EARTH'S INTERIOR

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Contents

Summary

This article presents Earth's interior as a dynamic system illustrated by many facts obtained by geophysical observation and experiments. Earth is the common homeland of humanity and other living beings. Naturally, as residents on the planet we should know Earth and its interior. In this article, Earth's interior, including its structure and dynamic process, are introduced. The solid Earth may be symmetrically divided into several major concentric spheres called the core, the mantle, and the crust, respectively. The major structural units of Earth's interior are as follows: (a) a solid inner core; (b) a liquid outer core; (c) a thick mantle; (d) a soft asthenosphere in the upper mantle; and (e) a rigid lithosphere of which the upper part is called the crust. The lower part belongs to the upper mantle. These major structural units are symmetrically arranged as concentric spheres from the central point of Earth to its surface. The asthenosphere and the lithosphere are recognized as additional units in terms of Earth's dynamics and plate tectonics. In Earth's interior every major dynamic action and heat movement is closely related. In particular, changes in geomagnetism, dynamic actions deep within Earth, the movement of lithospheric plates, and the sites of most crustal deformation, intense volcanism, and seismic activity caused by this movement, are directly controlled by heat movement in Earth's interior. These dynamic actions in Earth's interior influence the survival, death, and evolution of living beings on Earth. The power driving dynamic actions in Earth's interior is the heat energy of Earth's interior. Earth's interior is not

only a source for all natural life, but is also the origin of changes to environments on the surface of Earth, including natural hazards. Earth's systems should therefore be understood as the basis of our ecology.

1. Introduction

Earth is not only a common planet, but also a huge support system for all known life, including humankind. Generally, most life is found in the continents and oceans of Earth. Although continents and oceans are situated on the surface of Earth, they are the results of tectonic movement caused by the dynamic actions of Earth and its interior. Simultaneously, the interior of Earth is an important cause of geographical, climatic, and natural environmental changes, and natural hazards. These changes determine the destiny of life in Earth. Therefore, knowledge of the interior of the Earth is extremely important for the envelopment of civilization.

Earth is an interesting planet: it looks solid and stable but in reality it is active with violent seismic and volcanic activities, as well as slow, continuous, large-scale, and long-term tectonic motions. Why does Earth appear to be so contradictory? Most scientists think that movement in Earth's interior causes this strange phenomenon and thus this subject warrants investigation.

Earth is a very diverse planet. Seismic evidence reveals that several huge interfaces exist in its interior. These interfaces, called "discontinuities," symmetrically divide Earth into several major concentric spheres, for example, the inner core, the outer core, the mantle, the crust, and so on. Most of the concentric spheres are not calm, moving and change continuously on a large scale over a long time period. These motions and changes in Earth's interior play a major role in evaluating changes in Earth and its life systems.

2. Structure of the Earth's interior

The solid Earth is symmetrically divided into several major concentric spheres called the core, the mantle, and the crust, respectively. The major structural units of the Earth's interior are: (a) a solid inner core; (b) a liquid outer core; (c) a thick mantle; (d) a soft asthenosphere; which is in the upper mantle; and (e) a rigid lithosphere of which the upper part is called the crust and the lower part belongs to the upper mantle (Figure 1). These major structural units are symmetrically arranged as concentric spheres from the central point of the Earth to its surface. The asthenosphere and the lithosphere (Figure 2) are recognized as additional units in terms of the Earth's dynamics and plate tectonics.

2.1 Seismic Waves

Most knowledge that scientists have of the deep interior of Earth has been obtained through study of the seismic waves generated by large earthquakes and explosions. In addition, subsidiary information is gained from the study of Earth’s geomagnetic and gravitational fields, from a knowledge of Earth’s inertia, and from comparisons with meteorites and simulated systems in the laboratory that are thought likely to resemble conditions deep in the Earth.

Two kinds of seismic waves, called “body waves,” travel through the interior of Earth: “compressional” or “P” waves, which arrive first at a recording station and can travel and refract through both fluid and solid materials; and “shear” or “S” waves, which are transverse, arrive later and can only travel through solid materials (Figure 3). Other waves, called “surface” or “L” waves, travel more slowly around the surface of Earth. Besides traveling directly through Earth from the seismic source or focus to the observatory, body waves may also be reflected and refracted at the Earth’s surface and at interior interfaces. Seismic records, or seismograms, at stations far from the focus are therefore complicated by the arrival of many pulses of energy that have traveled by different paths (Figure 3).

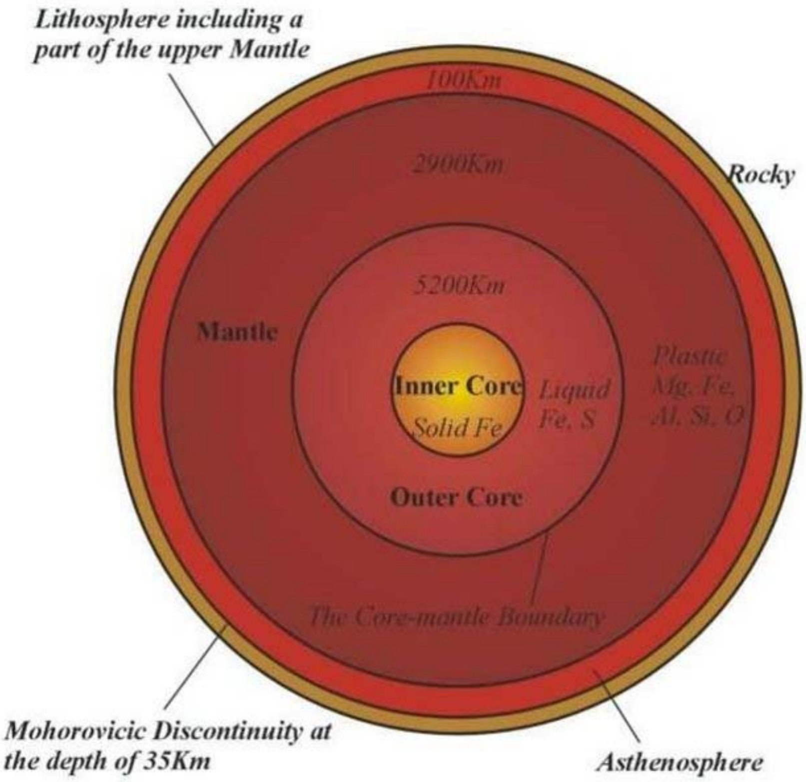

Figure 1. Cross section of Earth’s interior

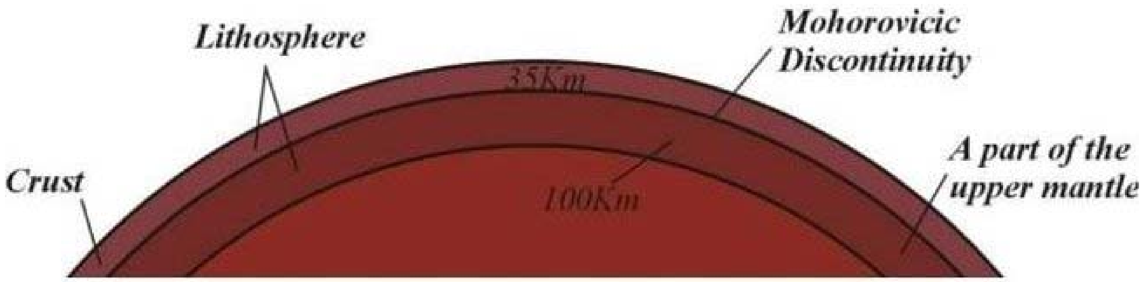

Figure 2. Cross section of Earth's lithosphere

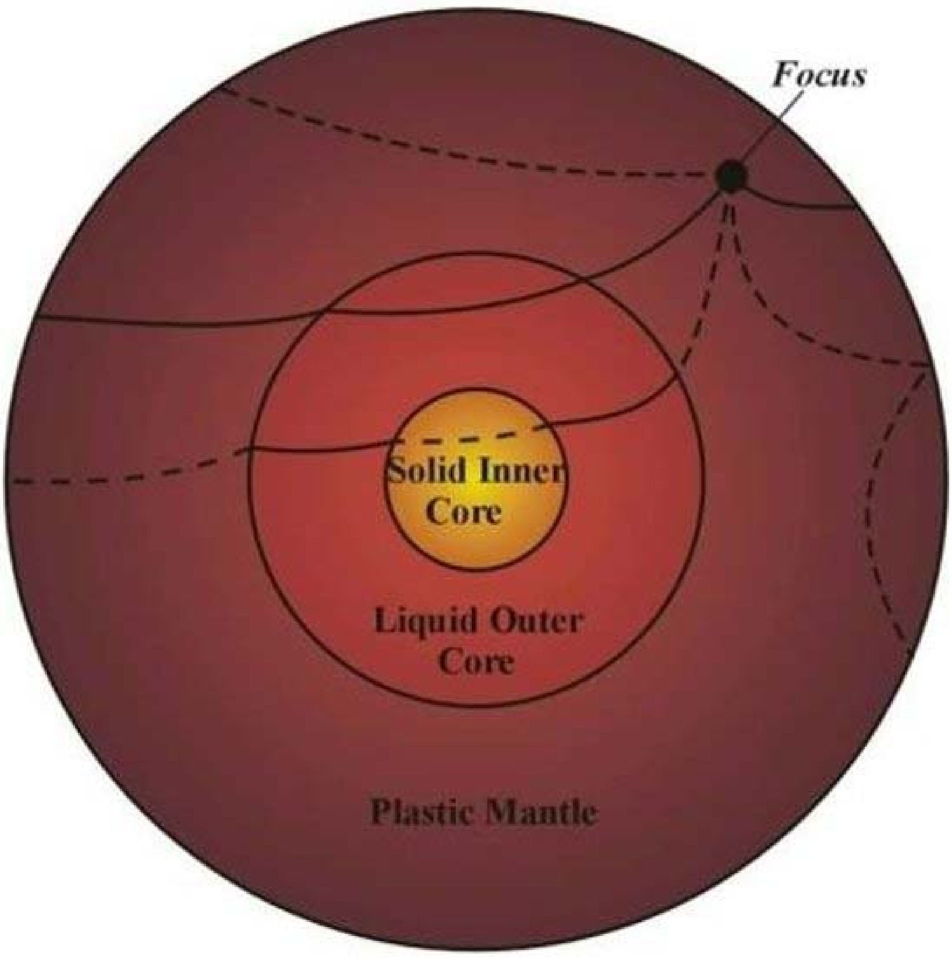

Figure 3. Siesmic waves propagating in Earth's interior

The velocities of seismic body waves depend upon the elastic properties and the densities of the materials through which they travel. In addition, the moment of inertia of Earth also depends on the distribution of these densities. Therefore, seismic observations can be used to determine the probable distributions of elastic parameters and densities of Earth (except for some uncertainty about the innermost core). In the last ten years, geophysicists found that the scattering of seismic waves due to lateral heterogeneity in Earth's interior may be recorded as codas following other pulses and precursors on seismograms. This provides a powerful tool to study lateral heterogeneity in Earth's interior.

Since the 1980s, seismologists have developed methods of seismic tomography inspired by medical CT (Computerized Tomography). These methods can be applied to the imagery of Earth's interior regarding natural parameters (for example, the elastic parameters, the density, the velocity and the quality factor) and geometric shapes of constructions at multiple scales. Scientists can obtain detailed information about Earth's interior using the above-mentioned methods. This progress opens a new page of study within the Earth sciences.

Scientists also find that "S" waves generated from the same focus and traveling through the same medium sometimes may be split into two "S" waves with different velocities, and their velocities change with different propagating directions. This phenomenon is caused by the elastic anisotropy of the regions in Earth's interior. The effective anisotropy may be caused by many factors; for example, differences of crystal and structural orientations, oriented cracks, faults, cracked structures, and so on, all have an effect. Anisotropy of the materials in Earth's interior may also cause scattering of seismic waves that may be recorded on seismograms. In addition, information about the viscoelastic nature of the materials in Earth's interior may be obtained from the attenuation of seismic waves. Because of improvements in observation conditions, richer information about Earth's interior may be found from seismograms. Information carried by seismic waves is so plentiful that current scientists cannot fully interpret and deal with it all. However, an understanding of Earth's interior can be made clearer through studying seismic waves. It is likely that information from seismic waves will play a major role in the study of Earth's interior for a long time to come.

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Biographical Sketch

Xiaofan Li received a PhD (1996) in applied mathematics (geophysics) from the University of Cambridge, UK. He works at the Institute of Geology and Geophysics, Chinese Academy of Sciences as a full professor of geophysics. His research interests focus on seismology, geodynamics, geophysics, wave dynamics and solid mechanics.