2. Lamellae are commonly bent about detrital grains. This is accompanied by undulatory extinction in the area of bending so that the rational relationship between lamellae and $c_v$ is maintained. Maximum displacement of $c_v$ occurs immediately adjacent to detrital grains.

3. Lamellae are best developed on those sides of fractured grains that are subparallel to the microfracture surfaces. Commonly, only a few lamellae are developed on those sides of the grains that are normal to the microfracture surfaces (fig. 10).

4. In the untwinned portions of the crystal, some *r* cleavage planes and extension fractures have developed. The extension fractures are parallel to, and sometimes continuous with, those in neighboring detrital grains.

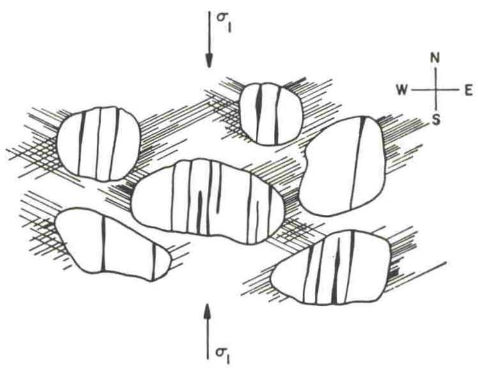


FIG. 10.—Sketch of fractured detrital grains and twin lamellae in calcite crystal. Twin lamellae are best developed on east and west sides of fractured grains and tend to die out into the interstices. Few lamellae are developed north and south of grains.

It is also interesting to compare the fracture indexes and twin-lamellae spacing indexes for specimens 1049 and 877. The fracture index of specimen 1049 (300) is higher than that for specimen 877 (212). This again probably reflects the greater strain of specimen 1049. The twin-lamellae spacing index of specimen 1049 (153) is about half that in specimen 877 (297), even though specimen 1049 has been strained about 2.7 times as much as specimen 877. There is no doubt that this difference is associated with the fact that specimen 1049 was loaded unfavorably for twin gliding.

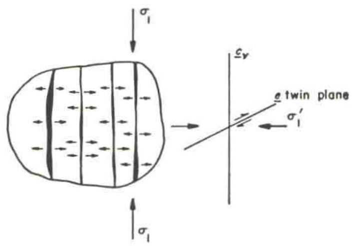


FIG. 11.—Schematic explanation of development of twin lamellae in 1046 and 1049. Detrital grain exhibits extension fractures. Movement on extension fractures is normal to fracture surfaces. This sets up a local stress ($\sigma_1'$) which produces a high resolved share stress parallel to the *e* twin plane and in the correct sense for twin gliding.

*Discussion.*—It is apparent that specimens 1046 and 1049 are stronger and exhibit fewer twin lamellae than specimens 878 and 877. However, if specimens 1046 and 1049 were loaded unfavorably for twin gliding, why should they contain any twin lamellae? In both specimens the twin lamellae are well developed only adjacent to detrital grains with extension fractures. Theoretically, movement associated with extension fractures is normal to the walls of the fracture and creates a local stress situation in which $\sigma_1$ is oriented to produce a high resolved shear stress in the proper sense for twin gliding parallel to the *e* planes in the adjacent calcite crystal (fig. 11). As the critical resolved shear stress is low, the local

PLATE 4

Photograph shows thin section cut parallel to the long axis of the deformed cylinder. The greatest principal stress ($\sigma_1$) is N.–S. The macroscopic shear zone containing gouge of quartz fragments and calcite cement is inclined at about 30° to $\sigma_1$. Fractures in detrital grains are predominantly parallel to $\sigma_1$; i.e., they are extension fractures. Crossed nicols.

stress can induce twin gliding despite the orientation of $\sigma_1$ on the specimen as a whole.

It is also important to emphasize that with increased strain (table 1, cols. [4] and [8]) the number of microfractures tends to increase independently of the orientation of the load axis with respect to the specimen. Also, in specimen 1046, all deformation features are best developed adjacent to the macroscopic shear zone.

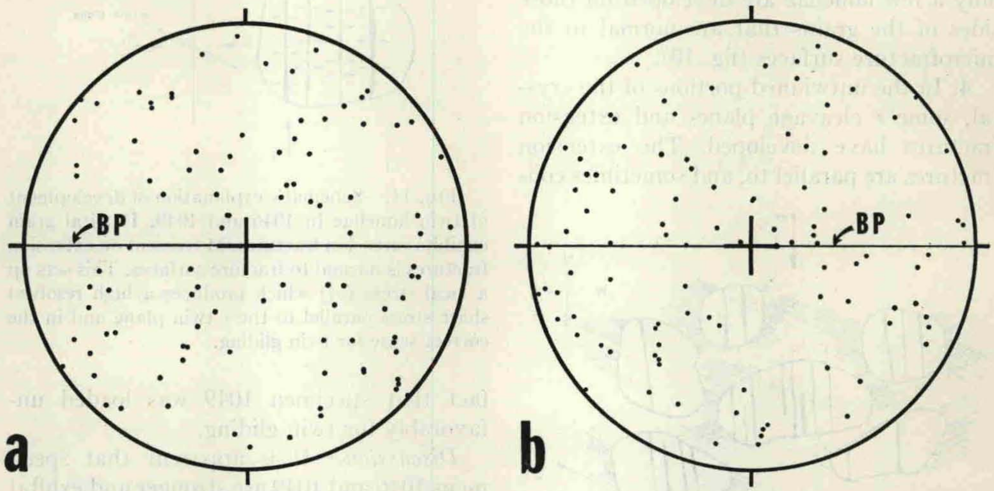


FIG. 12.—Diagrams show random orientation of 100 $c_v$ in calcite cement (*a*) and in quartz grains (*b*) of undeformed Tensleep sandstone. Plane of each diagram is normal to bedding plane (*BP*) as indicated.

## CALCITE-CEMENTED SANDSTONES

### UNDEFORMED TENSLEEP SANDSTONE

Undeformed Tensleep sandstone is well suited for this study because of its simple mineralogy, grain size, undeformed cement, unfractured detrital grains, and low porosity. It is characterized by:

1. Simple composition: the rock contains 69 per cent detrital grains (62 per cent quartz) and 31 per cent calcite cement.

2. Suitable crystal size: half the cement (15.8 per cent of the rock) is ideal for universal-stage study; that is, crystals are between 0.1 and 0.4 mm. in diameter.

3. Undeformed cement: only 2 per cent of the calcite crystals exhibit any twin lamellae; $c_v$ of the calcite are randomly oriented (fig. 12, *a*).

4. Low porosity: the porosity is 3.4 per cent (capillary-pressure determination); the low porosity minimizes the deformation effects caused by the collapse of voids upon application of confining pressure.

5. Lack of visible evidence of strong compaction: point- and long-grain contacts occur; the average number of contacts per grain is 2.1.

6. Unfractured detrital grains: the fracture index in the quartz grains is 114; $c_v$ of quartz grains are randomly oriented (fig. 12, *b*).

### UNDEFORMED SUPAI SANDSTONE

Undeformed Supai, which is similar to the Tensleep except for higher porosity and fewer contacts per grain, is characterized by:

1. Simple composition: the rock is composed of 55 per cent detrital grains (53 per cent quartz), 35 per cent calcite cement, and 10.5 per cent void space.

2. Calcite cement: the cement is almost entirely undeformed; the crystals range from 0.1 to 0.3 mm. in diameter; $c_v$ are randomly oriented.

3. Porosity: the porosity is 17.5 per cent (capillary-pressure determination).

4. Lack of compaction: the average number of contacts per grain is 1.1.