sition. Because a finite discontinuity in any physical quantity is difficult to distinguish from an extremely rapid continuous variation, it may seem futile to try to decide whether the transition is first or second order; the theoretical treatment should be capable of handling either possibility. Later, however, experimental details will be discussed that make us suspect that the transition is a first-order transition that closely resembles a λ transition but that does not rigorously satisfy the definition given in the Introduction for a λ transition.

Specimens

Cores about 1 cm in diameter by 2 cm in length were drilled from a single clear left-handed quartz crystal of unknown origin. Figure 4 shows the four orientations of the core axes that were determined from crystal morphology within an uncertainty of about 2°.

The ends of the cores were ground parallel within 10^{-3} cm. Some were more highly finished—optically flat, parallel, and polished to better than 0.5×10^{-4} cm and ground smoother and truer on the cylindrical walls as well. One of these samples was silver plated on the ends. These refinements appeared to have little effect on the experiments, except possibly to raise the fracture strength.

In addition, hollow samples were tested for all orientations except r' (Figure 4). All but one of these were made by ultrasonically drilling a small hole of roughly circular cross section (diameter about 0.175 cm) along the axis of a solid sample. One hollow sample with a larger hole (0.4 cm) was made with a diamond core drill. Although the inner holes differed in degree of ellipticity, taper, and eccentricity by as much as about 10%, the effects of these variations could not be detected in our experiments.

Apparatus

The experiments were done in an apparatus designed for rock deformation studies at pressures to 10 kb and temperatures to 1000°C (M. S. Paterson, unpublished data, 1969) [cf. *Raleigh and Paterson*, 1965]. It consists of an argon-filled pressure chamber with internal furnace into which a piston is introduced to apply an additional axial load to the specimen and has facilities for measuring the load exerted by the piston and its displacement as well as the temperature and the hydrostatic confining pressure.

Pressure was measured with an accuracy of ±1% by the change in resistance of a manganin coil and was controlled within ±10 bars. Temperature was measured with a commercial chromel-alumel thermocouple, sealed within a stainless steel sheath and insulated with magnesium oxide. In general, the sheath was 0.1 cm in outside diameter, but in some of the work a set of three 0.05-cm diameter thermocouples was used. The thermocouple was introduced along a small axial hole in the piston to make contact with the end of the specimen or to enter the specimen if it was hollow, the specimen being sheathed and sealed to the piston by use of a soft copper jacket of 0.025-cm wall thickness. Thus, the thermocouple was always at atmospheric pressure, eliminating any need for correcting for the effect of pressure. Sensitivity of temperature measurement was ±0.5 to 1°C, and the overall accuracy was probably ±2°C, except for some of the runs with 0.05-cm thermocouples, when local shorting near the junction introduced error and possibly reduced this to ±4°C.

The additional axial load was measured with about 5-kg sensitivity by a load cell inside the pressure chamber, thereby eliminating uncertainties due to piston friction. The load cell consisted of a hollow steel cylinder, to which electric resistance strain gages were attached, and was calibrated against an external load cell of known calibration, giving an accuracy of load measurement of about ±3%. (There is possibly a somewhat greater error in runs 580 and 590, Table 2, owing to erratic behavior of an earlier load cell.)

Piston displacement could be measured with a sensitivity of about 2×10^{-4} cm. However, an apparatus distortion correction of about $(7.0 \pm 0.5) \times 10^{-6}$ cm/kg load is needed for obtaining the actual strain, leading to an uncertainty of about 0.25×10^{-6} bar^{-1} in determining compliances in the specimen.

Experimental Procedure

The experiments were always conducted with a hydrostatic confining pressure of 1 kb or more in order to extend the range of the uniaxial stress that could be applied without fracturing

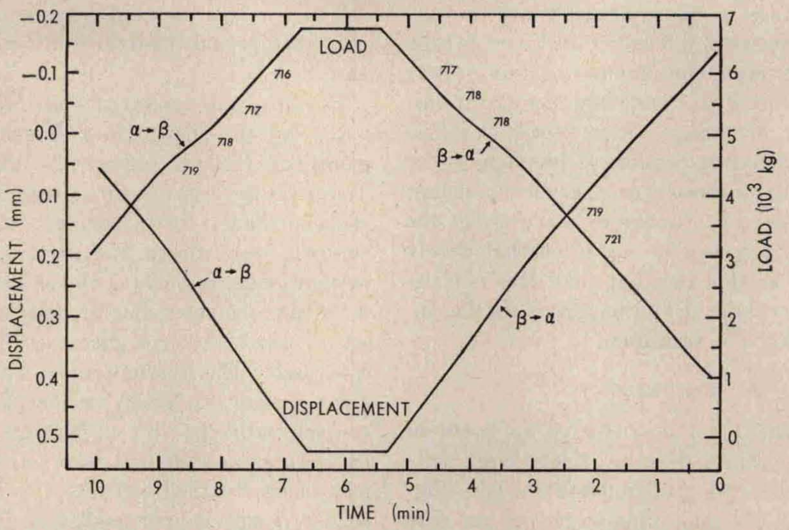

Fig. 5*a*. Tracing of load-displacement record for the 29th ($\beta \rightarrow \alpha$) and 30th ($\alpha \rightarrow \beta$) passage through the transition of run 602 (Table 2) at 3-kb confining pressure. Numbers along the load trace are sample temperatures in degrees C. The load pen led the displacement pen by the equivalent of 7–8 sec. The transition is marked by softening of the sample and can usually be seen in both the load and the displacement curves.

the sample. The technique was to hold the temperature and pressure fixed at values such that the sample was in the β field when the axial load was zero. The load was then smoothly increased to the point at which inversion to the α phase occurred and well beyond, then decreased until the β phase was regained (Figure 5*a*). The point on the load and displacement curves that corresponded to the greatest compliance was taken as the transition bound-

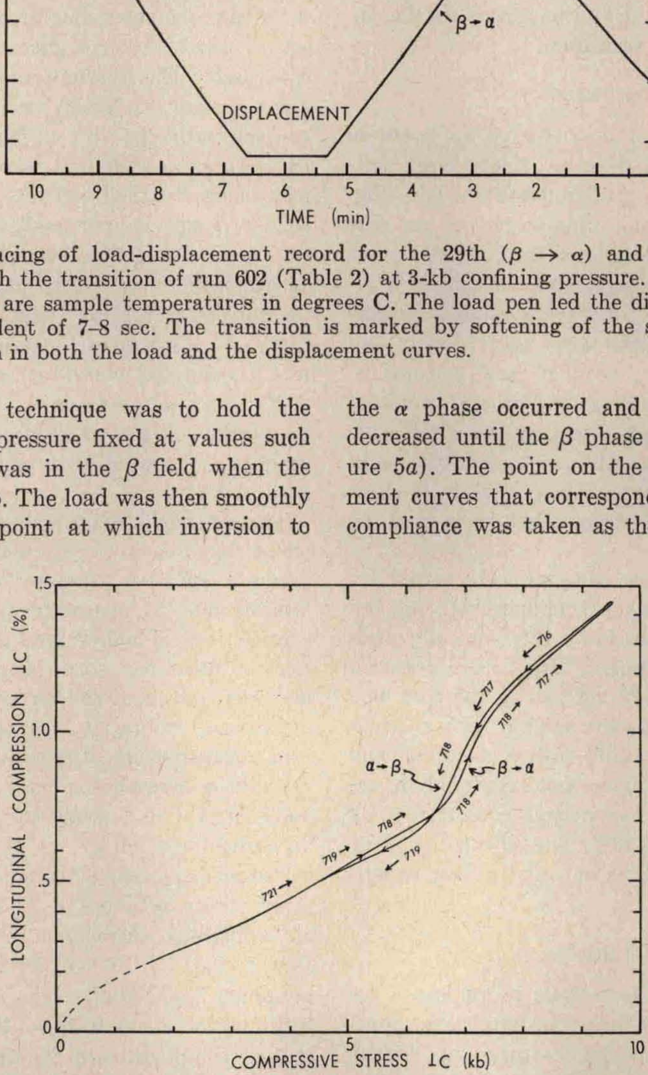

Fig. 5*b*. Stress-strain curve constructed from record of Figure 5*a* shows more clearly the softening that marks the transition as well as the hysteresis. The straightish section in the β field does not extrapolate to the origin because about 1-kb stress is needed to seat the various surfaces in the load column before the value 7×10^{-6} cm/kg taken for apparatus distortion is valid. The lack of coincidence below the transition stress of the curves of increasing and decreasing stress is unusually large in this example, and we have no ready explanation for it.