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AN INCLUSION HOURGLASS PATTERN IN SYNTHETIC GYPSUM[1]

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ABSTRACT

Gypsum crystals with an hourglass pattern of calcite inclusions have been synthesized. This experiment suggests that the pushing and incorporating mechanism as a function of growth rate is responsible for the formation of an inclusion hourglass pattern.

Inclusion hourglass patterns in authigenic albite from Rhodes and in some albites from Modane, France, have been observed and described by Kastner (1969) and Kastner and Waldbaum (1968). They have emphasized that inclusion hourglass patterns might furnish important information about the growth histories of the enclosing crystals.

According to Becke (1892) and Harker (1932) inclusion hourglass patterns in minerals indicate that on some crystallographic forms nearly all foreign particles were excluded from and pushed aside and that on other forms foreign particles were incorporated into the crystal. Experimental work confirming this interpretation is scarce. Moreover, as yet no one has reproduced an *inclusion* hourglass pattern. Uhlman (1963) studied the interaction between particles ranging in size from one to several hundred microns and a solid-liquid interface. He observed that particles are either pushed ahead by the advancing interface or incorporated in the solid. The pushing of foreign particles by an interface demands two forces: 1) a force which tends to keep the particles from being incorporated. This force depends on the differential surface energy factor; the solid-particle surface energy has to exceed the sum of the solid-liquid and particle-liquid surface energies. 2) A feeding force needed for material transport to the regions of interface back of the particles. The material is transported by a diffusive mechanism. Trapping will occur when the feeding force needed for material transport exceeds the pushing force keeping the particles out of the solid.

At sufficiently low growth rates, nearly all particles are pushed ahead by the advancing interface. As the growth rate is increased, some particles begin to be incorporated in the solid. A further increase in growth rate results in the incorporation of all particles. He defined the "critical velocity" (C.V.) as the lowest velocity at which no particles are pushed, and observed that for small particles (1 to 15 microns) the C.V.

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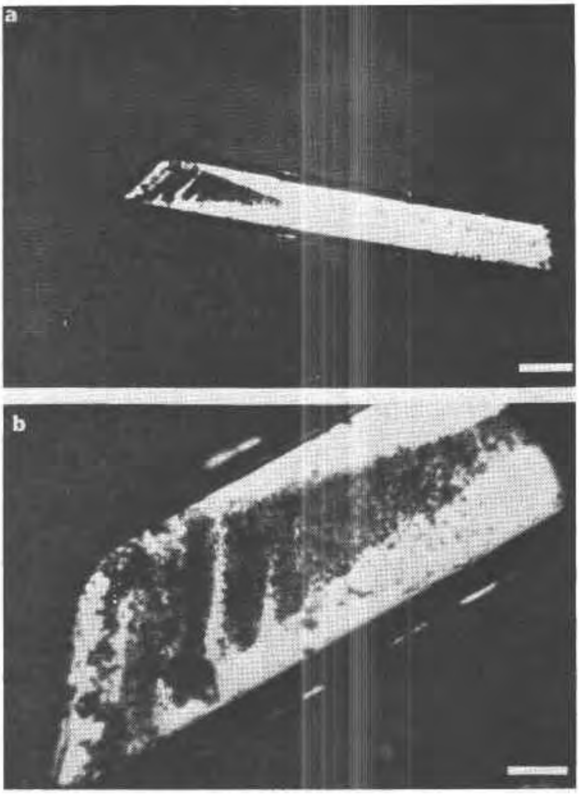

FIG. 1. Inclusion hourglass pattern in a synthetic gypsum crystal.
a) An inclusion hourglass pattern in the left (upper) half of the crystal; the right (lower) half is clear of calcite inclusions. White line in lower right represents 0.4 mm.
b) Enlarged view of left (upper) half of Fig. 1a. Note the clear areas parallel to the most rapidly growing face. White line in lower right represents 0.1 mm.

is independent of particle size and generally independent of its shape. For larger particles a size dependence is observed, the C.V. being smaller for larger particles and generally also dependent of their shape. The size dependence of the C.V. for large particles results from the difficulty of feeding to the region back of the particle. Studies by Buckley (1934, 1951) and Corté[1] (1963) are consistent with Uhlman's data and interpretation. Their results have been discussed by Kastner (1969) and Kastner and Waldbaum (1968, p. 1599).

Figure 1 shows an inclusion hourglass pattern in a synthetic gypsum

[1] Work done at the U.S. Army Cold Regions Research Engineering Laboratory, Hanover, N. H., in 1963 (Report 105).

crystal, which has grown from a mixture of fine grained synthetic calcite and sea water. The slow evaporation rate of sea water over a one month period was controlled by enclosing the beaker in a desiccator. During most of this time the temperature was held constant at 70°C. However, for five short intervals of one to two days, it was held at room temperature, thus reducing the growth rate of the gypsum crystals.

Nucleation occurred at the interface calcite-mud/sea-water, and the crystal growth proceeded perpendicular to this interface. Consequently, an inclusion hourglass pattern developed only in the lower half of the crystal while the upper half, which grew in clear sea water, remained clear, as shown in Figure 1a.

Clear areas parallel to the most rapidly growing crystal faces (Fig. 1b) developed during the room temperature intervals in which growth velocities were reduced and all particles were pushed aside by the advancing interface, instead of being incorporated. If the crystal grew faster than in the experiment all the lower half of the crystal would contain inclusions.

This qualitative experiment suggests that the pushing and incorporating mechanism as a function of growth rate is an essential mechanism responsible for the formation of an *inclusion* hourglass pattern. Quantitative data are necessary for the formulation of mathematical expressions relating growth velocities to given particle sizes, shapes, viscosities, and surface free energies.

Acknowledgement

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