marked degree, in the quartz crystals before deformation. Thus the structures, cracks or inclusions, which give rise to this effect are present before deformation, but it is emphasized by the deformation. This effect is visible only in some natural quartz and it has been noted that it is quite common in, and perhaps restricted to, the quartz in igneous rocks (C. Durrell, personal communication).

The haloes must be due either to local rotation of the lattice by plastic deformation or induced birefringence due to residual stresses in the quartz, or a combination of the two effects. The significance of the structures is discussed below.

Other phases in the deformed quartz.—The isotropic material along many of the faults is brownish in plane-polarized light. The zone of isotropic material is extremely thin or absent along some faults, is commonly between 1 and 5 microns thick, and in a few cases is irregular and as thick as 100 microns. Where the zones are thicker than 5 microns, approximately, they contain high proportions of crushed and disoriented quartz fragments. The isotropic material has a refractive index markedly less than the lower index (ω) of quartz. In one of the fault-zones in a section of one deformed crystal there is an aggregate of finely crystalline material (pl. 2D) with low birefringence and refractive indices considerably higher than the higher index (ε) of quartz.

The thinness of the zones of isotropic material and the high proportion of quartz inclusions in them, make it impossible to isolate the material in sufficient quantity for satisfactory optical examination. The material along faults in three samples (separately treated) was removed by scraping with a knife-blade, finely ground in a mortar, and examined in immersion oils. The powdered material was found to consist predominantly of quartz, with only small proportions of other materials. Oils with indices of 1.544 and 1.553 were used with each of the preparations. Of the small amount of isotropic material, most of the grains had a refractive index considerably lower than 1.544, a few between 1.544 and 1.553, and an even smaller number greater than 1.553. In the preparations from two of the samples a few grains were slightly birefringent, with indices considerably higher than 1.553. In order to compare the refractive index of the isotropic material with that of natural silica glass (lechatelierite) the powders were immersed in an oil of index 1.46. All the material appears to have a refractive index greater than 1.46.

The isotropic material seems to have a variable refractive index, though no attempt was made to bracket the values more closely. Most of the material has an index between 1.46 and 1.54. The grains that appeared to have an index above 1.544 may in fact have been cryptocrystalline aggregates of quartz or cryptocrystalline mixtures of quartz and the anisotropic material with high indices, noted above.

The anisotropic material with high indices (>1.553) and low birefringence is probably the same as that identified in the thin section (pl. 2D). It was present in such minute proportions in the powdered samples that no attempt was made to determine the indices in immersion liquids. The relief of the material, by comparison with quartz, is quite marked, however, and the only known phase of silica which has the requisite optical properties is coesite.

DISCUSSION OF DATA

Values of strength.—The values obtained for the strength of quartz in the experiments (table 1) show more internal consistency than those of previous investigators. The strengths determined in the present study are compared with those obtained in experiments at room temperature and various confining pressures by earlier workers in figure 9.

The strengths of cylinders compressed parallel to the *c*-axis (fig. 9a) are similar to those obtained by Bridgman (1941) at confining pressures between 20 and 25 kb in an apparatus using isopentane as the confining medium; but they are considerably lower than those recorded by Griggs and Bell (1938), Bridgman (1940), and Goranson (1949) under similar conditions (fig. 9a). In these experiments Griggs and Bell and Bridgman used lead as the confining medium, and the confining pressure was obtained by a controlled flow of the lead around the piston. Goranson employed a hydrocarbon, which was supposed to retain its low viscosity at high pressures. Griggs, Turner, and Heard (1960, p. 67-68) have discussed these apparently anomalous results and concluded that the results at high pressure in experiments using the lead apparatus may be subject to question; the similarity of Goranson's results to these, however, still represents a problem. Strengths determined at atmospheric pressure by Berndt

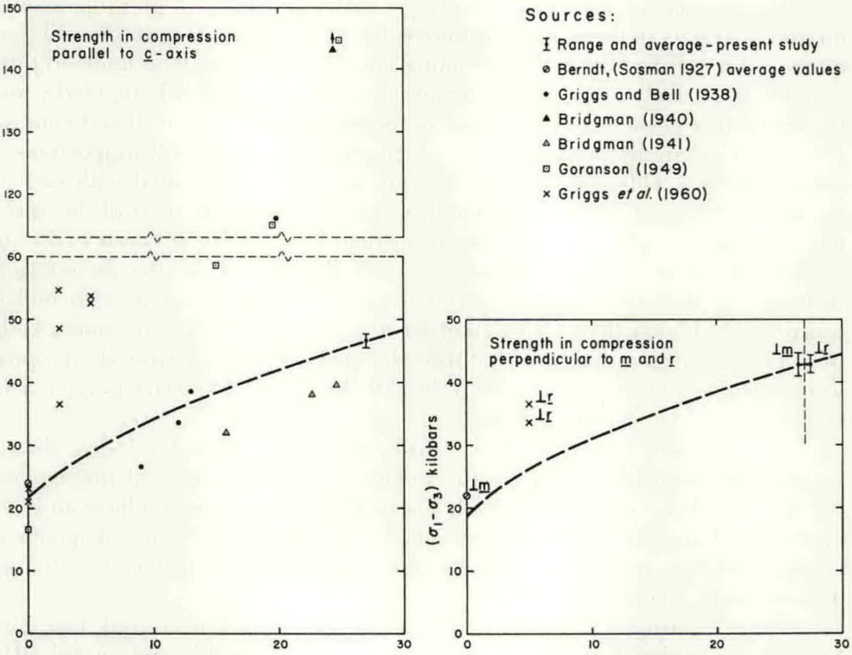

Fig. 9. Strengths of quartz at room temperature and various confining pressures, obtained in the present study and previous studies (as indicated). The broken curves represent strengths predicted by the Griffith theory, using constants derived from the average strengths in the present study.