Under pressure, the density of an olivine with a specific Fe/(Mg+Fe) ratio would increase through a gradual decrease in mean atomic volume. Application of pressure to the olivine will increase the sound velocities (V_p, V_s, and V_ϕ) and these velocities (interpolated to the zero-pressure point) will follow along the line of constant mean atomic weight. This trend is shown with arrows in Fig. 5. The significance of Fig. 5 can be illustrated by the two examples below. First, using these diagrams, a velocity-density distribution for an '*olivine upper mantle*' may be estimated, with an assumption that the changes of mean atomic weight in the upper mantle are associated with variations in the Fe/(Mg+Fe) ratio in olivine alone. Second, velocities of the elastic waves in the high-pressure form of olivine can be estimated from these figures.

Change of the Fe/(Mg+Fe) ratio from 0·1 to 0·3 (corresponding to mean atomic weights of 21·0 to 22·8) would produce a decrease in the compressional velocity of 0·32 km s^{-1} and an increase in the olivine density of about 0·25 g cm^{-3}. Similarly, for the shear wave velocity, we find that a change in the Fe/(Mg+Fe) ratio from 0·1 to 0·3 in the upper mantle would result in a decrease in the shear wave by about 0·28 km s^{-1} with a density increase of about 0·25 g cm^{-3}. In the same way, the velocity of the bulk waves (V_ϕ) will decrease by about 0·22 km s^{-1}. In the upper mantle, recent progress in geophysical theories leads us to believe that the mean atomic weight increases with depth to about 22 or slightly higher (see Press 1970b); this implies chemical changes taking place in the upper mantle structure. It is likely that this increase of the mean atomic weight in the upper mantle is also associated with iron enrichment in pyroxene, garnet, and olivine. Effects of iron on the elastic properties of pyroxene and garnet are presently under investigation. Our preliminary results suggest that the actual Fe/(Mg+Fe) ratio of olivine in the upper mantle is approximately 0·13. A more conclusive discussion on this subject will follow in a later communication as the elasticity data on pyroxene and garnet as a function of iron content become available.

With an increased density of about 10 per cent, olivine transforms into a spinel structure at high pressure (see Ringwood (1970) for a recent review). Mizutani *et al.* (1970) successfully prepared a fayalite-transformed spinel sample and measured the compressional velocity as a function of pressure to about 6 kb. They found the compressional velocity in the spinel form of $Fe_2 SiO_4$ is 8·05 km s^{-1} at ambient conditions. This value is about 21 per cent greater than that of fayalite. The datum of Mizutani *et al.* (1970) is plotted in Fig. 5(a). Note that this datum point meets at the intercept of the two lines drawn from the density and the mean atomic weight. Both D. L. Anderson and O. L. Anderson in their respective presentations at the Birch Symposium in April, 1970 (to be published), made similar observations. Incorporating Mizutani *et al's* datum with assumptions, Liebermann (1970) in his recent paper also made a similar observation. If one assumes that the olivines of other compositions behave similarly, a series of lines parallel to a specific mean atomic weight characterized by the Fe/(Mg+Fe) ratio in the olivine composition can be drawn as before (see C1, Fig. 1). Knowing the end-point density of the spinel of the given composition, one can estimate its velocity. In this manner velocities of the compressional and shear waves in the spinel phase of $(Mg_x Fe_{1-x})_2 SiO_4$ may be found; they are identified by open circles in Fig. 5. Table 6 lists these estimated values and compares them with experimental data on olivine. Note that, in every olivine composition considered here, there is an increase in density values of about 10 per cent. These density increases due to the phase change result in about 13 to 21 per cent increase in the compressional wave velocity, about 11 to 22 per cent increase in the shear wave velocity, and about 15 to 20 per cent increase in the bulk sound velocity as the Fe/(Mg+Fe) ratio changes from zero to one.

The bulk modulus changes with the phase change. Since the density of an olivine-transformed spinel increases about 10 per cent, and since, according to Anderson & Nafe (1965) the bulk modulus is inversely proportional to the volume per ion pair,

Table 6

Elastic properties of $(Mg_xFE_{1-x})_2SiO_4$ *before and after the olivine-spinel phase transformation*

+Fe) %	Structure and % change	Density, g cm^{-3}	V_p	V_s (km s^{-1})	V_ϕ	ϕ (km $s^{-1})^2$	μ	K_s mb	d c
Ig	Olivine	3·217	8·534	4·977	6·309	39·8	0·797	1·281	
	Spinel†	3·556	9·66	5·54	7·24	52·4	1·09	1·86	
	% Change	10·6	13·3	11·3	14·7	32·0	37	45	−1
	Olivine	3·330	8·317	4·815	6·189	38·3	0·772	1·274	4
	Spinel†	3·683	9·49	5·42	7·13	50·9	1·08	1·87	−1
	% Change	10·7	14·1	12·4	15·2	33·0	40	47	
	Olivine	3·440	8·116	4·663	6·075	36·9	0·748	1·69	
	Spinel†	3·815	9·33	5·29	7·05	49·8	1·07	1·89	−
	% Change	10·7	14·6	13·5	16·0	37·0	42	50	
	Olivine	3·800	7·534	4·213	5·753	33·1	0·674	1·256	
	Spinel†	4·209	8·85	4·92	6·80	46·1	1·02	1·93	−
	% Change	10·8	17·6	16·5	18·4	40·0	50	55	
Fe	Olivine	4·393	6·637	3·494	5·273	27·8	0·536	1·220	
	Spinel†	4·849	8·05‡	4·28	6·35	40·4	0·89	1·96	−
	% Change	10·4	21·1	22·5	20·4	45·0	65	60	

es (see text).

d by Mizutani *et al.* (1970).