REGIONS OF EXTENSION IN THE EARTH’ S SHELL

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Abstract

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GEOPHYSICS

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REGIONS OF EXTENSION IN THE EARTH' S SHELL

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The most reliable information on the state of the inner parts of the Earth is provided by the study of elastic oscillations caused by earthquakes.

The velocity of propagation of longitudinal (V_p) and transverse (V_s) seismic waves is related to density (ρ) and the elastic constants by the following relations:

$$v_p = \sqrt{\frac{K - \frac{3}{4}\mu}{\rho}}, \tag{1}$$

$$v_s = \sqrt{\mu/\rho}, \tag{2}$$

where K is the bulk-compression modulus, and μ is the rigidity modulus.

There are no data on density values at various depths. However, there is very valuable information on the mean densities of the upper horizons of the Earth. According to H. S. Washington, the mean density of the Earth' s crust, without taking sedimentary rocks into account, should be 2.79, and with them included, 2.77.

On the other hand, geodetic, gravimetric, and astronomical observations have made it possible to establish that the mean density of the Earth is 5.52, i.e., approximately twice the density of its surface.

From this information one may conclude that the density of the matter composing the Earth increases as one approaches its center.

Table 1

h, km	v_p, km/sec	v_s, km/sec	h, km	v_p, km/sec	v_s, km/sec	h, km	v_p, km/sec	v_s, km/sec
33	7.75	4.35	603	10.26	5.76	1679	12.37	6.77
96	7.94	4.44	667	10.55	5.85	1807	12.54	6.83
160	8.13	4.54	730	10.77	6.00	1934	12.71	6.89
223	8.33	4.64	794	10.99	6.12	2060	12.87	6.95

Fig. 1

Figure 1: Fig. 1

h, km	v_p, km/sec	v_s, km/sec	h, km	v_p, km/sec	v_s, km/sec	h, km	v_p, km/sec	v_s, km/sec
287	8.54	4.74	920	11.29	6.29	2187	13.02	7.01
350	8.75	4.85	1047	11.50	6.39	2313	13.16	7.07
413	8.97	4.96	1173	11.67	6.48	2441	13.32	7.14
477	9.50	5.23	1300	11.85	6.56	2568	13.46	7.20
540	9.91	5.46	1426	12.03	6.64	2695	13.60	7.26
603	10.26	5.67	1553	12.20	6.71	2822	13.64	7.31

Table 1 shows the velocities of propagation of longitudinal and transverse seismic waves as a function of the depth of their penetration into the Earth, according to seismological data ([2]).

It is evident from Table 1 that the velocity of propagation of elastic oscillations increases with depth. Taking this fact into account and comparing it with formulas (1) and (2), one may conclude that, as one approaches

toward the center of the planet the elastic properties of matter change more rapidly than its density.

For an exact interpretation of seismic data it is necessary to have information on the values of the elastic constants K and μ at various depths. An unambiguous solution of this question cannot be given, since the corresponding density values are unknown. However, knowing the velocities of longitudinal and transverse waves, it is not difficult to find the ratio K/μ

$$\frac{K}{\mu} = \frac{v_p^2}{v_s^2} - \frac{4}{3}. \tag{3}$$

When all-sided compression exists, repulsive forces opposing it arise.

Obviously, under compression of a given atomistic system the repulsive forces will increase, i.e., K will increase more rapidly than μ, whereas under stretching of this system the attractive forces will increase, i.e., μ will increase more rapidly than K. In the first case the ratio K/μ will increase, in the second it will decrease.

Fig. 1

Table 2

h, km	K/μ	h, km	K/μ	h, km	K/μ
96	1,864	730	1,889	1934	2,069
160	1,873	794	1,891	2060	2,113
223	1,890	920	1,888	2187	2,116
287	1,913	1047	1,906	2313	2,131
350	1,921	1173	1,910	2441	2,147
413	1,937	1300	1,930	2568	2,161
477	1,966	1426	1,949	2695	2,176
540	1,961	1553	1,972	2822	2,148
603	1,941	1679	2,005	2885	2,158
667	1,919	1807	2,038		

Using the data of Table 1 and calculating the values of K/μ by formula (3), we obtain for the Earth' s shell the values given in Table 2.

The data of Table 2, supplemented by B. Gutenberg' s data on the Earth' s crust, are shown in the graph of Fig. 1. From this graph it is first of all evident that the internal regions of the Earth are distinguished by a greater degree of compressibility, since even the minimum values of the ratio K/μ at depth are higher than this ratio at the Earth' s surface. Further, from Fig. 1 it is seen that in the depth intervals 30–96 km, 450–900 km, and 2700–2900 km the ratio K/μ undergoes

decrease, which indicates a relative stretching of the material.

The uppermost of the regions of stretching is located directly beneath the Earth' s crust. This region is distinguished by the presence of centers of volcanism and by a high frequency of earthquakes. The next region of relative stretching is located in the depth interval 450-900 km, i.e., it coincides with the transition layer. This layer is characterized by a rapid increase in the velocities of seismic waves and by the location of the foci of deep-focus earthquakes.

The presence of a third region of stretching in the depth interval 2700-2900 km is not revealed quite clearly, owing to the insufficiency of data on the corresponding velocities of seismic waves. By its position this is the region bounding the Earth' s core.

The stretching of the material in the indicated regions is confirmed by the study of the ratios of the elastic constants to density, which can also be expressed through the velocities of longitudinal and transverse waves.

From formulas (1) and (2) we find:

$$\frac{K}{\rho} = v_p^2 + \frac{3}{4}v_s^2, \qquad \frac{\mu}{\rho} = v_s^2.$$

Fig. 2

Fig. 2

Figure 2: Fig. 2

As is seen from Fig. 2, in the depth intervals 30–96 km and 450–900 km these ratios increase rapidly, with K/ρ increasing much more rapidly than μ/ρ.

If one takes into account that the ratio K/μ decreases in these intervals, it becomes obvious that such behavior of these quantities can be explained only by a decrease in the density of the material in these intervals in connection with its stretching.

It is interesting to note that the peaks on the curve in Fig. 1 have a symmetrical character. This shows that the stretching which, with depth, replaces the compressed state of the material increases at the same rate as the compression lying above it.

Thus, the data of seismology lead to the idea that the Earth' s shell is a solid compressed body, within which, against the background of general compression, there are regions of relative stretching. At the same time, the degree of stretching in each given region is the greater, the greater the compression in the neighboring region.

The presence of the indicated three regions of stretching can be explained by the nonuniform compression of the planet, which begins from the core and spreads with some lag toward its periphery.

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CITED LITERATURE

1. A. G. Betekhtin, *Course of Mineralogy*, 1952.

2. V. F. Bonchkovsky, *The Internal Structure of the Earth*, Publishing House of the Academy of Sciences of the USSR, 1953.

Note: Figure translations are in progress. See original paper for figures.