fig. 3d).

Absence of L_9 lamellae in a grain does not denote absence of {0001} translation, since L_9 lamellae appear only if {02$\bar{2}$1} lamellae were present in the grain prior to gliding on {0001}. The lattice orientation of grains with L_9 lamellae (figs. 4a, b) is not obviously different from that of the other grains (figs. 2a, b); so that many or all of the grains in the rock may well have undergone some degree of translation-gliding on {0001}. Thus the planes defined statistically by the orientation of {0001} could represent statistical slip-planes in the fabric (S_1 and S_2, fig. 3d). Kinematic *a*-axes in these slip-planes would be given by the preferred orientation of the glide directions in individual grains (a).

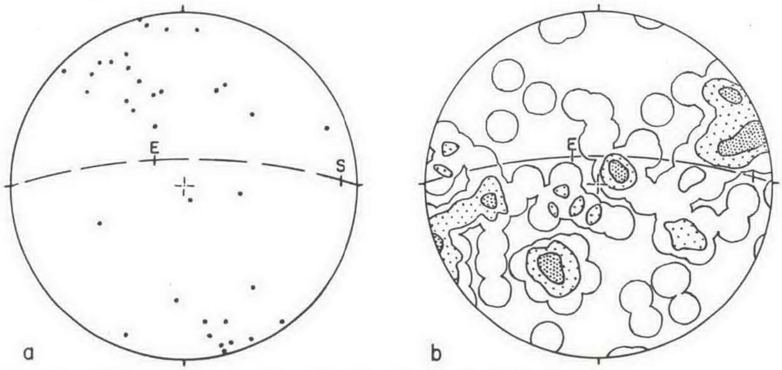


Fig. 4. Additional orientation data for the Loch Ailsh dolomite.
a. [0001]-axes in 35 grains containing L_9 lamellae.
b. *a* crystallographic axes in the same 35 grains. Contours: 1, 3, 5% per 1% area.

The geometry of the dolomite lattice is such that a compression applied subparallel to [0001] will tend to produce twin-gliding simultaneously on two or three of the {02$\bar{2}$1} planes. But if a tensile force is applied normal to [0001] in such a way as to give high resolved shear stress on one {02$\bar{2}$1} plane, the resolved shear stress on the other two {02$\bar{2}$1} planes will be low and twin-gliding will take place on only one set of {02$\bar{2}$1} lamellae. Thus we might expect to find two or three sets of twin lamellae in each grain in rocks which have been deformed by compression, whereas tension should give a fabric in which most grains contain only one set of twin lamellae. The presence of two or three sets of {02$\bar{2}$1} lamellae in the majority of grains in the specimen under consideration indicates that these have been produced by compression. Although grains containing three sets of {02$\bar{2}$1} lamellae are very common, only 20 percent of the grains contain optically recognizable twinned lamellae and the majority of these have only one such set. This feature, which is rather remarkable in view of the considerable post-crystalline deformation of the rock, may perhaps indicate a low temperature of deformation, for twinning has been produced experimentally only at temperatures above 300°C (Higgs and Handin, 1954).

Although the $\{02\bar{2}1\}$ lamellae in some grains are closely spaced, there is no indication, even where optically recognizable twinning is present, that the grains are more than partially twinned. This fact, along with the paucity of optically twinned grains, suggests that twinning was of minor importance during the final stages of deformation. The evidence of the fabric, then, suggests that translation-gliding on $\{0001\}$ was more important than twin-gliding on $\{02\bar{2}1\}$ during the latest stage of the deformation of the rock.

Orienting Mechanism.—This study yields little evidence as to the mechanism by which the strong preferred orientation of [0001] was achieved. It is probable that the intracrystalline structures described and interpreted above reflect only the final stage in the deformation of the rock. To produce such a strong preferred orientation by gliding of the types discussed would require a very high degree of strain, which would result in extreme elongation of the grains. Since the grains are predominantly equant, it is likely that there was a strong preferred orientation before the visible structures were produced. However, the pattern of preferred orientation is so similar to those of dolomite tectonites described by other authors (Fairbairn and Hawkes, 1941; Ladurner, 1953) that there can be little doubt that it was produced by deformation.

In an aggregate of dolomite crystals with random orientation subjected to compression, translation-gliding on $\{0001\}$ would tend to give a concentration of [0001]-axes close to the axis of compression, whereas twin-gliding on $\{02\bar{2}1\}$ would produce the opposite effect—a migration of [0001]-axes from the axis of compression. If these are the only two mechanisms of deformation in dolomite, the final pattern of preferred orientation would depend solely on which of the two types of gliding was produced with the greatest ease. The observed concentration of [0001]-axes could have been brought about by basal translation with minor twinning on $\{02\bar{2}1\}$ under compression directed parallel to the present [0001] concentration, but definite evidence as to the operative mechanism is lacking.

Calculation of Strain from Rotated Lamellae.—Theoretically it should be possible to estimate the post-crystalline strain in a rock from the degree of internal rotation of lamellae as a result of gliding according to a known system. In view of the extensive post-crystalline strain in the present specimen it should be well suited for such consideration (Turner, et al., 1956, p. 1292). The strain, ε, in individual grains is given by the equation:

$$\varepsilon = \frac{S_0\ (\cot\alpha - \cot\beta)}{\sin\gamma}$$

where α and β are the angles between the rotated lamellae and the glide-plane before and after rotation (selected so that $\beta > \alpha$); γ is the angle between the glide line and the axis of internal rotation and S_0 is the coefficient of resolved shear stress. For the glide system under consideration γ is 60° and S_0 is given values of 0.4-0.5 (Turner, et al., 1954). For rotations of L_9 ranging from 5° to 12° the calculated strains are 5 to 18 percent.

There are certain limitations to the acceptance of these figures as a measure of the actual strain in the rock. Estimation of strain from the rotation of L_9 lamellae assumes that all the deformation was achieved by translation-gliding on {0001}, and there is evidence in most grains of limited twin-gliding. Moreover, many of the grains contain minute dark granules which may have resulted from the disruption of rotated lamellae. It is probable, in the writer's opinion, that L_9 lamellae become too diffuse for measurement and are eventually disrupted when the strain is much in excess of the values recorded above. Thus the strain recorded in the rotation of L_9 lamellae in individual grains is probably less, and perhaps considerably less, than the total post-crystalline strain in the rock.

CONCLUSION

The Loch Ailsh dolomite has a strongly-oriented tectonite fabric of unknown origin, with almost orthorhombic symmetry. The fabric yields a unified picture of translation-gliding on {0001} and twin-gliding on $\{02\bar{2}1\}$, dating from the final stage of deformation of the rock. This late post-crystalline deformation probably took place at a comparatively low temperature and was produced by a strong compression directed along an axis plunging 50° to N315° E.

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REFERENCES

Borg, I., and Turner, F. J., 1953, Deformation of Yule Marble, Part 6: Geol. Soc. America Bull., v. 64, p. 1343-1351.

Bradley, W. F., Burst, J. F., and Graf, D. L., 1953, Crystal chemistry and differential thermal effects of dolomite: Am. Mineralogist, v. 38, p. 207-217.

Christie, J. M., 1956, A tectonic study of the post-Cambrian thrusts of the Assynt region: Thesis, University of Edinburgh.

Fairbairn, H. W., and Hawkes, H. E., Jr., 1941, Dolomite orientation in deformed rocks: AM. JOUR. SCI., v. 239, p. 617-632.

Felkel, E., 1929, Gefugestudien an Kalktektoniten: Jahrb. d. Geol. Bundesanstalt, v. 79, p. 33-85.

Handin, J., and Fairbairn, H. W., 1955, Experimental deformation of Hasmark dolomite: Geol. Soc. America Bull., v. 66, p. 1257-1273.

Higgs, D. V., and Handin, J., 1954, Experimental deformation of dolomite single crystals (Abstract): Geol. Soc. America Bull., v. 65, p. 1263.

Johnsen, A., 1902, Biegungen und Translationen: Neues Jahrb. f. Min., Geol. Pal., v. 2, p. 133-153.

Ladurner, J., 1953, Allgemeine Kennzeichung und regionale Stellung alpiner Dolomittektonite: Jahrb. d. Geol. Bundesanstalt, v. 96, p. 253-300.

Turner, F. J., 1953, Nature and dynamic interpretation of deformation lamellae in calcite of three marbles: Am. Jour. Sci., v. 251, p. 276-298.

Turner, F. J., Griggs, D. T., and Heard, H., 1954, Experimental deformation of calcite crystals: Geol. Soc. America Bull., v. 65, p. 883-934.

Turner, F. J., Griggs, D. T., Heard, H., and Weiss, L. E., 1954, Plastic deformation of dolomite rock at 380°C: Am. Jour. Sci., v. 252, p. 477-488.

Turner, F. J., Griggs, D. T., Clark, R. H., and Dixon, H. R., 1956, Deformation of Yule Marble, Part 7: Geol. Soc. America Bull., v. 67, p. 1259-1294.

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