Table 1
Elastic properties of olivine and olivine-transformed spinels in the Mg_2SiO_4–Fe_2SiO_4 system *.

Mg/(Mg+Fe) ratio, mole %	Phase	$\bar{m}$	ρ (g/cm³)	V_p (km/sec)	V_s (km/sec)	V_s (km/sec)	K_s (Mb)	$\left(\frac{\partial K_s}{\partial \rho}\right)$	Remarks
100	Olivine	20.1	3.217	8.534	4.977	6.309	1.281	5.04	Experimental
	Spinel	20.1	3.556	9.66	5.54	7.24	1.86	4.4	Estimated
95	Olivine	20.6	3.273	8.422	4.892	6.245	1.277	5.08	Experimental
	Spinel	20.6	3.620	9.57	5.48	7.18	1.87	4.4	Estimated
90	Olivine	21.0	3.330	8.317	4.815	6.189	1.274	5.13	Experimental
	Spinel	21.0	3.683	9.49	5.42	7.13	1.87	4.5	Estimated
85	Olivine	21.5	3.386	8.216	4.739	6.132	1.272	5.13	Experimental
	Spinel	21.5	3.750	9.41	5.36	7.10	1.88	4.5	Estimated
80	Olivine	21.9	3.440	8.116	4.663	6.075	1.269	5.23	Experimental
	Spinel	21.9	3.815	9.33	5.29	7.05	1.89	4.6	Estimated
50	Olivine	24.6	3.800	7.534	4.213	5.753	1.258	5.44	Experimental
	Spinel	24.6	4.209	8.85	4.92	6.78	1.93	4.8	Estimated
0	Olivine	29.1	4.393	6.637	3.494	5.273	1.220	5.92	Experimental
	Spinel	29.1	4.849	8.05	4.28	6.35	1.96	5.1	Estimated
			±0.2%	±0.5%	±0.5%	±0.8%	±1.8%	±5.0%	Expected error

* Data from ref. [3].

Birch's law for the bulk sound velocity-density-mean atomic weight relation is

$$V_\phi = a + b\rho \tag{2}$$

where the constants a and b can be obtained from a least squares fit of experimental values of V_ϕ obtained from substances of similar mean atomic weight (or from substances of the same mean atomic weight, as was done by Wang [8]). In terms of Birch's law, Chung [13] has shown that

$$\left(\frac{\partial K_s}{\partial p}\right)_{s,\bar{m}} = 1 + \frac{2b\rho}{V_\phi} + \frac{C}{K_s} \tag{3}$$

where K_s is in megabars and V_ϕ is in kilometers per second. Using eq. (3), values of $(\partial K_s/\partial p)$ for the olivine-transformed spinels were calculated from ρ, V_ϕ, and K_s in table 1; in table 2, these calculated results are then compared with earlier estimates made by this author. The agreement between these two sets is satisfactory.

Although the chemistry of spinels in the (Mg,Fe) Al_2O_4 compositions differs from that of the $(Mg,Fe)_2SiO_4$–spinels, their elastic properties are probably identical.* Support for the present estimates of equation-of-state parameters for the olivine-transformed spinels then comes from recent ultrasonic measurements of $(\partial K_s/\partial p)$ for spinels in the (Mg,Fe) Al_2O_4 system. The elastic constants of the stoichiometric $MgAl_2O_4$ spinel were first studied by Chung et al. [15] with hot-pressed polycrystalline samples. Lewis [16] and more recently O'Connell and Graham [17] studied the single-crystal elastic properties of this spinel; their results at ambient conditions are found to be in good agreement with the results from polycrystalline work. Schreiber [18] measured a $(\partial K_s/\partial p)_T$ value of 4.18 for a spinel with the Mg(2. 6) Al_2O_4 composition. Chung [32], working with polycrystalline stoichiometric $MgAl_2O_4$ spinel, determined a $(\partial K_s/\partial p)_T$ value of 4.3 (±0.25). Using spinel of the same composition, but working with single crystals, O'Connell and Graham [17] found the value of 3.76. O'Connell and Graham [17] also measured $(\partial K_s/\partial p)_T = 3.76$ for the *same specimen* of Mg(2. 6) Al_2O_4 spinel that Schreiber [18] used in his original work; thus the apparent disagreement is noted for the work of refs. [17] and [18]. (The apparent difference in the $(\partial K_s/\partial p)_T$ value measured on the same sample, but different investigators, seems to represent the present state-of-the-art in the attempt to characterize this important equation-of-state parameter of mantle minerals). In their recent paper, Wang and Simmons [19] reported a $(\partial K_s/\partial p)$ value of 4.9 (±0.25) for a pleonaste-spinel of the "$(Mg_{0.75}Fe_{0.36})\,Al_{1.9}O_4$ composition". For comparison with the elastic parameters estimated for spinels in the $(Mg_xFe_{1-x})_2SiO_4$ system, the density and other parameters of various spinels in the (Mg,Fe) Al_2O_4 compositions are listed in table 3. As is clearly shown in table 2 and 3, the elastic properties of these spinel compositions are similar; values of K_s are in the neighborhood of 2 Mb and for $(\partial K_s/\partial p)$ values are about 4 to 5. Thus, in the absence of experimental measurement, the equation-of-state parameters of the $(Mg_xFe_{1-x})_2SiO_4$–spinels estimated in this report provide a basis for specifying the desired equations of state of these olivine-transformed spinels in the Mg_2SiO_4–Fe_2SiO_4 system.

* From the structural point of view, the spinels in the (Mg, Fe) Al_2O_4 system differ in two ways from those of the $(Mg, Fe)_2SiO_4$ composition. In the former case, there are 8 (Mg, Fe) Al_2O_4 units per unit cell, wherein the divalent cations are in the fourfold coordination and *two* trivalent aluminum ions are in the six fold coordination. In the latter case, there are 8 $(Mg, Fe)_2SiO_4$ units per unit cell; the divalent cations, which are *twice* as numerous as the tetravalent silicon in a given unit cell, are in the fourfold coordination and the silicon ion in the sixfold coordination. In both cases, however, the structure consists of a cubic closely-packed array of oxigen ions with the sixfold coordinated cations occupying the octahedral interstices and the divalent cations the tetrahedral interstices. Ionic sizes of these cations in the octahedral sites do not differ much, i.e., according to Pauling [14] Al^{3+} has the ionic radius of 0.50Å and Si^{4+} has 0.41Å. One would expect that, for the same (Fe/Mg) ratio in the tetrahedral sites in these two spinel compositions, the elastic properties like the bulk modules and its rate of change with pressure would not differ very much from each other. However, because there are twice the number of iron atoms in the $(mg,Fe)_2SiO_4$ composition as compared with the (Mg, Fe) Al_2O_4 spinels, the greater effect of an iron sustitution for magnesium on the elastic properties would be expected for the $(Mg,Fe)_2SiO_4$ composition than for the Al_2O_4 spinels.