*Journal of Structural Geology*, Vol. 8, No. 8, pp. 941 to 942, 1986
Printed in Great Britain

0191-8141/86 $03.00 + 0.00


# A universal stage method for very fine-grained crystal aggregates

FALK KOENEMANN

Department of Earth Sciences, University of New Hampshire, Durham, NH 03824, U.S.A.

(*Received* 4 *January* 1986; *accepted in revised form* 12 *June* 1986)

THE universal stage is a standard tool in microfabric work. Its application requires a minimum grain size of the polycrystalline aggregate; for very fine-grained rocks the method becomes necessarily selective. It is possible, for example, that the large grains in a tectonite show quite a different orientation from the small grains that decorate their boundaries. Thus important information will be lost. This problem could be partly overcome with a new U-stage method for very small grains of quartz or other uniaxial minerals.

In the following explanation it is assumed that the observer is sitting in front of a microscope, looking north. The gamma-ray of the accessory quartz plate vibrates NE–SW. After insertion of the accessory plate, the interference figure of a quartz grain with vertical *c*-axis shows blue interference color in the NE- and SW-quadrant, and red interference color in the NW- and SE-quadrant. An imaginary stereonet is placed below the microscope stage with its principal axes parallel to the polarization directions (Fig. 1).

In the conventional method, a quartz *c*-axis orientation in an arbitrary orientation (Fig. 1a) can be expressed in one of four different ways, the choice of which depends on the azimuth and plunge of the crystal axis. In the standard procedure the vertical plane containing the *c*-axis is aligned with the E–W axis of the universal stage: the *c*-axis is placed on the great circle about the N–S axis of the universal stage (Fig. 1b), and the grain is in extinction. This operation determines the azimuth of the *c*-axis. Then the stage is tilted about the E–W axis using the large drum to rotate the grain out of extinction. The *c*-axis describes a path on a small circle (Fig. 1c). The grain is then moved back into extinction by rotation about the N–S axis of the inner ring of the universal stage which itself has been inclined together with the *c*-axis. The grain describes a path on a great circle.

Thus, if the *c*-axis has a shallow inclination, it will be rotated until it is aligned with the E-axis itself (Fig. 1d). Removing the tilt of the inner ring about the E–W axis is equal to a rotation of the U-stage about the quartz *c*-axis. Or, if the *c*-axis has a steep inclination, it will be rotated such that it coincides with the vertical N–S plane (Fig. 1e). Removing the tilt of the inner ring about the E–W axis will bring the *c*-axis into an orientation parallel to the light propagation direction of the microscope. The plunge of the *c*-axis is read from the vertical scales, but different notation must be used on the record sheet depending on the method that has been used; the technique in Fig. 1(d) determines the true angle of plunge at the proper azimuth, whereas the technique in Fig. 1(e) measures the angular distance from the vertical, or the inverted plunge, on the side opposite to true azimuth. The four different ways are distinguished by four index characters.

The tilt about the E–W axis (Fig. 1c) is arbitrary in this method. It need not be large and usually causes no complications. Problems with small grains arise during the second step if the inclination of the *c*-axis is far from the plane of the thin section *and* its normal, as shown in the figure, because the required rotation about the N–S axis may lead to grain interference.

The only requirement for the new technique is that a grain must be cut on both sides by the surface of the thin section, i.e. its length parallel to the light propagation direction must be 20-30 $\mu$m. The other two dimensions may be much smaller.

It is always possible to determine the quadrant in which the *c*-axis is located (Table 1). The U-stage with thin section is in an initial standard position, and the *c*-axis is in an arbitrary orientation (Fig. 1a). In step 1 the accessory quartz plate is inserted; the grain will be blue if the *c*-axis is oriented in the NE- or SW-quadrant, or red if it is in the NW- or SE-quadrant. It follows the first part of the standard operation: the inner ring is rotated about the vertical axis until the grain is in extinction (the vertical plane containing the *c*-axis is oriented E–W, Fig. 1b) and then tilted gently about the E–W axis (the grain is moved out of extinction, Fig. 1c). Now, in step 2, the accessory plate is inserted again. The sequence of interference colors shown in Table 1 occurs if the thin section dips north during step 2; it reveals the quadrant in which the *c*-axis is oriented (cf. Figs. 1a & c).

The angle of tilt about the E–W axis must be recorded from the drum and should be 15 or 20°. Now the *c*-axis must be on a known great circle which runs through W and E. If the whole microscope stage including the

Table 1. Sequence of interference colors which determine the *c*-axis quadrant

| | | | | |
|---|---|---|---|---|
| First step | red | red | blue | blue |
| Second step | red | blue | red | blue |
| Quadrant | SE | NW | NE | SW |

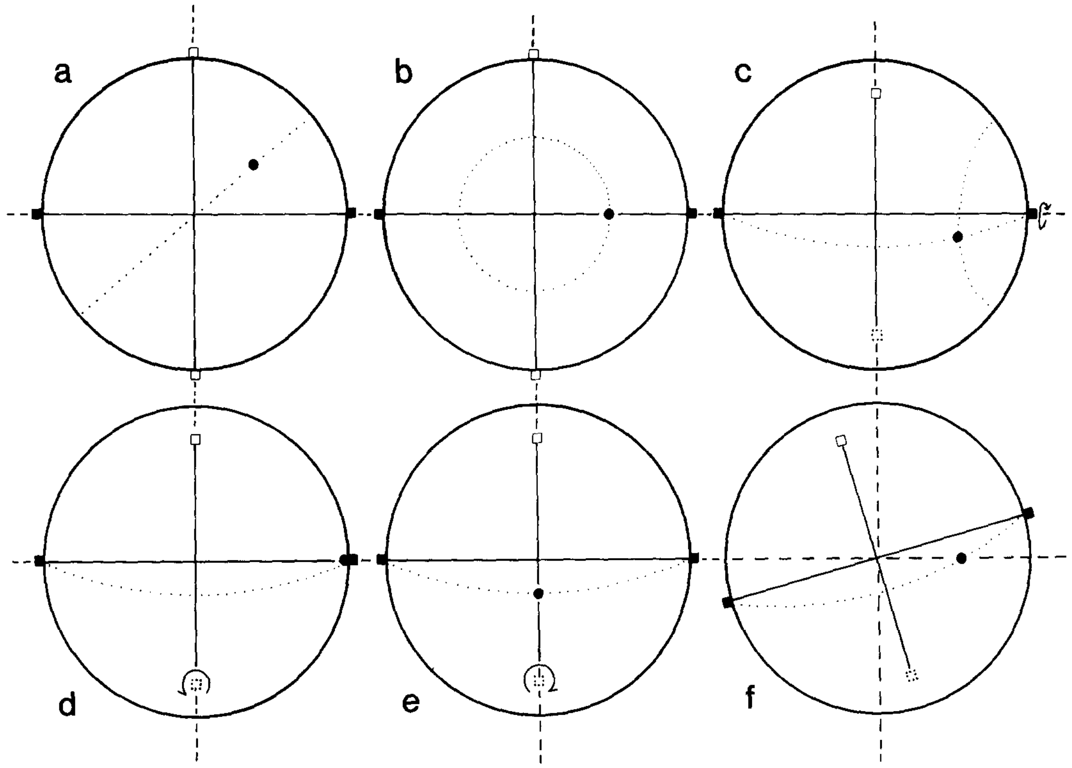


Fig. 1. Universal stage operations superimposed on a stereonet (lower hemisphere projection). Solid circle, external ring of universal stage; solid squares, mechanical joints of E–W axis (the drum); open squares, mechanical joints of N–S axis for inner ring (dotted if in the upper hemisphere); solid lines, rotation axes of the universal stage; dashed lines, polarization directions; dotted lines, elements of stereonet (great and small circles); solid dot, *c*-axis. (a) *c*-axis in arbitrary position, with the vertical plane (dotted) containing it. (b) The vertical plane containing the *c*-axis is rotated into E–W position; *c*-axis describes small-circle path about vertical rotation axis. (c) Vertical plane containing *c*-axis is tilted about E–W axis, thin section dips N; *c*-axis describes small-circle path. (d) Conventional method for shallow plunge: starting from step (c), the inner ring is rotated about tilted N–S axis; *c*-axis describes great-circle path to coincide with E–W rotation axis. (e) Conventional method for steep plunge: starting from step (c), the inner ring is rotated about N–S axis; *c*-axis describes great-circle path until its position is within the vertical N–S plane. (f) Starting from step (c), universal stage is rotated about vertical microscope axis until the grain is in extinction.

U-stage is turned until the grain is again in extinction (Fig. 1f), the *c*-axis must lie both in the vertical plane parallel to the polarization direction of the light and in the known great circle through the major E–W axis of the stage. The intersection line of the two planes is parallel to the *c*-axis.

The operation can be simulated with a real stereonet and a ruler. The ruler represents the polarization direction. On the paper it must be rotated opposite to the sense of rotation of the microscope stage. The intersection of the great circle on which the *c*-axis must be and the ruler is the orientation of the lattice axis. The angle between this intersection point and the point marking the E–W rotation axis of the U-stage is the inclination angle of the *c*-axis in the standard position of the stage. It can be read directly from the stereonet, but the quadrant information must be considered for the notation on the record sheet. The index character should be the same as that used for the standard technique in Fig. 1(d). The *c*-axis azimuth is read from the scale on the external U-stage ring, as in the conventional method. Comparisons of both techniques when applied to suitable quartz grains did not reveal any notable difference in precision.

*Acknowledgements*—The author thanks Rick Law and Rob Twiss for their comments on an early draft.