PETROFABRIC ANALYSIS OF EXPERIMENTALLY DEFORMED CALCITE-CEMENTED SANDSTONES

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PETROFABRIC ANALYSIS OF EXPERIMENTALLY DEFORMED CALCITE-CEMENTED SANDSTONES[1]

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ABSTRACT

Cylinders of sand crystals, composed of single crystals of calcite that poikilitically enclose detrital grains, and calcite-cemented sandstones from the Tensleep (Pennsylvanian, Wyoming) and Supai (Permian, Nevada) formations were experimentally deformed dry at confining pressures of 1–5 kilobars and temperatures of 150°–300° C. Thin sections of the undeformed and deformed specimens were studied microscopically to gain a better understanding of the behavior of sandstones in simulated tectonic environments. The calcite and the detrital grains (quartz, feldspar, and others), which have radically different physical and mechanical properties, are shown statistically to have deformed with respect to the principal stresses across the boundaries of the whole specimens rather than with regard to local stress concentrations at grain contacts.

The deformation mechanisms of calcite and quartz are the same in the sandstones as in monomineralic aggregates, such as marbles and quartz sands. Statistically, twin lamellae are developed in those calcite grains that are favorably oriented for twin gliding with respect to the load axes. The resolved shear-stress coefficient for these twin planes averages 0.27. Compression and extension axes deduced from the best developed set of twin lamellae in each calcite grain yield derived positions for the principal stress axes that are in excellent agreement with those known from the experiments. In addition, the number of lamellae per millimeter increases with increased strain of the specimens.

Quartz, feldspar, rock fragments, and garnet grains comprise the bulk of the detrital material. These deform primarily by fracturing. The microfractures in the grains are nearly planar features which, because of their geometric relationship to the known principal stress directions, are recognized as extension and shear fractures. They develop independently of the grain mineralogy and, in quartz grains, greatly overshadow a slight tendency for fractures to parallel $r\{10\bar{1}1\}$ and $z\{01\bar{1}1\}$. The degree of fracturing in a specimen, expressed as a fracture index, tends to increase with increased strain of the specimen. In sand crystals loaded unfavorably for twin gliding in the calcite crystal, extension fracturing in the detrital grains causes local reorientation of the stresses and produces twin lamellae in the adjacent calcite.

Twin lamellae in calcite and fractures in detrital grains are shown to be criteria for simulated tectonism. The development of lamellae and microfractures is directly related to the orientations of the principal stresses in heterogeneous, sedimentary rocks at the time of deformation.

INTRODUCTION

Structural configurations are dependent upon stress conditions in rocks during tectonic events. This has been demonstrated theoretically by the treatments of Anderson (1951), Hafner (1951), Hubbert (1951), Odé (1957), Hubbert and Rubey (1959), and Sanford (1959), to name a few. Moreover, the fact that the behavior of rocks with respect to states of stress and other tectonic environmental factors can be predicted has been experimentally demonstrated primarily by the studies of Griggs and of Handin and their associates.[3] Until recently, however, it has not been possible to augment these treatments by direct determination of the principal stress orientations in rocks at the time of deformation. Petrofabric techniques, based upon detailed knowledge of the mechanisms of deformation in a number of commonly occurring minerals, now permit such determinations. Some of these techniques have been applied successfully to the study of monomineralic, metamorphic rocks (Turner, 1953; McIntyre and Turner, 1953; Gilmour and Carman, 1954; Weiss, 1954; Crampton, 1958; and Christie, 1958).

The present study was designed to evaluate twin lamellae in calcite and fractures in detrital grains as sound criteria of deformation in deformed, heterogeneous, sedi-

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[3] See Griggs (1936, 1939); Griggs and Bell (1938); Griggs and Miller (1951); Griggs, Turner, Borg, and Sosoka (1951, 1953); Griggs and Handin (1960); and Griggs, Turner, and Heard (1960); Handin and Griggs (1951); Handin (1953); Handin and Fairbairn (1955); and Handin and Hager (1957, 1958).