GEOCHEMICAL NOTE

Constitution of the mantle—a revision*

In some papers recently published (RINGWOOD, 1958, Parts I, II, III) the nature of the phase transition zone in the mantle between 2–400 km and 900 km has been extensively discussed. The large width of the transition zone was attributed primarily to the presence of a high temperature gradient in this region combined with a high pressure gradient dP/dT for the transitions, and secondarily to solid solution effects among the participating phases. Subsequent data have shown that the relative importance of these factors should be reversed.

The slope dP/dT of the olivine–spinel transition in Mg_2SiO_4 was estimated very tentatively as 100 bars/degree. This implies an entropy change of 10 cals/mole per degree. MEIJERING and ROOYMANS (in press) have pointed out that the entropy change would probably be substantially less than this, which means that dP/dT would probably be proportionally smaller. ROY and ROY (1954) have determined the initial slope dP/dT for the olivine–spinel transition in Mg_2GeO_4 as 40 bars/degree, and the corresponding value for Mg_2SiO_4 may well be close to this. At higher temperatures and pressures it would probably be somewhat larger. This is supported by the later work on the transition in Mg_2SiO_4 at 600°C, which was presented as an appendix to Part II. This showed that the transition pressure was substantially higher than the calculated value at 600°C. This result was obtained too late for incorporation of its implications in the manuscript.

As a result of the smaller gradient, the width imparted to the transition region by any plausible temperature distribution is less than previously assumed.

On the other hand, an investigation by MEIJERING and ROOYMANS (in press) has shown that solid solution effects are more important than previously supposed in spreading the transition region. They made a thermodynamic study of the olivine–spinel transition as a function of pressure at constant temperature, in the ternary system MgO–FeO–SiO_2 and concluded that solid solution effects could spread the transition over a range of several hundred kilometres.

A further contribution to the transition range, which has not previously been considered, is made by solid solution between diopside and enstatite which occurs at temperatures above 1200°C. A small amount of diopside (which is probably present) would extend upwards the pressure required for solid solution of $MgSiO_3$ in Mg_2SiO_4 spinel, or for decomposition of $MgSiO_3$ into Mg_2SiO_4 spinel and SiO_2 (coesite).

In view of these considerations it seems reasonable to attribute the transition range in the mantle largely to solid solution effects. This does not exclude the possibility of a high temperature gradient in this region, which may be supported by other evidence (TOZER, in manuscript). The influence of the temperature gradient in spreading the transition region would still be important, but not dominant.

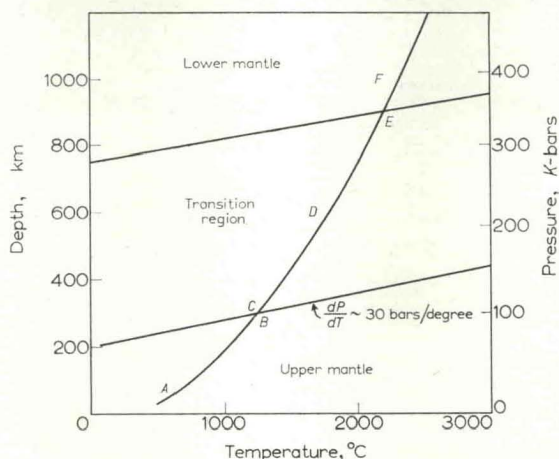A diagram illustrating the revised interpretation is presented (Fig. 1).

Fig. 1. Possible relationship between transition zone and temperature distribution in the mantle. Letters on temperature depth curve refer to phase assemblages which may be present (RINGWOOD, Part III), 1958.

A. Olivine $\left(\dfrac{\text{MgO}}{\text{FeO}} \sim 5\right)$, enstatite $\left(\dfrac{\text{MgO}}{\text{FeO}} \sim 5\right)$, small amounts of diopside-jadeite solid solution, pyrope rich garnet.

B. Olivine, enstatite-diopside-jadeite solid solution (henceforth called "pyroxene"), minor garnet.

C. Olivine, pyroxene, iron-rich spinel.

D. Spinel $\left(\dfrac{\text{MgO}}{\text{FeO}} \sim 5\right)$, pyroxene.

E. Disordered, non stoichiometric spinel, containing $(MgFe)SiO_3$ in solid solution, minor diopsidic pyroxene.

F. Homogeneous, highly disordered, spinel solid solution.

Notes:

(I) Disappearance of garnet between B and C is controlled by solubility of Al_2O_3 and Cr_2O_3 in spinel and pyroxene. All other components present in garnet are readily soluble in these phases. In regions where Al_2O_3 is locally concentrated, garnet may persist as a phase, to greater depths.

(II) Principal transition between C and D is the olivine–spinel inversion, which takes place over a substantial depth range due to Mg–Fe solid solution.

(III) Principal equilibria involved in spinel-pyroxene solid solution between D and E are:

$$2(MgFe)SiO_3 \rightarrow (MgFe)_2SiO_4 \text{ (spinel)} + SiO_2 \text{ (Coesite)}$$

$$(MgFe)_2SiO_4 \text{ (Spinel)} + SiO_2(\text{coesite}) \rightarrow \text{non-stoichiometric defect spinel.}$$

A. E. RINGWOOD

Department of Geophysics, Australian National University
Canberra, A. C. T., Australia

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