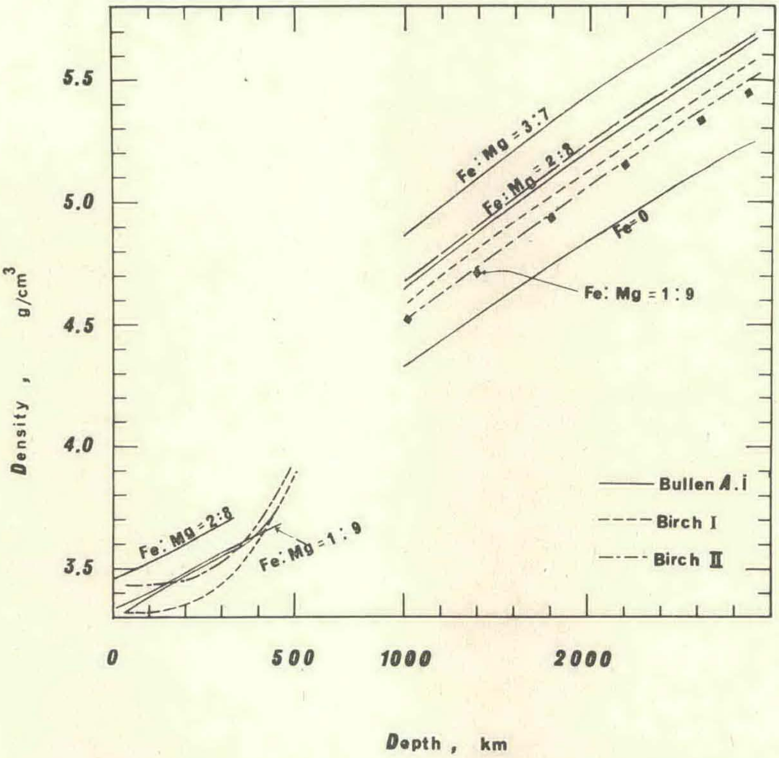

Fig. 2. Comparison of the density distributions based on four cases of the hypothetical mineral assemblages, together with the Bullen mode A-i, the Birch models I and II.

and so

$$\rho_{\text{center}}/\rho_{\text{core boundary}} = 3.11$$

where ρ denotes density. This value seems too high in view of recent results from shock experiments. Even under the pressures existing in the core none of the solid substances that are thought to be main constituents of the earth could be so compressible. For example, the ratios of zero-pressure density to density under pressures of the order of megabars in an element, an alloy, and two compounds are shown below.

Fe [*Al'tshuler et al.*, 1960]:

$$\rho_{(3.560\text{ Mb})}/\rho_0 = 1.664$$

$Fe_{80.2}Si_{19.8}$ alloy [*Balchan and Cowan*, 1966]:

$$\rho_{(3.6\text{ Mb})}/\rho_0 = 1.77$$

Dunite (R. G. McQueen and S. P. Marsh, unpublished; see *Birch* [1966]):

$$\rho_{(1.123\text{ Mb})}/\rho_0 = 1.56$$

Periclase (R. G. McQueen and S. P. Marsh, unpublished; see *Birch* [1966]):

$$\rho_{(1.258\text{ Mb})}/\rho_0 = 1.41$$

In these calculations, the Bullen model A was used for the upper part of the mantle, and its use does not have any significant effect on the conclusions obtained above.

Fe/Mg ratio and density in the upper mantle. From the above discussion, we need only to treat values of the Fe/Mg ratios in the range between Case 2 and Case 3. Shock compression data are available for both olivine-rich (dunite: 92% olivine, Fe/Mg = 12/88) and pyroxene-rich (two bronzites: 92 and 94% pyroxene (90% enstatite)) rocks [*McQueen et al.*, 1967]; the Fe/Mg ratios of these are similar to the values for olivines and pyroxenes discussed below. In the following calculation we will assume the compressibility values of the above rocks, as deduced from the shock compression data, as the values for olivine and pyroxene having an Fe/Mg ratio of 1:9 or 2:8. When the compressibility is reduced from the shock compression data, the results of static experiments [see *Birch,* 1966] are also taken into account in the low-pressure region.

Results are shown in Table 1 and Figure 2 together with the density distributions of the Bullen model A and the Birch models I and II. As is seen from this figure, the calculated density of the mineral assemblage of case 3 is higher than any of those distributions, whereas for the case 2 density is approximately consistent with the value estimated from the seismic observation.

However, the Fe/Mg ratio in the mantle may not as yet have been strictly determined, because the effect of temperature is neglected in this calculation and the density distribution in the mantle itself is now in dispute. Therefore, we also consider the petrological evidences for determining the Fe/Mg ratio in the upper mantle.

Petrological evidences for the Fe/Mg ratio of olivine in the upper mantle. Mafic and ultramafic inclusions in basaltic rocks and the kimberlite may be regarded as *cores of deep drilling* carried out by nature, and some kinds of peridotite inclusions may quite possibly be the slightly altered fragments of the upper mantle [e.g., *Ross et al.,* 1954; *O'Hara and Mercy,* 1963; *White,* 1966; *Kuno,* 1968]. The Fe/Mg ratio of olivine in the peridotite inclusion may provide useful information on the Fe/Mg ratio of olivine in the upper mantle.

Some kinds of peridotite inclusions are believed to represent the upper mantle materials for the following reasons: (1) The localities of the inclusion-bearing basalts are distributed throughout the world; nearly 200 localities are known throughout the oceanic, the orogenic, and the non-orogenic regions of the world [*Forbes and Kuno,* 1965]. (2) Peridotite is the commonest rock type as inclusion [*Kuno,* 1968]. (3) The close correlation that exists between suites of peridotite inclusions and types of host rocks implies a genetic relation between the two. Consequently, an origin as *accidental* fragments of crustal or mantle materials can be discounted for most of peridotite inclusions [e.g., *White,* 1966; *Kuno,* 1968]. (4) Striking systematic differences are found in the mineral composition, the bulk chemical composition, and other physical appearances of these suites of peridotite inclusions, and we can presume the origin mechanism of each suite of them. Accordingly, most of the suites can be divided into two categories on the basis of their origin mechanisms: (*a*) peridotite inclusions that are non-altered or slightly altered fragments of the upper mantle material, and (*b*) the peridotite inclusions that originated by accumulation of crystals from host basaltic magma at its fractionation process. Garnet-peridotite inclusions in the kimberlite and garnet-peridotite of Norway and Switzerland [*O'Hara and Mercy,* 1963] and the lherzolite inclusions [*White,* 1966; *Kuno,* 1968] are believed to belong to the first category. (5) The peridotite inclusions in kimberlite, which is surely a mantle origin, shows close correlations to other peridotite inclusions which are believed to be fragments of mantle materials. (This is a strong support for the above discussions.)

The most interesting feature of the Fe/Mg ratio of olivine in peridotite inclusions is that this ratio increases in proportion to the stage of fractionation of the host rocks and gradually goes away from the primary ratio of the mantle material. Consequently, the values of the Fe/Mg ratio of these inclusions vary over a wide range according to the stage of differentiation of host rocks. In the case of olivines that are thought to be fragments of the upper mantle materials, however, the values are strongly concentrated

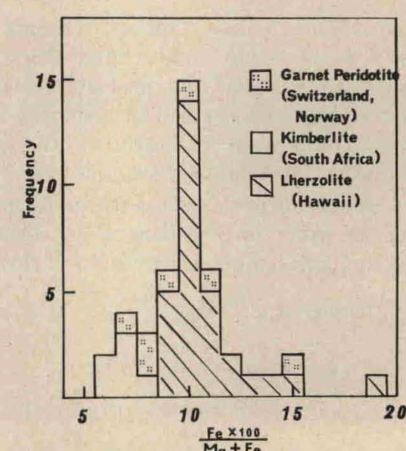

Fig. 3. Histogram of the Fe/Mg ratio of olivines in some peridotite inclusions. Garnet peridotite of Switzerland, Norway, the kimberlite [after *O'Hara and Mercy,* 1963], and the lherzolite [after *White,* 1966].