Kumazawa, M. & Anderson, O. L., 1969. Elastic moduli, pressure derivatives, and temperature derivatives of single-crystal olivine and single-crystal forsterite, *J. geophys. Res.*, **74,** 5961–5972.

Lazarus, D., 1949. The variation of tha adiabatic elastic constants of KCl, NaCl, CuZn, Cu, and Al with pressure to 10,000 bars, *Phys. Rev.*, **76,** 545–551.

Liebermann, R. C., 1970. Velocity-density systematics for the olivine and spinel phases of Mg_2SiO_4-Fe_2SiO_4, *J. geophys. Res.*, **75,** 4029–4034.

Macdonald, J. R., 1969. Review of some experimental and analytical equations of state, *Rev. mod. Phys.*, **41,** 316–349.

Mao, N., Ito, J., Hays, J. F., Drake, J. & Birch, F., 1970. Composition and elastic constants of hortonolite dunite, *J. geophys. Res.*, **75,** 4071–4076.

Mao, H., Takahashi, T., Bassett, W. A., Weaver, J. S. & Akimoto, S., 1969. Effect of pressure and temperature on the molar volumes of wüstite and three (Fe, $Mg)_2SiO_4$ spinel solid solutions, *J. geophys. Res.*, **74,** 1061–1069.

McQueen, R. G., Marsh, S. P. & Fritz, J. N., 1969. Hugoniot equation of state of 12 rocks, *J. geophys. Res.*, **72,** 4999–5036.

Mizutani, H., Hamano, Y., Ida, Y. & Akimoto, S., 1970. Compressional wave velocities in fayalite, Fe_2SiO_4-spinel, and coesite, *J. geophys. Res.*, **75,** 2741–2747.

Murnaghan, F. D., 1944. Compressibility of media under extreme pressure, *Proc. Nat. Acad. Sci. U.S.*, **30,** 244–246.

Murnaghan, F. D., 1951. *Finite deformation of an elastic solid*, John Wiley & Sons, Inc., New York.

Olinger, B. & Duba, A., 1971. Compression of olivines to 100 kbars, *J. geophys. Res.*, *Res.*, **76,** 2610–2616.

Press, F., 1968. Earth models obtained by Monte Carlo inversion, *J. geophys. Res.*, **73,** 5223–5234.

Press, F., 1969. The suboceanic mantle, *Science*, **165,** 174–176.

Press, F., 1970a. Earth models consistent with geophysical data, *Phys. Earth Planet. Int.*, **3,** 3–22.

Press, F., 1970b. Regionalized earth models, *J. geophys. Res.*, **75,** 6575–6581.

Ringwood, A. E., 1970. Phase transformation and the constitutions of the mantle, *Phys. Earth Planet. Int.*, **3,** 89–155.

Robie, R. A. & Waldbaum, D. R., 1968. Thermodynamic properties of minerals and related substances at 298·15° K and one atmosphere pressure and high temperatures, *Geol. Survey Bull.* **1259,** 256.

Schreiber, E., 1969. The effect of solid solutions upon the bulk modulus and its pressure derivative: Implications for equations of state, *Earth Planet. Sci. Lett.*, **7,** 137–140.

Schreiber, E. & Anderson, O. L., 1967. Pressure derivatives of the sound velocities of polycrystalline forsterite with 6 per cent porosity, *J. geophys. Res.*, **72,** 762–764, and correction p. 3751.

Simmons, G., 1964. Velocity of shear waves in rocks to 10 kb, Part 1, *J. geophys. Res.*, **69,** 1123–1130.

Singh, H. P. & Simmons, G., 1971. Variation of cell parameters of olivines with temperature, to be published.

Skinner, B. J., 1966. Thermal expansion, in *Handbook of Physical Constants, Momoir* **97,** edited by S. P. Clark, Jr., Geological Soc. of America, New York. p. 92.

Soga, N. & Anderson, O. L., 1967. High temperature elasticity and expansivity of forsterite and steatite, *J. Am. Ceram. Soc.*, **50,** 239–242.

Takahashi, T., 1970. Isothermal compression of fayalite at room temperature, *Trans. A.G.U.*, **51,** 827. (Abstract only).

Verma, R. K., 1960. Elasticity of some high-density crystals, *J. geophys. Res.*, **65,** 757–766.

Walsh, J. B., 1965. The effect of cracks on the compressibility of rocks, *J. geophys. Res.*, **70,** 381–390.

Walsh, J. B. & Brace, W. F., 1966. Elasticity of rocks: A review of some recent theoretical studies, *Rock Mechanics & Engineering Geology*, Springer-Verlag, Wien. pp. 284–297.

Whitcomb, D. L., 1970. Reflection of P'P' seismic waves from discontinuities in the mantle, *J. geophys. Res.*, **75,** 5713–5728.

Appendix

The thermal properties of olivine may be found in a large number of the original literature. Table 8 lists those literature data on thermal expansion α_v and specific heat C_p used in the present work. The α_v values were obtained from Skinner (1966) and Singh & Simmons (1971). The C_p data were based on work of Robie & Waldbaum (1968) and JANAF Thermochemical Data tables (Dow Chemical Company (1960)). Incorporating the elasticity data with these thermal data, Gruneisen's parameters γ_G and δ_s have been evaluated as a function of temperature; results on two temperatures (one at ambient temperature and the other at the Debye temperature) for three chosen olivine compositions are entered in Table 8. The γ_G and δ_s values evaluated at the Debye temperature θ_D represent constant values at high temperature. Values of the Debye temperature of olivine, as listed in the last row of Table 2, were calculated from the present elastic constant data at 296° K in the usual way. The critical thermal gradients for density and P and S wave velocities of 100 Fo, 50 Fo, and 100 Fa olivines are presented in Table 8. In geophysics, the critical thermal gradient for density evaluated at the Debye temperature is of more interest than that evaluated at the ambient temperature.

Table 8

Thermal properties, Grüneisen's parameters, and critical thermal gradients of olivine

Olivine property	Unit	T, °K	Olivine composition, mole % 100 Fo	50 Fo	100 Fa
ρ_0	g cm^{-3}	296	3·217	3·800	4·393
		θ_D†	3·162	3·760	4·364
α_v	10^{-5}/°K	296	2·54	2·45	2·40
		θ_D	3·86	3·20	2·88
C_p	cal/mole−°K	296	28·2	(30·0)‡	31·8
		θ_D	39·2	(39·1)	39·0
$\frac{d \ln K_s}{dT}$	10^{-4}/°K	296	−1·02	−1·07	−1·13
		θ_D	−1·44	−1·39	−1·31
γ_G	None	296	1·21	1·10	1·02
		θ_D	1·26	1·08	0·98
δ_s	None	296	4·0	4·4	4·7
		θ_D	3·7	4·3	4·5
$(\partial T/\partial p)_{V_p}$	°K/kb	296	24	24	23
$(\partial T/\partial p)_{V_s}$	°K/kb	296	12	8	2
$(\partial T/\partial p)_\rho$	°K/kb	296	31	33	35
		θ_D	22	27	30

† The Debye temperature values used here are tabulated in Table 2. They are respectively 754°K for 100 Fo, 633°K for 50 Fo, and 523°K for 100 Fa, and these values were calculated from the present elastic constants data in the usual way.

‡ These values are calculated from the Debye temperature of this material.