TABLE A3. Expansion Coefficients A_n^N with Standard Errors of W^2 according to (A1) for Shear and Quasi-Shear Modes

Coefficient	Mode No.	$\vec{N}$	$\vec{U}$	Sample	$N = 2$ and $n = 2$, 10^{-8}cm^2 sec^{-2} kb^{-2}	$N = 3$ and $n = 2$, 10^{-8}cm^2 sec^{-2} kb^{-2}	$N = 3$ and $n = 3$, 10^{-8}cm^2 sec^{-2} kb^{-3}
c_{44}	1	[010]	[001]	1	-447 ± 27	-685 ± 148	16 ± 10
	2	[010]	[001]	4	-501 ± 35	-605 ± 205	7 ± 13
	3	[001]	[010]	1*	-392 ± 36	-486 ± 100	10 ± 8
	4	[001]	[010]	1	-361 ± 24	-711 ± 100	22 ± 6
	Average				-425 ± 31	-622 ± 51	14 ± 3
c_{55}	5	[100]	[001]	1	-917 ± 24	-1127 ± 132	13 ± 8
	6	[100]	[001]	3	-806 ± 33	-1306 ± 134	32 ± 8
	7	[001]	[100]	1	-881 ± 45	-1584 ± 192	46 ± 12
	Average				-868 ± 33	-1339 ± 96	31 ± 10
c_{66}	8	[100]	[010]	1	-253 ± 22	30 ± 119	-19 ± 8
	9	[100]	[010]	3*	-200 ± 35	298 ± 155	-32 ± 10
	10	[010]	[100]	1	-257 ± 56	-723 ± 309	30 ± 20
	11	[010]	[100]	4	-237 ± 28	10 ± 151	-16 ± 10
	Average				-237 ± 13	-385 ± 459	-9 ± 50
c_{12}	12	$[l m 0]$	$[m \bar{l} 0]$	2*	-459 ± 45	-714 ± 256	17 ± 17
	13	$[l m 0]$	$[m \bar{l} 0]$	2	-448 ± 76	-1037 ± 419	40 ± 21
	Average				-454 ± 35	-876 ± 115	29 ± 8
c_{13}	14	$[l 0 n]$	$[n 0 \bar{l}]$	4*	-632 ± 71	1 ± 374	-44 ± 25
	15	$[l 0 n]$	$[n 0 \bar{l}]$	4*	-659 ± 83	-806 ± 491	10 ± 33
	Average				-646 ± 10	-403 ± 285	-17 ± 19
c_{23}	16	$[0 m n]$	$[0 n \bar{m}]$	3*	-375 ± 24	-498 ± 139	8 ± 9
	17	$[0 m n]$	$[0 n \bar{m}]$	3	-349 ± 33	395 ± 201	2 ± 3
	Average				-362 ± 9	-52 ± 315	5 ± 2

*Run made with Arenberg PSP AFC ultrasonic equipment. All other data were taken with MRL PSP AFC equipment.

those for $N = 2$ and $N = 3$, and it is therefore reasonable to expect that an increase of 50% represents an upper bound for the truncation error. To eliminate or reduce the truncation error for A_2^N, all measurements would have to be extended to substantially higher pressures and the data fitted to a polynomial of degree N greater than 3 or 4, such that this fit would still be statistically significant and A_2^N would become independent of N within its standard deviation. This task remains for the future.

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REFERENCES

Ahrens, T. J., and E. S. Gaffney, Dynamic compression of enstatite, *J. Geophys. Res., 76,* 5504–5513, 1971.

Akimoto, S. I., and Y. Syono, High-pressure decomposition of the system $FeSiO_3$-$MgSiO_3$, *Phys. Earth Planet. Interiors, 3,* 186–188, 1970.

Alexandrov, K. A., and T. V. Ryzhova, The elastic properties of rock-forming minerals, 1, Pyroxenes and amphiboles, *Bull. Acad. Sci. USSR. Geophys. Ser.,* no. 9, 871–875, 1961.

Alexandrov, K. A., T. V. Ryzhova, and B. P. Belikow, The elastic properties of pyroxenes, *Soviet Phys. Crystallogr.,* no. 8, 589–591, 1963.

Anderson, D. L., and C. Sammis, Partial melting in the upper mantle, *Phys. Earth Planet. Interiors, 3,* 41–50, 1970.

Anderson, O. L., Determination and some uses of isotropic elastic constants of polycrystalline aggregates using single crystal data, in *Physical Acoustics,* vol. 3B, edited by W. P. Mason, pp. 43–95, Academic, New York, 1965.

Anderson, O. L., The use of ultrasonic measurements under modest pressure to estimate compression at high pressures, *J. Phys. Chem. Solids, 27,* 547–565, 1966.

Anderson, O. L., E. Schreiber, R. L. Liebermann, and N. Soga, Some elastic constant data on minerals relevant to geophysics, *Rev. Geophys. Space Phys., 6,* 491–524, 1968.

Barron, T. H. K., On the thermal expansion of solids at low temperatures, *Phil. Mag., 46,* 720–734, 1955.

Barsch, G. R., Adiabatic, isothermal and intermediate pressure derivatives of the elastic constants for cubic symmetry, 1, Basic formulae, *Phys. Status Solidi, 19,* 129–138, 1967.

Barsch, G. R., and A. L. Frisillo, Determination of second pressure derivatives of elastic constants from elastic wave velocities for orthorhombic, tetragonal, trigonal, hexagonal, and cubic symmetry, *J. Acoust. Soc. Amer., 46,* in press, 1973.

Barsch, G. R., and H. E. Shull, Pressure dependence of elastic constants and crystal stability of alkali halides, NaI and KI, *Phys. Status Solidi, 43,* 637–649, 1971.

Beattie, J. A., Six place tables of the Debye energy and specific heat functions, *J. Math. Phys. Cambridge Mass., 6,* 1–32, 1926.

Bechmann, R., The elastic piezoelectric and dielectric constants of piezoelectric crystals, in *Landolt-Börnstein, Numerical Data and Functional Relationships in Science and Technology,* vol. 2, *Group III: Crystal and Solid State Physics,* edited by K. H. Hellwege, pp. 40–101, Springer, New York, 1969.

Birch, F., The velocity of compressional waves in rocks to 10 kilobars, 1, *J. Geophys. Res., 65,* 1038–1102, 1960.

Bogardus, E. H., Elastic anharmonicity in germanium, magnesium oxide and fused silica, Ph.D. thesis, 117 pp., Pa. State Univ., University Park, 1964.

Bridgman, P. W., Rough compression on 177 substances to 40,000 kg/cm², *Proc. Amer. Acad. Arts Sci., 76,* 71–87, 1948.

Chang, Z. P., and G. R. Barsch, Nonlinear pressure dependence of elastic constants and fourth-order elastic constants of cesium halides, *Phys. Rev. Lett., 19,* 1381–1383, 1967.

Chang, Z. P., and G. R. Barsch, Pressure dependence of the elastic constants of RbCl, RbBr and RbI, *J. Phys. Chem. Solids, 32,* 27–40, 1971.

Chang, Z. P., and G. R. Barsch, Pressure dependence of single-crystal elastic constants and anharmonic properties of spinel, submitted to *J. Geophys. Res.,* 1972.

Chung, D. H., Equations of state of pyroxenes in the (Mg, Fe)SiO_3 system (abstract), *Eos Trans. AGU, 52,* 919, 1971.

Draper, N., and H. Smith, *Applied Regression Analysis,* p. 305, John Wiley, New York, 1966.

Fisher, E. S., and H. J. McSkimin, Adiabatic elastic moduli of single-crystal alpha uranium, *J. Appl. Phys., 29,* 1473–1484, 1958.

Frisillo, A. L., The elastic coefficients of bronzite as a function of pressure and temperature, Ph.D. thesis, 170 pp., Pa. State Univ., University Park, 1972.

Frisillo, A. L., and S. T. Buljan, The linear thermal expansion coefficients of orthopyroxene to 1000°C, *J. Geophys. Res., 77,* in press, 1972.