

enes have not transformed to a denser phase [Ahrens *et al.*, 1969] gives the densities 3.70 (W1) and 3.66 (F) g/cm³, which are also compatible, but this alternative seems less attractive in view of the enstatite and bronzite results. It is also possible that the augite transformed to the ilmenite structure, giving densities ~3.85 g/cm³, which are rather high.

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REFERENCES

- Ahrens, T. J., Don L. Anderson, and A. E. Ringwood, Equations of state and crystal structures of high-pressure phases of shocked silicates and oxides, *Rev. Geophys.*, **7**, 667-707, 1969.
- Al'tshuler, L. V., R. F. Trunin, and G. V. Simahov, Shock-wave compression of periclase and quartz and the composition of the earth's lower mantle, *Bull. Acad. Sci. USSR, Geophys. Series*, English trans. no. 10, 1-6, 1965.
- Anderson, Don L., A seismic equation of state, *Geophys. J.*, **13**, 9-30, 1967.
- Anderson, Don L., Bulk modulus-density systematics, *J. Geophys. Res.*, **74**, 3857-3864, 1969.
- Anderson, Don L., and T. Jordan, The composition of the lower mantle, *Phys. Earth Planet. Interiors*, **3**, 23-35, 1970.
- Anderson, Don L., and H. Kanamori, Shock-wave equations of state of rocks and minerals, *J. Geophys. Res.*, **73**, 6477-6502, 1968.
- Anderson, O. L., On the use of ultrasonic and shock-wave data to estimate compressions at extremely high pressures, *Phys. Earth Planet. Interiors*, **1**, 169-176, 1968.
- Anderson, O. L., E. Schreiber, R. C. Liebermann, and N. Soga, Some elastic constant data on minerals relevant to geophysics, *Rev. Geophys.*, **6**, 491-525, 1968.
- Clark, S. P., Jr., editor, *Handbook of Physical Constants*, Memoir 97, Geological Society of America, New York, 1966.
- Fritz, T. C., and R. N. Thurston, Extrapolation formula for finding the volume of solids at high pressures, *J. Geophys. Res.*, **75**, 1557-1569, 1970.
- Gaffney, E. S., and T. J. Ahrens, Stability of mantle minerals from lattice calculations and shock wave data, *Phys. Earth Planet. Interiors*, **3**, 205-212, 1970.
- Keane, A., An investigation of finite strain in an isotropic material subjected to hydrostatic pressure and its seismological applications, *Aust. J. Phys.*, **7**, 323-333, 1954.
- Kumazawa, M., The elastic constants of single-crystal orthopyroxene, *J. Geophys. Res.*, **74**, 5973-5980, 1969.
- Manghnani, M. H., E. Schrieber, and N. Soga, Use of ultrasonic interferometry technique for studying elastic properties of rocks, *J. Geophys. Res.*, **73**, 824-826, 1968.
- March, N. H., Equations of state of elements from the Thomas-Fermi theory, *Proc. Phys. Soc. London, A*, **68**, 726-734, 1955.
- McQueen, R. G., S. P. Marsh, and J. N. Fritz, Hugoniot equation of state of twelve rocks, *J. Geophys. Res.*, **72**, 4999-5036, 1967.
- Reid, A. F., and A. E. Ringwood, High pressure scandium oxide and its place in the molar volume relationship of dense structures of M₂X₃ and ABX₃ type, *J. Geophys. Res.*, **74**, 3238-3252, 1969.
- Ringwood, A. E., Phase transformations in the mantle, *Earth Planet. Sci. Lett.*, **5**, 401-412, 1969.
- Shannon, R. D., and C. T. Prewitt, Effective ionic radii in oxides and fluorides, *Acta Cryst.*, **B25**, 925-946, 1969.
- Strens, R. G. J., The nature and geophysical importance of spin pairing in minerals of iron (II), in *The Application of Modern Physics to the Earth and Planetary Interiors*, edited by S. K. Runcorn, Wiley-Interscience, New York, 1969.
- Thomsen, L. T., On the fourth-order anharmonic equation of state of solids, *J. Phys. Chem. Soc.*, **31**, 2003-2016, 1970.
- Trunin, R. F., V. I. Gon'shakova, G. V. Simakov, and N. E. Galdin, A study of rocks under the high pressures and temperatures created by shock compression (in Russian), *Izv. Acad. Sci., USSR, Phys. Solid Earth*, no. 9, 1-12, 1965. (Also English trans., no. 9, 579-586, 1966.)
- Wackerle, J., Shock-wave compression of quartz, *J. Appl. Phys.*, **33**, 922, 1962.
- Wang, C. Y., Constitution of the lower mantle as evidenced from shock wave data for some rocks, *J. Geophys. Res.*, **73**, 6459-6474, 1968.

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