**Table 2**

*Elastic parameters and their pressure and temperature derivatives of olivine as a function of (Fe/Mg) Ratio (at 296° K)*

| Property† | Unit | Olivine composition, mole % | | | | | | | Estimated uncertainty, % |
|---|---|---|---|---|---|---|---|---|---|
| | | 100 Fo | 95 Fo | 90 Fo | 85 Fo | 80 Fo | 50 Fo | 100 Fa | |
| $\rho_0$ | g cm$^{-3}$ | 3·217 | 3·273 | 3·330 | 3·386 | 3·440 | 3·800 | 4·393 | ±0·2 |
| $\bar{m}$ | g | 20·12 | 20·58 | 21·00 | 21·48 | 21·93 | 24·60 | 29·10 | ±0·2 |
| $V_p$ | km s$^{-1}$ | 8·534 | 8·422 | 8·317 | 8·216 | 8·116 | 7·534 | 6·637 | ±0·5 |
| $V_s$ | km s$^{-1}$ | 4·977 | 4·892 | 4·815 | 4·739 | 4·663 | 4·213 | 3·494 | ±0·5 |
| $\phi$ | (km s$^{-1}$)J | 39·8 | 39·0 | 38·3 | 37·6 | 36·9 | 33·1 | 27·8 | ±1·1 |
| $\sigma_s$ | None | 0·242 | 0·245 | 0·248 | 0·251 | 0·254 | 0·273 | 0·308 | ±1·2 |
| $L_s$ | mb | 2·343 | 2·322 | 2·303 | 2·286 | 2·266 | 2·157 | 1·935 | ±0·8 |
| $\mu$ | mb | 0·797 | 0·783 | 0·772 | 0·760 | 0·748 | 0·674 | 0·536 | ±0·9 |
| $K_s$ | mb | 1·281 | 1·277 | 1·274 | 1·272 | 1·269 | 1·258 | 1·220 | ±1·8 |
| $K_T$ | mb | 1·270 | 1·266 | 1·263 | 1·261 | 1·258 | 1·248 | 1·211 | ±2·0 |
| $dL_s/dp$ | None | 7·51 | 7·50 | 7·52 | 7·47 | 7·42 | 7·18 | 6·75 | ±3·0 |
| $d\mu/dp$ | None | 1·85 | 1·81 | 1·80 | 1·76 | 1·64 | 1·31 | 0·62 | ±3·0 |
| $dK_s/dp$ | None | 5·04 | 5·08 | 5·13 | 5·13 | 5·23 | 5·44 | 5·92 | ±5·0 |
| $dK_T/dp$ | None | 5·07 | 5·11 | 5·16 | 5·16 | 5·27 | 5·48 | 5·97 | ±5·3 |
| $d\sigma_s/dp$ | mb$^{-1}$ | 0·33 | 0·33 | 0·36 | 0·36 | 0·40 | 0·46 | 0·62 | ±8·0 |
| $dV_p/dp$ | (km s$^{-1}$)/mb | 10·3 | 10·3 | 10·3 | 10·2 | 10·1 | 9·5 | 8·8 | ±3·0 |
| $dV_s/dp$ | (km s$^{-1}$)/mb | 3·8 | 3·7 | 3·7 | 3·6 | 3·3 | 2·4 | 0·6 | ±3·0 |
| $dL_s/dT$ | kb/°K | −0·296 | −0·294 | −0·293 | −0·292 | −0·291 | −0·284 | −0·273 | ±2·0 |
| | | (−0·360)‡ | (−0·357) | (−0·355) | (−0·352) | (−0·350) | (−0·336) | (−0·312) | ±2·0 |
| $d\mu/dT$ | kb/°K | −0·124 | −0·123 | −0·122 | −0·122 | −0·120 | −0·113 | −0·100 | ±2·0 |
| | | (−0·140)‡ | (−0·140) | (−0·139) | (−0·138) | (−0·138) | (−0·132) | (−0·120) | ±2·0 |
| $dK_s/dT$ | kb/°K | −0·131 | −0·131 | −0·132 | −0·132 | −0·133 | −0·135 | −0·138 | ±2·0 |
| | | (−0·180)‡ | (−0·179) | (−0·177) | (−0·176) | (−0·175) | (−0·168) | (−0·155) | ±2·0 |
| $d \ln V_p/dT$ | $10^{-6}$/°K | −50·2 | −50·4 | −50·8 | −51·2 | −51·5 | −53·4 | −57·0 | ±3·0 |
| $d \ln V_s/dT$ | $10^{-6}$/°K | −64·6 | −65·3 | −66·0 | −66·6 | −67·4 | −71·4 | −78·9 | ±3·0 |
| $d\sigma_s/dT$ | $10^{-6}$/°K | 9 | 9 | 9 | 10 | 10 | 13 | 17 | ±6·5 |
| $\theta_D$ (elastic) | °K | 754 | 740 | 727 | 715 | 703 | 633 | 523 | ±1·0 |

† The elastic parameters at ambient conditions are from Table 2 in Cl. It is noted that the density value of the 50 Fo composition in Cl should have been 3·800 g cm$^{-3}$ (see Birch 1969, p. 34 and discussion therein).

‡ Data in parenthesis are estimated values at $T = \theta_D$ (see text for description).

75 per cent for fayalite, as compared to forsterite, is noteworthy, since this quantity is closely related to the seismic structure of the upper mantle. We shall return to this subject in a later section.

## 4.2. *Variation with temperature*

In Table 3, the data obtained from ultrasonic-temperature measurements at 1 bar pressure are tabulated in a convenient form. Combining these data with the elastic constants at ambient conditions, we can evaluate all the first derivatives of the elastic parameters with respect to temperature. Table 2 (18th through 26th rows of this table) summarizes the isobaric temperature derivatives of various elastic parameters, evaluated at 296° K, for olivines in the forsterite-fayalite series.

Values of the temperature coefficients of the elastic constants vary with temperature. It was observed that these coefficients increased almost linearly with temperature for all the olivine samples. This experimental observation permits the use of the present data for estimating the elastic properties of olivine at high temperatures. At high temperatures (where $T \geqslant \theta_D$), the elastic constants of crystalline solids decrease almost linearly with temperature, and their gradient with temperature approaches a constant value. The values in parentheses entered in Table 2 are these high-temperature values of the isobaric temperature derivatives of the elastic constants, evaluated at the Debye temperature of olivine; these high-temperature values should be of more interest to geophysics in the discussions of the Earth's mantle than those values evaluated at the ambient temperature.

Fig. 4 shows values of the temperature derivatives of the elastic constants of olivine as a function of Fe/(Mg+Fe) ratio. It is seen that values of both $(dL_s/dT)$ and $(d\mu/dT)$ decrease with increasing the Fe/(Mg+Fe) ratio in olivine. Effects of this Fe/(Mg+Fe) ratio on the $(dK_s/dT)$ value are seen to be small; at 300° K, for example,

**Table 3**

*Variation of density, shear modulus, and adiabatic bulk modulus of olivine with temperature (at one bar)*

| Property | Temperature °K | Olivine composition, mole % | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 100 Fo | 95 Fo | 90 Fo | 85 Fo | 80 Fo | 50 Fo | 100 Fo |
| $\rho_0$, g cm$^{-3}$ | 296 | 3·217 | 3·273 | 3·330 | 3·386 | 3·440 | 3·800 | 4·393 |
| $\mu°$, mb | 296 | 0·797 | 0·783 | 0·772 | 0·760 | 0·748 | 0·674 | 0·536 |
| $K_s°$, mb | 296 | 1·281 | 1·277 | 1·274 | 1·272 | 1·269 | 1·258 | 1·220 |
| $\rho(T)/\rho_0$ | 273 | 1·0005 | 1·0005 | 1·0005 | 1·0005 | 1·0005 | 1·0004 | 1·0004 |
| | 350 | 0·9982 | 0·9982 | 0·9982 | 0·9983 | 0·9983 | 0·9984 | 0·9986 |
| | 400 | 0·9965 | 0·9966 | 0·9967 | 0·9968 | 0·9969 | 0·9971 | 0·9973 |
| | 450 | 0·9947 | 0·9948 | 0·9949 | 0·9951 | 0·9953 | 0·9956 | 0·9958 |
| $\mu(T)/\mu°$ | 273 | 1·0023 | 1·0023 | 1·0023 | 1·0023 | 1·0023 | 10··22 | 1·0021 |
| | 350 | 0·9920 | 0·9922 | 0·9924 | 0·9927 | 0·9930 | 0·9936 | 0·9943 |
| | 400 | 0·9838 | 0·9840 | 0·9843 | 0·9846 | 0·9850 | 0·9862 | 0·9880 |
| | 450 | 0·9758 | 0·9762 | 0·9766 | 0·9770 | 0·9774 | 0·9789 | 0·9811 |
| $K_s(T)/K_s°$ | 273 | 1·0024 | 1·0024 | 1·0024 | 1·0024 | 1·0023 | 1·0022 | 1·0021 |
| | 350 | 0·9941 | 0·9941 | 0·9941 | 0·9941 | 0·9941 | 0·9941 | 0·9942 |
| | 400 | 0·9880 | 0·9880 | 0·9880 | 0·9880 | 0·9880 | 0·9881 | 0·9883 |
| | 450 | 0·9816 | 0·9816 | 0·9817 | 0·9818 | 0·9818 | 0·9820 | 0·9822 |