Depth of Isostatic Compensation and Mohorovičić Discontinuity, etc. in Continental and Oceanic Areas

On the basis of the probable average density of rock below the oceans and over land, up to 160 km. or so, estimates of have been made of the depth of isostatic compensation. The depth of the Mohorovičić discontinuity is inferred from an analysis of refraction type travel-time curves, assuming the existence of layers in which there is a uniform velocity and that there is a discontinuous increase in velocity on crossing the Mohorovičić discontinuity between an upper 'granitic' layer and a lower 'basaltic' layer. Due to this discontinuity critical reflexions occur, which may explain arrivals of high intensity at certain distances. The layer of relatively low velocities above the discontinuity is thought to consist of sediments; unconsolidated at the top and consolidated and or metamorphosed below. Usually the depth of the Mohorovičić discontinuity is calculated as 15–40 km. beneath continents and 5–15 km. below the oceans.

There are practical difficulties if all this is accepted. The depth of isostatic compensation remains highly hypothetical. The Mohorovičić discontinuity, though regarded as a physical phenomena, does not manifest itself everywhere. In a number of cases the critical reflexions associated with it are not observed, though as a zeroth-order approximation travel-time curves are still analysed on the layer hypothesis. The difference in thickness of sediments in oceanic and land areas cannot be explained by any plausible theory.

The seismic data might therefore be analysed assuming that the computed thickness of sediments under the oceans is more or less correct but that the currently accepted values for land areas are much too high. This is compatible with the seismic data on the basis of a gradual increase of velocity with depth. In actual fact the velocity gradient will change with depth. Further, it is likely to be high in the upper layers and to decrease as one goes deeper, getting very small once velocities of the order of 8·8 km./sec. or so are reached. This is somewhat unlike the current ideas of velocity variation with depth. The seismic data can be analysed to a first-order approximation on the basis of a uniform velocity gradient. Seismologists have preferred not to do so in crustal seismology, since the analysis is rather insensitive and an independent justification for going beyond the simpler zeroth-order approximation was lacking. An indepenent justification has now been provided by an analysis of reverberation data which I have carried out (being communicated to the *Proceedings of the Royal Society*). This necessitates a gradual increase of velocity with depth and gives an accurate estimate of the average velocity gradient from the decay of reverberation observed close to a shot point.

In the state of Virginia, in the United States, where Mohorovičić-type reflexions are quite prominent for shots at a distance of about 100 km., the average velocity gradient is 0·075 km./sec./km. and the penetration of rays responsible for the high-intensity arrivals is only 14 km. On the usual hypothesis of two layers, the depth of the discontinuity in this area is computed to be about 37 km. The average gradients in some other areas come out to be 0·04 km./sec./km. in South Africa and 0·055 km./sec./km. in Tennessee. These values are somewhat weighted in favour of deeper rock as they have been calculated from the tail ends of reverberation records or from more distant portions of travel-time curves. The value for ocean bottom in mid-Pacific is about 0·35 km./sec./km. and there is an intermediate value of about 0·16 for coastal areas like western California, decreasing to 0·09 in relatively deeper sediments.

Values of the order of 8·8 km./sec. for the velocity of P-waves (the highest observed during the recent *Downwind* expedition in the mid-Pacific) are found in the oceanic records. One can reasonably assume this to be the velocity in the heavier rock into which the roots of continental blocks have to extend. Presumably the velocity gradient is very small once this velocity has been reached. Now assuming 0·04 km./sec./km. to be the smallest average gradient observed, and 5·6 km./sec. to be the velocity in the top layers, the depth of isostatic compensation or the depth of deepest penetration of the roots of the land in question seems to be of the order of 80 km., since the velocity difference of 3·2 km./sec. will be made up in this depth. The recent work in the South American Andes requires deep roots, and perhaps the Himalayas require still deeper roots. From existing data one can see that the velocity of 8·8 km./sec. will be reached at the following depths:

Oceanic areas: about 5 km. to more than 15 km.
Continental areas: about 30 km. to more than 80 km.

The depths which give rise to Mohorovičić-type effects over certain continental areas seem to vary from 10 to 20 km. Thus these depths and the depths under oceans where the velocity reaches 8·8 km./sec. are of same order, and this perhaps corresponds to the thickness of the sediments. Over land, the rock between a depth of about 15 km., that of isostatic compensation, as envisaged above, consists of rock underneath and lighter rock, transformed from the deeper rock during continental formation, on top. Under the mountains with the deepest roots the lighter rock extends right down to the depth of compensation, but under the oceans it is missing.

The patchy nature of Mohorovičić phenomena can also be understood easily. In certain areas, the gradual increase of velocity with depth in sediments may lead to velocities greater than those in the topmost layers of the crustal rock in the area. This might give rise to the so-called 'low velocity layer', as well as to focusing due to an increase of velocity after a sudden decrease. The thickness of the sediments over land would be likely to be approximately that in oceanic geosynclines that exist now or which are reflected in oceanic rises, for example, the Easter Island rise. The above considerations also help to resolve the paradox of almost equal heat flow from below in oceanic and continental areas.

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