the original rock cylinder and end cups, (2) preparation of the oriented thin section, (3) optical measurements, and (4) plotting. The error may be as much as 10°, but it rarely exceeds 5°.

Thin sections from sand-crystal specimens are cut parallel to the long axis of each deformed cylinder. Thin sections from calcite-cemented sandstone specimens are cut both parallel and normal to the axis of each cylinder.

The point-count method (Chayes, 1956) is used to obtain modal analyses of experimentally deformed materials. "Point" spacing is 100 μ, and data are recorded for six hundred points per specimen.

All measured data (orientation of c_v, calcite twin lamellae, and microfracture surfaces in quartz and in other detrital grains) and the derived positions of compression and extension axes are plotted stereographically on a Lambert-Schmidt equal-area net. The lower hemisphere of the projection sphere is projected on the horizontal plane.

Sand Crystals

UNDEFORMED SAND CRYSTALS

A sand crystal (pl. 2*A*) consists of a large single crystal of calcite that poikilitically encloses detrital grains. The undeformed sand crystals used in this study are characterized as follows:

1. Mineral composition:	Per Cent (by Volume)
Calcite	38
Quartz	25
Feldspar	22
Rock fragments	15
Garnet	Trace

2. The average number of contacts per detrital grain as measured in thin section is 0.71.

3. The calcite crystal is undeformed; that is, no twin lamellae are developed.

4. The detrital grains are relatively unfractured: The fracture index is 111 (see table 1, n. †).

5. There is no marked dimensional or crystallographic orientation of the detrital grains.

DEFORMATION FAVORABLE FOR TWIN GLIDING

EXPERIMENTAL DEFORMATION

Cylinders $\frac{1}{2}$ inch in diameter and 1 inch long were cored from the sand crystals parallel and perpendicular to c_v of the calcite and were deformed dry under the conditions listed in table 1, columns (1)–(4). The ultimate strengths (table 1, col. [5]) were taken from the stress-strain curves of figure 4. Descriptions of the experimental technique and apparatus are given by Handin (1953) and by Handin and Hager (1957, 1958). The cylinders were loaded to promote twin gliding in the calcite crystal, that is, compressed perpendicular to or extended parallel to c_v, respectively.

PETROGRAPHIC OBSERVATIONS OF DEFORMED SPECIMENS

All deformed specimens are characterized by at least two sets of twin lamellae parallel to $e\{01\bar{1}2\}$ in calcite and by relatively planar microfractures in detrital grains. Both the spacing index of twin lamellae and the index of fracturing in grains tend to increase with increased strain (table 1, cols. [7] and [8]). In all specimens the great majority of microfractures tend to lie perpendicular to the direction of σ_3 and thus, by definition, are extension fractures (in compression tests $\sigma_2 = \sigma_3$) and fractures are distributed radially and parallel to σ_1. The spacing and orientation of the microfractures are independent of mineralogy and, in quartz grains, are independent of crystallography. In addition, specimens 878, 877, and 915 exhibit microscopic and/or macroscopic shear zones marked by granulation of the detritus and calcite. These zones are inclined from 26° to 38° to σ_1.

Specimen 878.—Twin lamellae are developed parallel to two of the three potential *e* twin planes. The average spacing index (99) is low compared to those of the other specimens. A macroscopic shear zone is inclined at 33° to σ_1. Microfractures are inconspicuous, and those that do occur are confined to the shear zone. This is reflected by a low fracture index (126). Although the

TABLE 1

Experimental Conditions and Data

Specimen	Compressed or Extended (1)	Confining Pressure (Bars) (2)	Temperature (° C.) (3)	Total Strain (Per Cent) (4)	Ultimate Strength* (Bars) (5)	Remarks (6)	Fracture Index† (7)	Twin-Lamellae Spacing Index‡ (8)
Sand Crystals Deformed Favorably for Twin Gliding								
Undeformed							111	0
878	Comp.	1,000	150	1.7	515	Sheared 33° to σ_1	126	99
915	Ext.	5,000	300	5.1	3,600	Experiment ended before fracture	219	212
877	Comp.	2,000	300	8.5	4,350	Sheared 30° to σ_1	212§	297
911	Ext.	2,000	300	13.5	1,560	Sheared 30° to σ_1	288	315
Sand Crystals Deformed Unfavorably for Twin Gliding								
1046	Comp.	1,000	150	2.9	2,290	Sheared 28° to σ_1	136	22
1049	Comp.	2,000	300	22.1	6,040	Incipient shear 35° to σ_1	300	153
Calcite-Cemented Sandstones								
Undeformed						Tensleep	114	0
Undeformed						Supai	114	0
724		1,000	150			Confining pressure only	115	0
763	Ext.	1,000	150	2.6	1,160	Broke near center	114	0
745	Ext.	2,000	150	2.9	1,690	Experiment ended before fracture	117	22
762	Comp.	1,000	150	3.9	4,660	Sheared 29° to σ_1	169	212
725	Comp.	1,000	150	5.9	4,800	Sheared 30°–35° to σ_1	184	152
778	Comp.	2,000	300	9.2	2,040	Sheared 29° to σ_1	189	238
780	Comp.	5,000	300	10.1	6,890	Experiment ended before fracture	203	302

* Ultimate strength, as defined by Handin and Hager (1957), is the maximum ordinate of the stress-strain curve.

† Based on fracturing in four hundred grains per specimen as follows: Per cent unfractured grains ×1, plus per cent of grains with 1–5 fractures ×2, plus per cent with 6–10 fractures ×3, plus per cent with greater than 10 fractures ×4, plus per cent of demolished grains (grain shape obliterated) ×5, ×100 (Borg, Friedman, Handin, and Higgs, 1960, p. 159). Index may vary from 100 to 500. The method is subjective, but indexes determined by one operator can be used to compare relative amounts of fracturing from specimen to specimen.

‡ Based on the number of lamellae per mm. when viewed on edge and measured along a line normal to the twin planes.

§ A macroscopic shear zone, probably containing highly fractured and demolished grains, was destroyed during sectioning. It is reasonable to assume that the index for this specimen would have been higher if grains along this zone could have been counted.

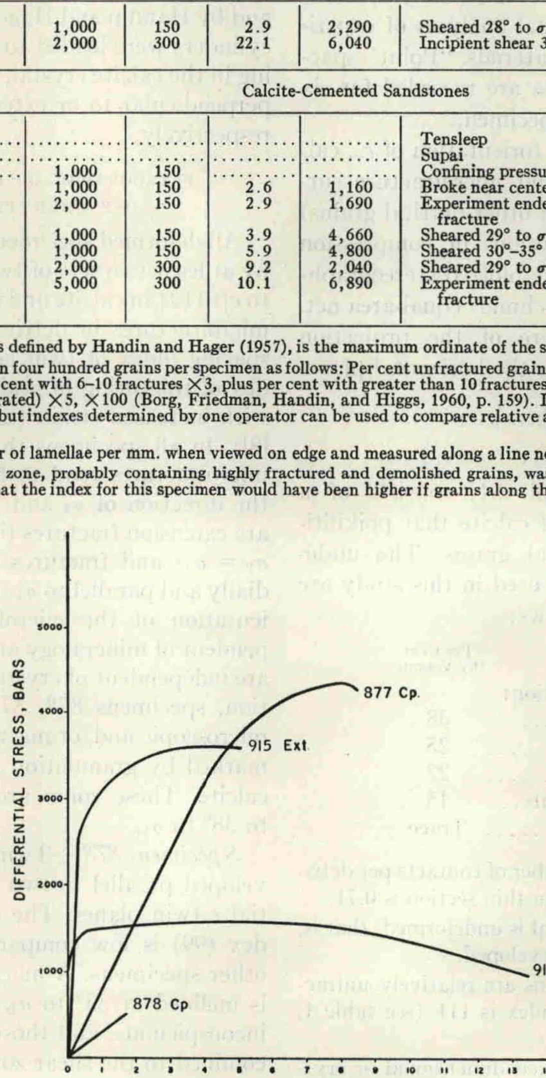

Fig. 4.—Stress-strain curves for sand crystals deformed favorably for twin gliding