On the geometry of S-shaped inclusion trails in garnet porphyroblasts

THE origin of S-shaped inclusion trails within porphyroblasts in metamorphic rocks has been debated by many authors (Ramsay, 1962 and Spry, 1963, are among the more recent). Although most studies have involved the examination of thin sections cut at different angles to each other a clear understanding of the three-dimensional geometry of the inclusion trails has not emerged.

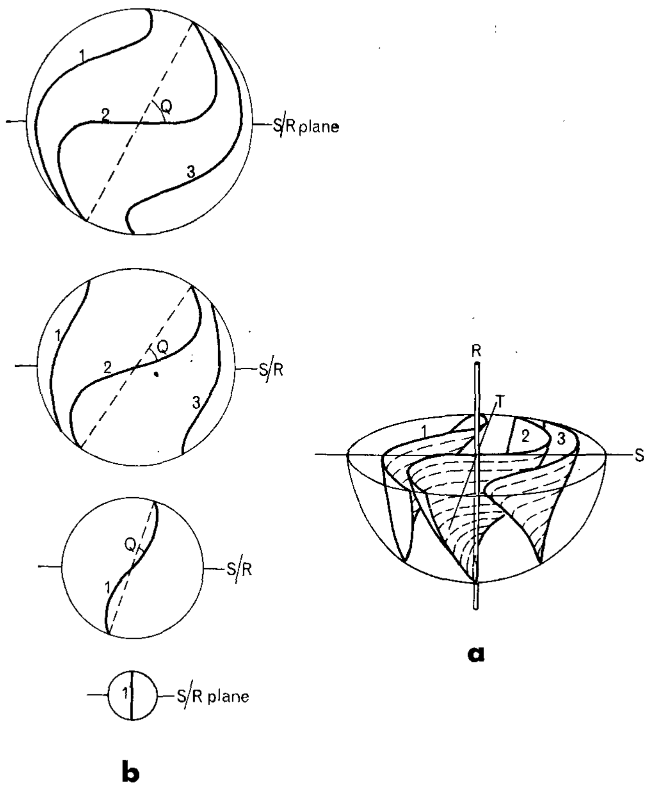

FIG. 1. (*a*) Schematic diagram of three inclusion planes (1, 2, and 3), within a theoretical model. *R*, *S*, and *T* reference axes. Only half of the model is shown; the *S*/*T* plane is a plane of symmetry. (*b*) Serial sections through the model in and parallel to the *S*/*T* plane. 1, 2, and 3 inclusion planes as in *a*. Note that angle *Q* decreases outwards from the centre of the sphere and that the trends of inclusion trails change systematically. For further explanation see text

In the present work thick rock slices (0·5–1·0 mm thick), have been studied with the aid of a universal stage mounted upon a stereoscopic microscope; a technique that allows the measurement of the attitudes of the various planar and lensoid inclusions and inclusion trails within

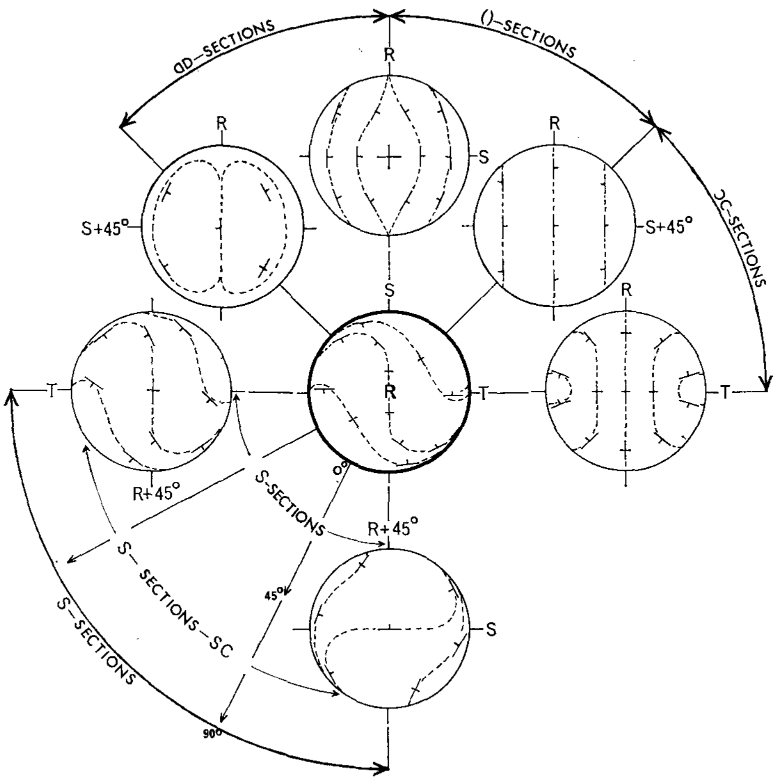

Fig. 2. Inclusion patterns shown by different sections through the model illustrated in fig. 1*a*. Only median sections are illustrated; *R*, *S*, and *T* reference axes as in fig. 1. Inclusion trails are indicated by dashed lines and their attitude by dip and strike symbols

porphyroblasts (Powell, 1966). Such studies are leading to an appreciation of the three-dimensional geometry of trails within some so-called syntectonic garnet crystals. The observations so far made agree well with a theoretical model (Treagus, 1964).

The model (fig. 1*a*), is based on a consideration of the growth of a near spherical body while it is rotating or while its matrix is rotating about it, through 90°, in an environment whereby originally rectilinear elements of the matrix are preserved as inclusions within the growing body.

The model has several characteristics: individual curved planes defined by inclusion trails are not cylindroidal (fig. 1 *a* and *b*): the pattern of inclusion trails varies with a change in the orientation of a section through the model; while S-patterns predominate, (| |)-,)(-, and ()-shaped patterns occur in certain sections (fig. 2): the degree of curvature and trend of inclusion trails varies in serial sections cut normal to and at high angles to the rotation axis (figs. 1 *b* and 2).

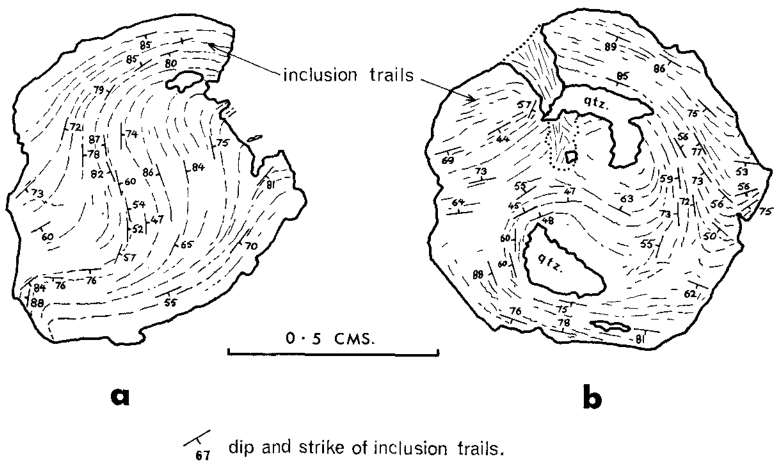

FIG. 3. Thick sections of garnet porphyroblasts in Norwegian schist (specimen kindly loaned by Dr. P. H. Banham). (*a*) Section comparable with one subparallel to the *S*/*T* plane but non-median. The rotation axis plunges at about 80° to the ENE. (*b*) Section comparable with (| |) section through the model. The rotation axis plunges to the NW. at a small angle. Both sections are from the same rock and are cut at approximately 90° to one another. They illustrate differences in apparent angle of rotation, which are probably due to 'cut effect'

Preliminary studies of 'syntectonic' garnet porphyroblasts from certain Norwegian schists support the validity of this model (fig. 3), and thus give rise to important conclusions. It is possible to distinguish between 'syntectonic' porphyroblasts and 'post-tectonic' fold overgrowths by establishing whether or not the S-patterns are cylindroidal. In thin sections the rotation axis of a 'syntectonic' crystal showing inclusion trails may be located by reference to sections with straight trails or (| |)-,)(-, and ()-patterns (fig. 2), but not to sections showing S-patterns. It may be located more readily by measurement of the attitudes of planes of inclusion trails in thick slices (fig. 3).

These observations suggest that earlier conclusions relating to angles of rotation of porphyroblasts and the relationships between rotation axes and structures within the enclosing rock are probably incorrect.

The problem of the mechanism of rotation during growth of 'syntectonic' porphyroblasts has been the subject of debate and various mechanisms have been proposed. These include rotation of the growing crystal (Mügge, 1930; Schmidt, 1918; Spry, 1963), and rotation of the matrix around a growing but static crystal by 'flattening' (Ramsay, 1962). Consideration of these and other possible mechanisms involving essentially simple shear or simultaneous rotation of both crystal and matrix or both is not the concern of this communication but such mechanisms are at present being assessed in the light of the new work.

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A point-counting computer programme for petrofabric analysis of uniaxial mineral orientations

THIS programme will handle simultaneously the orientations of any number of uniaxial mineral grains (up to the limit of the computer store) observed in any number of thin sections cut in any number of different orientations. The orientations of the optic axes of the grains (lower hemisphere extremities) with respect to the plane of each thin section are given in the form of readings on universal stage axes A_1, A_2, A_4. The orientation of each thin section is defined in terms of three field observations: its strike, its dip, and the azimuth of its normal.