from a study of the external and internal rotations in deformation bands, as measured in standard thin sections of deformed crystals. More recent studies, employing reflected light and electron microscopy of polished and etched surfaces of single-crystal specimens, have yielded stronger evidence of this slip mechanism. In view of this, the latter evidence is presented before the geometry of the deformation bands is discussed.

SLIP MARKINGS ON POLISHED CRYSTALS

A classic method for the identification of slip systems in crystals is the study of slip markings (slip lines or slip bands)[4] on the surfaces of deformed polished crystals. These represent the traces of individual slip planes or groups of slip planes on the surface of a crystal. The orientations of slip lines on two or more surfaces of a crystal define the slip plane and further study of the displacements may also identify the slip direction.

In five experiments, polished cylinders cored from single crystals of quartz were deformed in compression by relatively small amounts (1–10 per cent shortening). The orientations of the crystals and the approximate strains are listed in table 1, with the conditions and duration of the experiments. There was high shear stress on the base in all five experiments. The samples were carefully impregnated with Ambroid cement, the furnaces were removed, and the surfaces of the crystals were subsequently cleaned with solvent; the complete cylinders recovered in this way retained their orientation marks. The cylindrical surfaces of the samples were examined optically for slip markings.

Well-developed slip bands (pl. 1, *A*, *B*) were present on the surfaces of all the crystals. On parts of some samples the slip bands are thin, evenly spaced, and continuous; but they are commonly discontinuous and thick, due to clustering of several bands or many thinner slip features. The slip bands are not equally developed around the circumference of the cylinders, and in two samples (C-247 and C-254) there are clearly defined longitudinal zones on opposite sides of the cylinders which show no slip markings. The planes tangential to the cylinders at these "null zones" must be parallel to the slip direction in the slip planes.

The orientation of the slip bands relative to the orientation marks on the cylinders was determined using the simple apparatus illustrated in figure 1, *a*. The cylinder is cemented to a metal spindle of the same diameter, to which is attached a graduated circle. The spindle is mounted in a frame so that it may be rotated about a horizontal axis, and the frame is attached to a rotating stage on a reflecting microscope. The orien-

TABLE 1

EXPERIMENTS ON POLISHED CRYSTALS

Experiment No.	Orientation*	Temperature (° C.)	Confining Pressure (Kb.)	Duration (Min.)	Strain (Per Cent) Shortened
C-193	$\perp r$	500	20	23	1
C-246	$\perp r'$	500	20	24	1
C-247	O^+	500	20	33	10
C-253	$\perp r'$	500	20	35	6
C-254	O^+	750	20	38	5

* Illustrated in figure 2 of the preceding paper. In the $\perp r$ and $\perp r'$ specimens, the highest shear stress on the basal plane is parallel to a^*, while in the O^+ specimens, the highest shear stress is parallel to a.

[4] We use the term "slip band" for a surface marking which is visible with an optical microscope and "slip lines" for finer features which may be resolved only with the electron microscope (Kuhlmann-Wilsdorf and Wilsdorf, 1953).

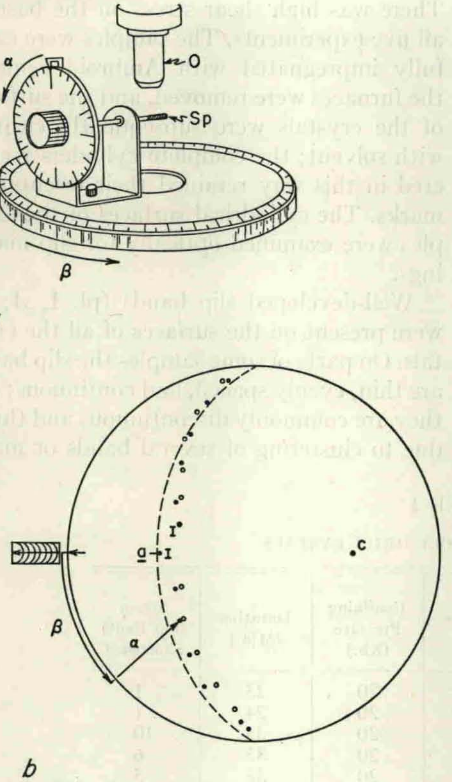

FIG. 1.—*a*, apparatus for measuring orientation of slip bands on surface of polished cylinders. Microscope objective (O) and specimen (Sp.) are indicated. Angles α and β are the angles of rotation of the graduated circle and microscope stage, respectively. *b*, equal-area projection showing orientation of slip bands on crystal C-247, along with crystal showing orientation mark (*arrow*) and slip bands. Original crystallographic orientation of sample is shown by *c*- and *a*-axes in the projection. *Broken line* is the original orientation of basal plane; *open circles* and *black circles* represent orientations of slip bands measured on back and front of the cylinder, respectively, and *short line segments* represent null zones on each side of the cylinder.

tation of the slip lines was obtained for different settings of the graduated circle (α) by rotating the apparatus on the microscope stage until the slip bands were parallel to one of the cross-hairs of the microscope and noting the rotation of the microscope stage (β). The measurements are considered to be accurate within 3°. The data were plotted on an equal-area projection, as illustrated in figure 1, *b*, which shows the measurements for sample C-247 with the original orientation of the sample as determined from the arrow marks.

The slip bands in all five crystals define a plane which is very close to the basal plane. Slight departures of the plane defined by the slip bands from the original orientation of the base are believed to be due to external rotation of the slip planes accompanying the deformation, since the departures are greatest in the specimens with largest strain and are consistent with the sense of shear on the slip planes. Small deviations of the lines from a planar configuration appear to be due to inhomogeneity of the slip along the length of the samples. The consistent parallelism of the slip bands with the basal plane indicates that the basal plane was the slip plane.

In the specimens deformed so that the maximum resolved shear stress in the base was parallel to an *a*-axis[5] (C-247, C-254)

[5] The usual notation for the crystallographic axes of quartz is used in the paper: *a* denotes the two-fold axes, *c* the threefold axis; the bisectors of the *a*-axes are referred to as a^* (the reciprocal *a*-axes). These axes *a*, a^*, and *c* are equivalent, respectively, to the x_1-, x_2-, and x_3-axes of reference commonly used for physical properties (Nye, 1957) and to *x*, *y*, and *z* in Pöckels (1906). In the four-index notation (Barrett, 1952) the equivalent directions are $\langle 11\bar{2}0\rangle$, $\langle 10\bar{1}0\rangle$, and [0001], respectively.

PLATE 1

Polished crystal C-193, compressed $\perp r$ (axis of compression N.-S.) at 500° C., 20 kb. confining pressure (shortened by *ca.* 1 per cent). E.-W. cracks are extension fractures produced on unloading sample. Scale lines beneath photos represent 0.1 mm.

A, *B*, Photomicrographs, taken in reflected light, show slip bands on polished surface. Bands in *A* (fine NW.-trending linear features) are narrow and evenly spaced. They are concentrated into thick bands (near center of *B*) in other parts of the crystal. Slip bands are small offsets where active slip planes intersect cylindrical surface. They are parallel to the basal (0001) plane.

C, *D*, Deformation lamellae (NW.-trending linear features) in thin section from same crystal as *A*, *B* (phase-contrast illumination). Lamellae show similar types of distribution to the slip bands and are parallel to (0001). Lamellae are visible traces of slip on (0001).