

they have been put. Data used in the calculations are no more than approximations.

Within the framework outlined, however, the failure model has shown a consistency relative to experimental verification, at least to the extent presently possible, and to the nature of events as they occur within the earth. Additional experimentation to higher pressures and temperatures is needed for further verification.

As presently developed, the model suggests that earthquakes are caused by shear-induced catastrophic failure of rock and that magnitudes are primarily a function of the volume of failure and, for a planar failure, of its surface area. The periodic occurrence of earthquakes within seismically active regions would be related to variable functions of strength, stress, and time.

*Acknowledgment.* Thanks are given to Alfred Bobrowsky for helpful criticism and discussion on the behavior of materials under pressurized stress and the Bridgman pinch-off effect.

#### REFERENCES

- Abey, A. E., and H. D. Stromberg, 70 kilobar shear apparatus. *Rev. Sci. Instrum.*, 40, 557, 1969.
- Anderson, O. L., E. Schreiber, R. C. Liebermann, and N. Soga. Some elastic constant data on minerals relevant to geophysics. *Rev. Geophys. Space Phys.*, 6, 491, 1968.
- Bäth, M., Earthquake seismology. *Earth Sci. Rev.*, 1, 69, 1966.
- Bobrowsky, A., Pressure alteration through use of solid containers or jackets in high-pressure environments, in *High Pressure Measurement*, edited by A. A. Giardini and E. C. Lloyd, p. 172. Butterworths, London, 1963.
- Bridgman, P. W., Breaking tests under hydrostatic pressure and conditions of rupture. *Phil. Mag.*, 24, 63, 1912.
- Bridgman, P. W., Shearing phenomena at high pressure of possible importance for geology. *J. Geol.*, 44, 653, 1936.
- Bridgman, P. W., The compression of twenty-one halogen compounds and eleven other simple substances to 100,000 kg/cm<sup>2</sup>. *Proc. Amer. Acad. Arts Sci.*, 76, 1, 1945.
- Carter, N. L., C. B. Raleigh, and P. S. DeCarli, Deformation of olivine in stony meteorites. *J. Geophys. Res.*, 73, 5439, 1968.
- Giardini, A. A., The nature of granodiorite under triaxial stress and a possible model for seismic disturbances. *Southeast. Geol.*, 10, 125, 1969.
- Giardini, A. A., and A. E. Abey, Room-temperature shear strengths of rocks under near-hydrostatic confining pressure to 80 kbar. 1. Solnhofen limestone and three Georgia marbles. *Tectonophysics*, 14, 121, 1972.
- Giardini, A. A., and A. E. Abey, The torsional shear strength of granodiorite and dunite under near-homogeneous confining stress to about 90 kbar, 2. *Tectonophysics*, 18, 147, 1973.
- Giardini, A. A., J. F. Lakner, D. R. Stephens, and H. D. Stromberg, Triaxial compression data on nuclear explosion shocked, mechanically shocked, and normal granodiorite from the Nevada Test Site. *J. Geophys. Res.*, 73, 1305, 1968.
- Griggs, D. T., F. J. Turner, and H. C. Heard, Deformation of rocks at 500°C to 800°C, in *Rock Deformation, Mem. 79*, edited by D. T. Griggs and J. Handin, p. 39, Geological Society of America, Boulder, Colo., 1960.
- Gutenberg, B., and C. F. Richter, Earthquake magnitude, intensity, energy and acceleration. *Bull. Seismol. Soc. Amer.*, 32, 163, 1942.
- Gutenberg, B., and C. F. Richter, *Seismicity of the Earth and Associated Phenomena*, pp. 16-25, Princeton University Press, Princeton, N. J., 1949.
- Hodgson, J. H., and A. E. Stevens, Seismicity and earthquake mechanisms, in *Research in Geophysics*, vol. 2, edited by H. Odishaw, p. 27, MIT Press, Cambridge, Mass., 1964.
- Kalpakjian, S., *Mechanical Processing of Materials*, p. 175, D. Van Nostrand, Princeton, N. J., 1967.
- Kesler, S. E., and S. A. Heath, The effect of dissolved volatiles on magnetic heat sources at intrusive contacts. *Amer. J. Sci.*, 266, 829, 1968.
- Orowan, E., Mechanism of seismic faulting. in *Rock Deformation, Mem. 79*, edited by D. Griggs and J. Handin, p. 323, Geological Society of America, Boulder, Colo., 1960.
- Ramberg, H., Pegmatites in west Greenland. *Geol. Soc. Amer. Bull.*, 67, 185, 1956.
- Riecker, R. E., and T. P. Rooney, Shear deformation of Nevada Test Site rocks: Tests to 60 kb and 900°C. *Environ. Res. Pap.* 228, 22 pp., Air Force Cambridge Res. Lab., L. G. Hanscom Field, Bedford, Mass., 1966a.
- Riecker, R. E., and T. P. Rooney, Shear strength, polymorphism, and mechanical behavior of olivine, enstatite, diopside, labradorite, and pyrope garnet: Tests to 920°C and 60 kb. *Environ. Res. Pap.* 216, 57 pp., Air Force Cambridge Res. Lab., L. G. Hanscom Field, Bedford, Mass., 1966b.
- Scholz, C. H., L. R. Sykes, and Y. P. Aggarwal, Earthquake prediction: A physical basis. *Science*, 181, 803, 1973.
- Stacey, F. D., *Physics of the Earth*, p. 281, John Wiley, New York, 1969.
- Starr, A. T., Slip in a crystal and rupture in a solid due to shear. *Proc. Cambridge Phil. Soc.*, 24, 489, 1928.
- Sykes, L. R., B. L. Isacks, and J. Oliver, Spatial distribution of deep and shallow earthquakes of small magnitudes in the Fiji-Tonga region. *Bull. Seismol. Soc. Amer.*, 59, 1093, 1969.
- Toksöz, M. N., J. W. Minear, and B. R. Julian, Temperature field and geophysical effects of a downgoing slab. *J. Geophys. Res.*, 76, 1113, 1971.

(Received February 23, 1973;  
revised October 23, 1973.)