The Amplitude Ratio $PcP/P$ and the Core-Mantle Boundary

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Summary – Using the Haskell matrix formulation, theoretical reflection coefficient curves have been calculated for a multi-layered core-mantle boundary for comparison with observational data. Two cases are considered, first when the shear velocity in the core is equal to zero and second when the core has a finite rigidity. If the velocity contrast is large between the imbedded layer and the mantle, the reflection coefficient curves for the multi-layered medium are irregular in shape as compared to those for two half-spaces, representing the core and the mantle, respectively. The reflection coefficient curves show an oscillatory character if the imbedded layer is thick and has a high velocity contrast.

The observational data consist of short-period vertical-component seismograph records of $P$ and $PcP$ from nuclear explosions in the Aleutian chain, Nevada, Novaya Zemlya, Kazakh and Sahara. Attenuation and geometrical spreading are taken into consideration. Four different models for the quality factor $Q$ are applied to the observational data. The data are found to be much affected by the $Q$-model used for the corrections.

Based on proposed $Q$-values, a model for the core-mantle boundary is found, characterized by two low-velocity layers at the bottom of the mantle. The thicknesses are 16.10 km (outer layer) and 19.96 km (inner layer), the compressional wave velocities 12.17 km/sec and 10.94 km/sec and the shear wave velocities are 6.29 km/sec and 5.33 km/sec, respectively. A better fit to this model is found when in addition the shear velocity in the outer core is 2.20 km/sec and the density ratio at the core-mantle boundary is 1.07. In other words, the observations favour a layer of finite rigidity in the outer core rather than a fluid one.

1. Introduction

During the last decade, the core-mantle boundary has become one of the main and more difficult topics of investigation in the physics of the earth. Several kinds of observations, such as of free oscillations, diffracted, reflected and multi-reflected body waves, have been used to provide information on this transition boundary, but so far no unified values have been found. This paper will concentrate on an examination of the compressional waves reflected from the core-mantle boundary with a view to extracting some information on the physical parameters on both sides. The energy of the reflected waves is much influenced by the property of the matter at this transition boundary.

Earlier, different investigators have indicated that observational data of the amplitude ratio $PcP/P$ disagree with theoretical reflection curves calculated for two half-spaces. MARTNER [18] found that his observed amplitude ratios $PcP/P$ are two to...
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five times greater than according to calculated theoretical curves. Similarly, ERGIN [9] was not able to explain the large observed amplitude ratio of \( \frac{PcP}{P} \) by any reasonable assumption about velocity and density at the core-mantle boundary. Out of 150 seismograms, BUCHBINDER [4] was able to measure the ratio \( \frac{PcP}{P} \) for only 26 seismograms, also showing a large deviation from theory.

KOGAN [16] presents the amplitude ratio \( \frac{PcP}{P} \) for nuclear explosions in different regions, i.e. representing a wide coverage of azimuth. Some of his ratios are greater than unity, which he attributes both to errors of the geometrical spreading coefficients, calculated from the travel-time curves of \( P \) and \( PcP \), and to differences in absorption of \( P \) and \( PcP \). KANAMORI [15] says that the deviation between observed and calculated values of \( \frac{PcP}{P} \) is reduced if attenuation and geometrical spreading are taken into account. Vinnik and Dashkov [28] indicate that the scatter of the ratio \( \frac{PcP}{P} \) can be attributed to inhomogeneities of the medium. As a result, they propose a very inhomogeneous zone at the bottom of the mantle.

So far, most investigators who have dealt with this problem have tried to compare their observational data of \( \frac{PcP}{P} \) with theoretical reflection coefficient curves calculated for a solid-liquid interface. In other words, they assume that the core-mantle boundary is a sharp discontinuity. But during the last decade, some doubt has been raised about the sharpness of this boundary. GUTENBERG [11] proposes a decrease in velocity at the base of the mantle. DORMAN et al. [8] suggest a soft layer at the core-mantle boundary to satisfy their free oscillation data. Similarly, PHINNEY and ALEXANDER [21] propose a soft layer at the base of the mantle. Such a layer may reduce the disagreement between theoretical reflection coefficient curves and observational data. Or as stated by BERZON et al. [3]: ‘One of the possible models, which leads to a clarification of the differences between the observed data and the theoretical calculations, is a thin-layer model of the transition zone between the core and the mantle’.

On the other hand, BALAKINA and VVEDENSKAYA [2] indicate that the top of the outer core resembles an elastic solid. They suggest a shear velocity below the core-mantle boundary of 0.7 km/sec. Also SATÔ and ESPÍNOSA [23] suggest a mean upper bound for the rigidity in the outer part of the earth’s core to be \( 5.45 \times 10^{10} \) dyne/cm\(^2\), and the upper bound for the shear velocity to be 0.73 km/sec.

The aim of this paper is to investigate the effects of layering at the core-mantle boundary on the reflection coefficients and the possibility of a finite-rigidity core. We shall find that the layering and the finite-rigidity core will reduce the great discrepancy between theoretical reflection coefficient curves and observational data, when the geometrical spreading and attenuation are taken into consideration.

2. List of symbols

We shall be using the following symbols, here explained in alphabetical order:

- \( a \) radius of shot cavity
- \( A \) amplitude of seismic body wave