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GEOPHYSICS

Rigidity and Density in the Earth's Core

In two previous papers[1,2], I have shown that, taking a fairly direct interpretation of Bolt's revised P seismic velocities[3] for the Earth's core, it is possible to arrive at an estimate of order 15 g/cm^3 for the Earth's central density (ρ_0). In the second of the two papers, I pointed out that the estimate could be lowered if one made the *ad hoc* assumption that there is rigidity (μ) decreasing with depth in the lower core. I have since carried out some calculations related to this assumption, and the present report is to give an account of some of the more interesting tentative results. Details of the calculations are to be published elsewhere.

Let r denote the distance from the Earth's centre. As in the earlier papers, the symbols E'', F, and G will refer to the regions for which $1{,}660 < r < 1{,}810$ km, $1{,}210 < r < 1{,}660$ km, $r < 1{,}210$ km, respectively. Reference will also be made to the coefficient η which serves[4] as an index of the departure (if any) from chemical homogeneity. As usual, k will denote the incompressibility.

Following are some of the conclusions:

(1) By selecting, compatibly with the seismic data, but otherwise *ad hoc*, the most favourable distributions of both k and μ, it is possible to have the index η equal to unity throughout the regions F and G, that is, it is possible to have F and G (but not E'') chemically homogeneous. In that case, the estimated minimum value of ρ_0 is about 12·6 g/cm^3. In order to arrive at this minimum, it is necessary to postulate a sudden small drop in k and jump in μ at the E''–F boundary, to have μ falling to zero at the bottom of F, then jumping to about $1{\cdot}8 \times 10^{12}$ dynes/cm^2 at the top of G, and falling to $1{\cdot}1 \times 10^{12}$ dynes/cm^2, or less, at the centre of G. (If the sudden drop in k is dispensed with, the estimate of ρ_0 needs to be raised by 0·15 g/cm^3.)

(2) If the regions F and G are not *both* solid, the minimum central density is 13·5 g/cm^3. For ρ_0 to be less than this figure, it is formally necessary for μ both to exist significantly and to diminish with depth in both F and G.

(3) If neither F and G is solid, the indicated minimum central density is 14·7 g/cm^3.

These results are of some special interest in view of evidence put forward by Birch[5] and others that the Earth's central density probably does not exceed 13 g/cm^3. If this view be accepted, then the calculations presented here provide new evidence that the region G is solid and, further, require the rigidity in G to diminish with depth.

The calculations give rise to the view that the region F is also solid, with μ again diminishing with depth. This conclusion is, of course, not as strongly established as in the case of G since the value 13·5 g/cm^3 in (2) above is not so very much in excess of 13 g/cm^3, and also some allowance must be made for uncertainties in the source data; the latter include Bolt's velocities, and taking dk/dp (p = pressure) to be of the order of 4 units or so in the lower core.

The suggestion that F, as well as G, may be solid is, however, a matter of some interest. For example, Verhoogen informs me that, with the four-layer core indicated by Bolt's velocity distribution, the sequence liquid, liquid, solid, solid would be among the more geochemically plausible. The suggestion of diminishing rigidity inside F and G is also of geochemical interest.

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Serpentinization as a Possible Cause of High Heat-flow Values in and near the Oceanic Ridges

Prof. v. Bemmelen recently asked me to calculate the thermal effect of serpentinization of an upper layer of the mantle, if fresh peridotite is supplied through a process of convexion currents or mass circuits. This question is related to the hypothesis of Hess[1,2], according to which the seismologically determined 'basaltic' layer under the oceans would be a serpentinite.

In the following computation I use the model for convexion currents as advocated by Hess[1,2] and Wilson[3,4]. According to this model the ocean floor as a whole, together with its topographical features as oceanic islands and guyots, and its sedimentary cover, moves away from the ridges, representing the loci of rising convexion currents. The ocean floor is renewed during this process. In order to simplify calculations, which anyhow can lead only to an order of magnitude of the thermal effect of serpentinization, I used the following model: the upper 4 km of peridotite of density 3·2, which is brought to the surface by convexion currents, rising under the oceanic ridges, undergoes a serpentinization during its horizontal movement along the ocean floor, according to the following idealized equation:

$$\underset{\text{(olivine)}}{Mg_2SiO_4} + \underset{\text{(enstatite)}}{MgSiO_3} + 2H_2O \rightarrow \underset{\text{(serpentine)}}{Mg_3Si_2O_5(OH)_4}$$

The serpentinite of density 2·6 has a thickness of 5 km.

In order to calculate the heat of reaction of this hydration-reaction, we make use of the following formula:

$$\Delta G = \Delta H - T\,\Delta S$$

where: ΔG = Gibbs free energy of reactions = $G_{(\text{serp.})} - G_{(\text{ol. + en. + }2H_2O)}$; ΔH = heat of reaction of the above equation; T = temperature of reaction in °K; ΔS = entropy$_{(\text{serp.})}$ − entropy$_{(\text{ol. + en. + }2H_2O)}$.

Now in equilibrium $\Delta G = 0$. The temperature of equilibrium of the foregoing reaction is about 700° K at a water pressure of 500 bars[5,6]. If we neglect the effect of pressure on the entropy of the solid phases, we may calculate the following entropies at 700° K, using data of Olsen[6], Fyfe, Turner and Verhoogen[7] and Kelley[8]:

$$S_{\text{olivine (700° K)}} = 51{\cdot}85$$
$$S_{\text{enstatite (700° K)}} = 36{\cdot}35$$
$$S_{\text{serpentine (700° K)}} = 119{\cdot}6$$

Two moles of water at 700° K and at a pressure of 500 bars have an entropy of about 67·5, according to the tables of Pistorius and Sharp[9].

The entropy-difference ΔS for the serpentinization reaction at 700° K and 500 bars water-pressure thus