possess non-centrosymmetric structures. The elastic constants of such solids as olivine, for example, depend also on the electronic polarizabilities of the constituent ions; hence, their variations with pressure and temperature are sensitive to how the polarizabilities are affected by these thermodynamic variables. The quantity represented by the implicit term in equation (9) is thus a measure of the contribution from these electronic polarizabilities, as well as that arising from lattice vibrations of the constituent ions in olivine. The role of these polarizabilities is particularly important for understanding the constitution of the seismic structure and the electrical properties of the mantle.

4.3. *Discussion of literature data*

The present data on the elasticity of olivine may be related to some other data already found in a number of geophysical manuscripts. This discussion is essential since some data strongly oppose others. Many authors, however, use data now believed to be ‘ questionable ’ in geophysical and geochemical theories and experiments.

Experimental data on the elastic properties of olivine come from several distinctively different sources: (1) from the velocity measurements on ultrabasic rocks, typified by the work of Birch (1960, 1961a), Simmons (1964), Christensen (1966a, 1966b), and Mao *et al.* (1970); (2) from the systematic determinations of the elastic constants of gem-quality olivine single-crystals, typified by the work of Verma (1960), Kumasawa & Anderson (1969), and Graham & Barsch (1969); and (3) from the velocity measurements on synthetic polycrystalline olivine aggregates, typified by the work of Schreiber & Anderson (1967) and Chung (1970). Recently, Fujisawa (1970) and Graham (1970) also performed velocity measurements on an aggregate sample of olivine. Of course, much information about compressibility of olivine comes from a study of pressure effects on volume of olivine samples, work of a kind performed by Adams (1931), Bridgman (1948), and more recently Takahashi (1970) and Olinger & Duba (1971). Shock compression of olivine, as performed by McQueen *et al.* (1967) and Ahrens, Lower & Lagus (1971), provides further information on the compressibility of this material at very high pressures.* In the earlier report (see C1; Table 3, and discussion on page 7356), a systematic comparison and discussion was given of these elasticity data at ambient conditions. The following summary can be made. The present elasticity data of olivine are in general agreement with most of the literature data cited above. Exceptions to this agreement are those data reported by Adams (1931), Schreiber & Anderson (1967), Soga & Anderson (1967), and Graham (1970). The writer believes Adams' bulk modulus for fayalite is about 10 per cent too small, Graham's shear modulus for fayalite is about 30 per cent too big,† and the bulk modulus value reported by Soga & Anderson and Schreiber & Anderson for forsterite is about 25 per cent too small. The large differences noted for data of Soga & Anderson and Schreiber & Anderson are probably due to porosity in their samples.

Table 5 tabulates and compares all the experimental data found in the literature to date for the pressure and temperature derivatives of the elastic constants of olivine with the present data. (It may be noted that some elasticity data estimated or extra-

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*It is noted that neither the isothermal compression nor the shock compression studies provide information about the behaviour of shear waves. The use of these compression data alone cannot described the elasticity of the compressed materials completely. In addition, the compression data direct their emphasis to the compliance property like compressibility, whereas the ultrasonic elasticity data direct emphasis toward the stiffness property such as the adiabatic bulk modulus and shear modulus.

†Graham's (1970) elasticity data ($K_s = 1 \cdot 060$ mb and $\mu = 0 \cdot 688$ mb) have been revised in personal communications to give $K_s = 1 \cdot 202$ mb and $\mu = 0 \cdot 560$ ($\mp 0 \cdot 8$ per cent) mb. These revised data of Graham agree favourably with those reported by Chung (1970, Table 2).

Table 5

Experimental bulk modulus and shear modulus for various olivines and their pressure and temperature derivatives; Comparison with literature data (evaluated at zero-pressure and 296° K)

Olivine composition mole %	ρ g cm^{-3}	μ mb	K_s mb	$\frac{d\mu}{dp}$	$\frac{dK_s}{dp}$	$\frac{d\mu}{dT}$	$\frac{dK_s}{dT}$	Reference
						kb/°K		
100 Fo	3·021	0·574	0·974	1·3	4·8	—	—	Schreiber & O. L. Anderson (1967)
100 Fo	2·996	0·5869	0·9641	—	—	−0·11	−0·13	Soga & O. L. Anderson (1967)
100 Fo	3·224	0·811	1·286	1·80	5·37	−0·130	−0·150	Kumasawa & O. L. Anderson (1969)*
100 Fo	3·222	0·816	1·296	1·82	4·97	−0·136	−0·176	Graham & Barsch (1969)*
100 Fo	3·217	0·797	1·281	1·85	5·04	−0·12	−0·13	This work
95 Fo	3·273	0·783	1·277	1·81	5·08	−0·12	−0·13	This work
93 Fo	3·331	0·791	1·294	1·79	5·13	−0·130	−0·156	Kumasawa & O. L. Anderson (1969)*
90 Fo	3·330	0·772	1·274	1·80	5·13	−0·12	−0·13	This work
85 Fo	3·386	0·760	1·272	1·76	5·13	−0·12	−0·13	This work
80 Fo	3·440	0·748	1·269	1·64	5·23	−0·12	−0·13	This work
50 Fo	3·800	0·674	1·258	1·31	5·44	−0·11	−0·14	This work
100 Fa	4·393	0·536	1·220	0·62	5·92	−0·10	−0·14	This work

* VRH values from single-crystal data.

polated from various assumptions, such as those of Schreiber (1969) and Graham (1970, p. 287 and 288), could not be listed in Table 5.) Included in the comparison are the single-crystal forsterite data (VRH values) of Kumasawa & Anderson (1969) and Graham & Barsch (1969) and polycrystalline forsterite data of Soga & Anderson (1967) and Schreiber & Anderson (1967). The single-crystal peridot data (VRH values) of Kumasawa & Anderson (1969) are also entered in Table 5. Considering the experimental errors involved in each set of these elasticity data, there is general agreement for most of the pressure derivative data for forsterite and peridot. In particular, the present data agree very well with forsterite data of Graham & Barsch (1969, p. 5955), and also with peridot data of Kumasawa & Anderson (1969, p.5970). It seems, however, that the $(d\mu/dp)$ value originally reported by Schreiber & Anderson (1967, p. 763) and later summarized by Anderson *et al.* (1968, p. 494, Table 1) is about 30 per cent too small when compared with most other data. Table 5 also indicates that the (dK_s/dp) value for forsterite reported by Kumasawa & Anderson 1969, p. 5970) seems rather high (considering the experimental accuracy stated therein). Furthermore, the elasticity data of these authors for their forsterite and peridot shows that the bulk modulus increases slightly with increasing iron content in the olivine samples. The present work, as summarized in Table 2 and also in Fig. 3, shows an increase of (dK_s/dp) with increasing Fe/(Mg+Fe) ration in the forsterite-fayalite series. Our data also show that this (dK_s/dp) increase with the iron content in the olivine lattice is accompanied by a slight decrease in the bulk modulus of olivine. The bulk modulus and its pressure derivature are important parameters entering into solid equations of state and thermodynamics of these solids. The change of these parameters with the iron content in olivine should be understood, therefore, if the physical state and chemical composition of the Earth's mantle is to be correctly characterized.