

TABLE 5. Aggregate Properties of Single-Crystal Olivine and Dunite*

Pressure, kb	V_p , km sec ⁻¹		V_s , km sec ⁻¹		VRH Bulk Mod- ulus, mb	VRH Shear Mod- ulus, mb	VRH Poisson's Ratio	VRH $\partial V_p / \partial P$, km sec ⁻¹ mb ⁻¹	VRH $\partial V_s / \partial P$, km sec ⁻¹ mb ⁻¹	Density, g cm ⁻³
	V	R	V	R						
Olivine [<i>Kumazawa and Anderson, 1969</i>], $m = 20.79$										
10 ⁻³	8.48	8.36	4.94	4.84	1.29	0.79	0.25	10.2	3.6	3.311
Dunite A, $m = 20.84$										
1.0	8.14	8.09	4.42	4.40	1.30	0.63	0.28			3.268
2.0	8.19	8.14	4.45	4.43	1.32	0.64	0.29	34.2	18.6	3.271
4.0	8.25	8.20	4.48	4.46	1.34	0.65	0.29	23.5	11.1	3.276
6.0	8.29	8.23	4.49	4.48	1.36	0.66	0.29	14.8	5.0	3.281
8.0	8.31	8.25	4.50	4.49	1.37	0.66	0.29	8.0	4.9	3.286
10.0	8.32	8.26	4.51	4.50	1.37	0.67	0.29			3.291
Dunite B, $m = 20.98$										
1.0	8.25	8.17	4.71	4.67	1.27	0.73	0.26			3.319
2.0	8.31	8.23	4.73	4.70	1.29	0.74	0.26	40.3	22.7	3.322
4.0	8.38	8.29	4.77	4.74	1.31	0.75	0.26	27.0	16.0	3.327
6.0	8.42	8.34	4.80	4.77	1.33	0.76	0.26	20.4	7.7	3.332
8.0	8.46	8.38	4.81	4.78	1.35	0.77	0.26	17.0	3.0	3.337
10.0	8.49	8.40	4.81	4.78	1.36	0.77	0.26			3.343

* V, Voigt average; R, Reuss average; VRH, Voigt-Reuss-Hill average; m , mean atomic weight.

An additional indication of the error involved in using the mean of three velocities for the calculation of isotropic elastic constants is given by a comparison of the Voigt-Reuss velocities of dunite B with measurements from a sample of Twin Sisters dunite of similar density by Birch [1960] and Simmons [1964]. Birch reported longitudinal wave velocities at 10 kb in three directions of 8.07, 8.23, and 8.95 km/sec. The mean of these measurements, 8.42 km/sec, agrees well with the Voigt and Reuss averages in Table 5. Transverse wave velocities at 10 kb measured by Simmons [1964] for the same sample studied by Birch are 4.70, 4.88, and 4.90 km/sec. The mean velocity of 4.83 km/sec for this rock is also in close agreement with the Voigt and Reuss averages for dunite B.

Acknowledgments. We wish to thank M. Mulcahey and K. V. Campbell for assistance in the petrographic and chemical studies. Financial support was provided by National Science Foundation grant GA-20317.

REFERENCES

- Alexandrov, K. S., T. V. Ryzhova, B. P. Belikov, and L. A. Shabanova, Anisotropy of elastic properties of rocks, *Intern. Geol. Rev.*, **11**, 539-548, 1969.
- Birch, Francis, The velocity of compressional waves in rocks to 10 kilobars, 1, *J. Geophys. Res.*, **65**, 1083-1102, 1960.
- Birch, Francis, The velocity of compressional waves in rocks to 10 kilobars, 2, *J. Geophys. Res.*, **66**, 2199-2224, 1961.
- Brace, W. F., Relation of elastic properties of rocks to fabric, *J. Geophys. Res.*, **70**, 5657-5667, 1965.
- Christensen, N. I., Compressional wave velocities in metamorphic rocks at pressures to 10 kilobars, *J. Geophys. Res.*, **70**, 6147-6164, 1965.
- Christensen, N. I., Shear wave velocities in metamorphic rocks at pressures to 10 kilobars, *J. Geophys. Res.*, **71**, 3549-3556, 1966a.
- Christensen, N. I., Elasticity of ultrabasic rocks, *J. Geophys. Res.*, **71**, 5921-5931, 1966b.
- Christensen, N. I., and R. S. Crosson, Seismic anisotropy in the upper mantle, *Tectonophysics*, **6**, 93-107, 1968.
- Christensen, N. I., and G. H. Shaw, Elasticity of mafic rocks from the mid-Atlantic ridge, *Geophys. J.*, **20**, 271-284, 1970.
- Graham, E. K., and G. R. Barsch, Elastic constants of single-crystal forsterite as a function of temperature and pressure, *J. Geophys. Res.*, **74**, 5949-5960, 1969.
- Hearmon, R. F. S., *Applied Anisotropic Elasticity*, Oxford University Press, London, 136 pp., 1961.
- Hess, H. H., Seismic anisotropy of the uppermost mantle under the oceans, *Nature*, **203**, 629-631, 1964.
- Keen, C., and C. Tramontini, A seismic refraction survey on the mid-Atlantic ridge, *Geophys. J.*, **20**, 473-491, 1970.
- Kumazawa, M., The elastic constants of rocks in terms of elastic constants of constituent mineral grains, petrofabric and interface structures, *J. Earth Sci., Nagoya Univ.*, **12**, 147-175, 1964.
- Kumazawa, M., and O. L. Anderson, The elastic moduli, pressure and temperature derivatives, of single-crystal olivine and single-crystal forsterite, *J. Geophys. Res.*, **74**, 5961-5972, 1969.
- Love, A. E. H., *A Treatise on the Mathematical Theory of Elasticity*, 4th ed., Dover, New York, 643 pp., 1944.
- Meyer, R. P., L. M. Dorman, and L. Ocola, The search for anisotropy in the upper mantle: Experiments off Hawaii in 1966, *Trans. AGU*, **50**, 246, 1969.
- Raitt, R. W., G. G. Shor, T. J. G. Francis, and G. B. Morris, Anisotropy of the Pacific upper mantle, *J. Geophys. Res.*, **74**, 3095-3109, 1969.
- Simmons, G., The velocity of shear waves in rocks to 10 kilobars, *J. Geophys. Res.*, **69**, 1123-1130, 1964.
- Topping, J., *Errors of Observation and Their Treatment*, Chapman and Hall, London, 119 pp., 1966.
- Verma, R. K., Elasticity of some high-density crystals, *J. Geophys. Res.*, **65**, 757-766, 1960.

(Received October 19, 1970;
revised February 10, 1971.)