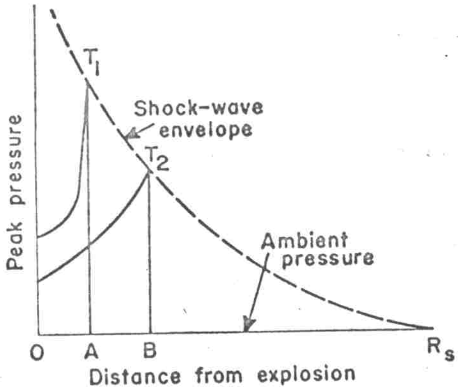

Fig. 5. Diagram of shock-wave propagation (*8*).

and magnitude to reorient the local stress field, thereby creating the second-order shears required to develop the 70° concentrations.

There does not seem to be a relation between the formation of kink-bands and the relation of the direction of the crystallographic axes of the biotite to the direction of shock-wave propagation. Whereas previous workers (*2*) suggested that kink-bands tended to develop preferentially in grains whose [001] axes [that is, normals to (001)] are steeply inclined to the compression axis, the present work indicates no such preference. Rather, in the shock zone of a nuclear explosion, kink-bands in biotite can be formed almost without regard to the crystallographic orientation. One difference in the conditions of the laboratory experiment (*2*) and the nuclear explosion which may account for the indiscriminate development of kink-bands with respect to the crystallographic axes is that the stress produced by the nuclear explosion's shock wave is of such a large magnitude and rapid application that the crystallographic anisotropy of biotite has little influence on kink-band formation.

The mode of failure, under the extremely rapid dynamic loading of a shock wave from a nuclear explosion, may be quite different from the mode of failure under the essentially static loading applied in laboratory experiments. The mode of failure, therefore, may not follow the same preferred crystallographic orientation under shock loading as under static loading.

DAVID CUMMINGS*

U.S. Geological Survey, Denver, Colorado

References and Notes

1. The radius of the shock zone for the granodiorite, R_s, may be obtained by using the scaling formula $R_s = 75\ W^{1/3}$, where W is the yield of the nuclear explosive in terms of trinitrotoluene equivalents.
2. D. T. Griggs, F. J. Turner, H. C. Heard, *Geol. Soc. Am. Mem.* **79**, 65 (1960).
3. M. S. Paterson and L. E. Weiss, *Nature* **198**, 1046 (1962).
4. J. G. Ramsey, *Geol. Mag.* **99**, 516 (1962).
5. H. E. McKinstry, *Am. J. Sci.* **251**, 401 (1953).
6. J. D. Moody and M. J. Hill, *Bull. Geol. Soc. Am.* **67**, 1207 (1956).
7. "Mathematically, a shock wave is an actual discontinuity propagating with a velocity greater than the local sound velocity," E. H. Freedman and E. F. Green, in *American Institute of Physics Handbook*, D. E. Gray, Ed. (McGraw-Hill, New York, 1957), pp. 2–231.
8. S. Glasstone, Ed., *The Effects of Nuclear Weapons* (U.S. Atomic Energy Commission, Washington, D.C., 1962), p. 104.

9. Work done on behalf of the U.S. Atomic Energy Commission. Publication authorized by the Director, U.S. Geological Survey. I thank the Lawrence Radiation Laboratory for providing the core samples.

* Present address: Astrogeological Branch, U.S. Geological Survey, Flagstaff, Arizona.

8 February 1964

Growth Layers on Ammonium Dihydrogen Phosphate

Abstract. *Microscopic observations of growth layers and etch pits on ammonium dihydrogen phosphate crystals reveal screw dislocations on the {100} face generating elliptical spirals that change rapidly but reversibly to rectangular shape when chromium-ion impurity is added. The effects of the impurity on crystal habit are judged to be secondary to changes in the morphology of the growth layers. No sources of growth are observed on the {101} faces; the layers spread inward from the edges and at times are mutually annihilating so that, temporarily, no steps are observed. Similar behavior is recorded for the* {$10\bar{1}1$} *faces of* $NaNO_3$.

Bunn and Emmett (*1*) stimulated interest in the formation of growth layers at the same time that Frank (*2*) suggested that crystal dislocations could provide the sources of steps required for continuous crystal growth. Albon and Dunning (*3*) developed a particularly fine experimental technique for the observation of layer morphology and growth kinetics of sucrose. Their methods have been emulated and extended in our investigation of the mechanism of growth of ammonium d[illegible] drogen phosphate crystals from aq[illegible] solution. In particular, we studied [illegible] nature of the deposition proce[illegible] self, whether by surface nucleati[illegible] as initiated at dislocation sites, [illegible] as influenced by impurities.

In experiments with crystals that [illegible] nucleated more readily than suc[illegible] the chief difficulty arises from the [illegible] currence of spontaneous growth [illegible] tubes connecting the storage vess[illegible] the growth cell. Undue heating [illegible] these leads necessarily interferes w[illegible] precise temperature control in the [illegible]

The crystals were grown in a [illegible] (3-mm) cell consisting of top and b[illegible] tom (black) glass plates of op[illegible] quality, secured in a gold-plated [illegible] block. Inlet and outlet tubes all[illegible] the circulation of salt solution from [illegible] external, carefully lagged, st[illegible] thermostat (40°C) by means of a [illegible] able peristaltic pump. Housed in a p[illegible] (methyl methacrylate) container, [illegible] cell could be rotated about the ax[illegible] the microscope tube and given [illegible] degree of tilt so that a particular [illegible] of a crystal could be brought into p[illegible] tion to be strongly illuminated [illegible] focused beam of light. Photom[illegible] graphs were taken with a 35-mm si[illegible] lens reflex camera and with fine-g[illegible] film. For cine-film recording we us[illegible] 16-mm camera and reversal film.

Heat was supplied to or withdr[illegible] from the growth cell by means [illegible] Peltier junction attached to the b[illegible] of the cell. Thus the temperature [illegible] the cell could be raised or lowered [illegible] increase super- or undersaturation [illegible] desired. While unintentional temp[illegible] ture fluctuations in the cell [illegible] amounted to a few thousandths [illegible] degree Celsius, as measured [illegible] a platinum resistance thermom[illegible] it was suspected that fluctuation[illegible] the solutions tended to be some[illegible] greater.

We found that growth on the [illegible] face of ammonium dihydrogen p[illegible] phate crystals proceeds by a s[illegible] dislocation mechanism. The s[illegible] are roughly elliptical in shape [illegible] centricity about 0.86) and o[illegible] with the short axis of the ellipse p[illegible] lel to the [001] axis of the cr[illegible] Growth proceeds by the movem[illegible] steps across the crystal face. The [illegible] are of varying height, visibility [illegible] roughly proportional to the step h[illegible] Occasionally we found single spir[illegible] in Fig. 1. However, most freq[illegible]