Dynamic Compression of Enstatite[1]

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New shock wave data for Bamle enstatite $(Mg_{0.86},Fe_{0.14})SiO_3$ in the range from 60–480 kb indicate a Hugoniot elastic limit of 67 ± 10 kb and a possible phase-transition-produced shock front of 135 ± 10 kb amplitude. Above the latter shock pressure, states in a mixed-phase regime are achieved up to ~350 kb, above which the Hugoniot states are believed to represent the equation of state of a shock-induced phase, probably having the majorite (garnet) structure with a zero-pressure density of ~3.67 g/cm³. The present data, representing the high-pressure phase, agree closely with those of R. G. McQueen, S. P. Marsh, and J. N. Fritz above 610 kb for a Stillwater bronzitite of similar mineralogy. It is suggested that the formation of majorite from enstatite in naturally impacted rocks and meteorites requires dynamic pressures of at least ~135 kb.

Shock-wave equations of state for pyroxenes are of considerable importance, both for the understanding of shock metamorphism processes in lunar gabbros and basalts and for determining the constitution of terrestrial planetary mantles. The proposed presence of 15 to 18% orthopyroxene and clinopyroxene in the pyrolite and 40% pyroxene in the eclogite earth upper-mantle models of *Clark and Ringwood* [1964] and from 40 to 80% pyroxene in the earth's lower mantle [*Birch,* 1964; *Anderson et al.,* 1971] provides ample motivation for the study of this mineral. The present detailed Hugoniot measurements were carried out on single-crystal Bamle orthoenstatite $(Mg_{0.86},Fe_{0.14})SiO_3$ to 480 kb. Previously ultrasonic data were reported by *Rhyzhova et al.* [1966] for a slightly porous sample and by *Kumazawa* [1969] for a gem-quality sample. Shock-compression measurements on two enstatite-bearing rocks to pressures of ~1.1 Mb by *McQueen et al.* [1967] and similar data by *Trunin et al.* [1965] indicated anomalously large compressions for the higher pressure states; however, their results have been variously interpreted in later papers by other workers. The present study was carried out on a single-phase enstatite in order to delineate the phase-change regime and to obtain the equation-of-state data for the shock-induced phase.

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SPECIMEN MATERIAL

A series of disk-shaped samples were cut from several large single crystals of orthoenstatite (Bamle, Norway) purchased from Ward's Natural Science Establishment. The cylindrical disk axes were oriented to within ±3° of (001) using the external crystal faces. After inspection by radiography, samples having no obvious inclusions and only minor cracks were retained. These remaining samples, which were light brown and translucent, were surface ground to a nominal thickness of 4.7 mm. The planar surfaces were machined flat and parallel to 0.008 mm.

Thin sections of this material were examined by Rex V. Gibbons. The specimen material had a negative optical sign, indicating that it contains more Fe^{++} than $En_{0.88}$. A measurement of the index of refraction n_z of 1.6820 ± 0.002 (white light) indicated a stoichiometry of $En_{0.86 \pm 0.015}$. A value of n_z (Na light) gives a value of 1.6695 ± 0.001, indicating stoichiometry of $En_{0.86}$ [*Deer et al.,* 1966]. Microprobe analysis by A. Albee and A. Chodos gave a stoichiometry of $(Mg_{0.86}, Fe_{0.14}, Ca_{0.005}, Al_{0.003})Si_{0.99}O_3$. A second analysis gave a similar result for the major elements but also indicated some manganese was present $(Mn_{0.01})$. On the basis of these analyses we conclude that the composi-