5. Previous deformation features: the fracture index is 114; small, incipient shear zones occur, with small amounts of gouge; c_v of quartz grains are randomly oriented.

EXPERIMENTAL DEFORMATION

Cylinders $\frac{1}{2}$ inch in diameter and 1 inch long were cored perpendicular to the bedding and with regard to reference markings so that similarly oriented thin sections of undeformed and deformed specimens could be compared. The cylinders are deformed dry under the conditions listed in table 1, columns (1)–(4). Specimens 778 and 780 are from the Supai sandstone; all others are from the Tensleep sandstone. Ultimate strengths (table 1, col. [5]) were taken from the stress-strain curves of figure 13.

PETROGRAPHIC OBSERVATIONS OF DEFORMED SPECIMENS

All specimens, except 724 and 763, are characterized by twin lamellae parallel to $e\{01\bar{1}2\}$ in the calcite, by microfractures in the detrital grains, and by macroscopic shear zones. Both twin-lamellae spacing and microfracture indexes tend to increase with increased strain (table 1, cols. [7] and [8]). Generally, the microfractures tend to lie perpendicular to σ_3; that is, they are extension fractures. The orientation and spacing of the microfractures are independent of mineralogy and, in quartz grains, are independent of crystallography. Macroscopic shear zones are inclined between 29° and 35° to σ_1 (pl. 4).

Specimen 724.—This specimen was subjected to a uniform pressure of 1,000 bars, thereby simulating about 15,000 feet of overburden. The cylinder suffered no permanent deformation. Detrital grains are unfractured (index is 115), and the average number of contacts per grain is unchanged (2.1). In addition, the calcite cement is undeformed; the twin-lamellae spacing index is the same as that of the undeformed material (0).

Specimen 763.—This specimen was extended 2.6 per cent under 1,000 bars confining pressure, but no evidence of the strain is apparent in the thin section (i.e., no microfractures or twin lamellae formed).

Specimen 745.—This specimen was extended 2.9 per cent under 2,000 bars confining pressure, and some evidence of the deformation is apparent. Some detrital grains exhibit microfractures (index is 117), and the calcite cement exhibits a few twin lamellae (spacing index is 22).

Specimens 762, 725, 778, and 780.—These specimens were compressed 3.9, 5.9, 9.2, and 10.1 per cent, respectively (table 1, col. [4]). They contain similar, pronounced deformation features that are characterized as follows:

1. Macroscopic shear zones occur in specimens 762, 725, and 778; they are inclined at 29°–35° to σ_1 (table 1, col. [6]), as shown in plate 4 for specimen 725. Along these zones, detrital grains have been smeared out to form fine-grained gouge (pl. 3*B*, *a*). In addition, elongate grains along shear zones have been bodily rotated to lie subparallel to the zones. Shearing is not as pronounced in specimen 778 as in specimens 725 and 762. This may be due to a combination of the effects of increased confining pressure and temperature in specimen 778.

2. Highly fractured detrital grains occur throughout all four specimens, as illustrated in plates 3*B* and 4. The fracture index increases with increased strain (table 1, col. [7]). Sets of microfractures are statistically oriented parallel to σ_1 and normal to σ_3 (pls. 3*B* and 4 and fig. 14, *a–e*). In thin sections cut perpendicular to the σ_1 axis, the normals to the microfractures form nearly complete peripheral girdles which are inclined at about 90° to σ_1 (fig. 14, *a*). The microfracture surfaces themselves, therefore, are subparallel to σ_1. In these experiments, $\sigma_1 > \sigma_2 = \sigma_3$, and the least principal stress ($\sigma_2 = \sigma_3$) is oriented everywhere about the circumference of the deformed cylinder. Therefore, the normals forming the girdle are also everywhere normal to the least principal stress. In thin sections cut parallel to the σ_1 axis, the orientation of the microfractures is clearly illustrated (fig. 14, *b–e*). It should be remembered that there is a central blind

spot in these diagrams. The concentrations of normals at nearly right angles to the direction of σ_1 show that, for the most part, the microfracture surfaces are oriented parallel to σ_1 and normal to σ_3. That all the microfractures are not extension fractures is clear from the number of normals that are not inclined at 90° to σ_1. Those normals inclined between 70° and 50° to σ_1 probably represent shear fractures. The distribution of microfractures in specimen 780 tends to be more diffuse than in specimens 762, 725, and 778, although extension fractures predominate. This is probably due to the bodily

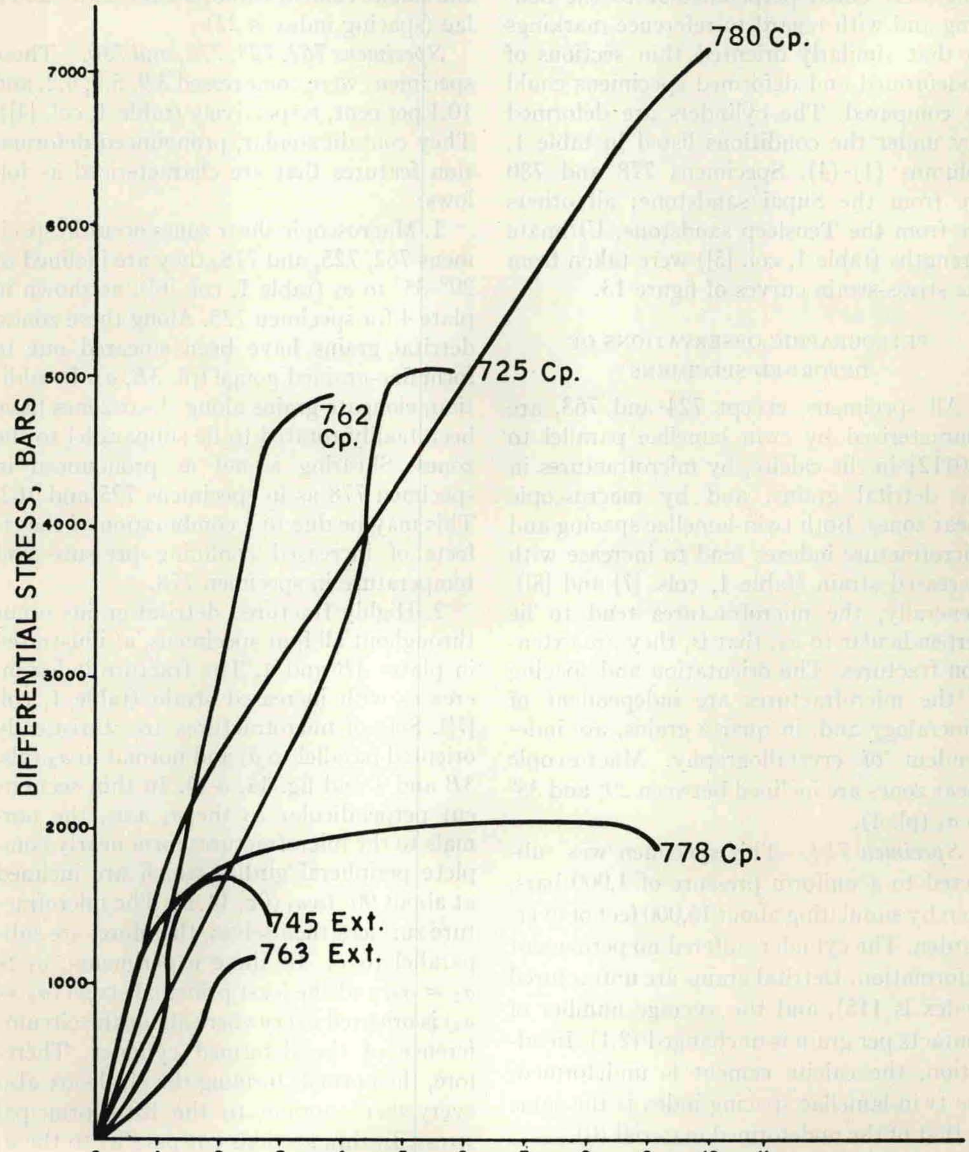

FIG. 13.—Stress-strain curves for calcite-cemented sandstones