

PLATE TECTONICS

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Keywords: plate tectonics, plate margin, hot spot, lithosphere

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Summary

The Earth is composed of layers of different composition and physical properties: the core, the mantle, and the crust. Two different types of crust exist, the thick and older continental crust and the thin and younger oceanic crust. Horizontal movements within the rigid crust are expressed by the concept of seafloor spreading which is based on magnetic anomaly patterns on oceanic crust as a result of repeated reversals of the Earth's magnetic field. This concept is part of the plate tectonic theory which describes the dynamic formation of new oceanic crust at mid-oceanic ridges, the subduction and destruction of oceanic crust at convergent plate boundaries, the collision of continental plates and formation of mountain ranges, and the conservative movement of plates past each other along transform faults. Hot spots are thought to be stationary points with high volcanic activity which may reflect the plate movement by producing hot spot tracks at the surface when the plate moves over it.

1. Introduction

In the early 17th century natural scientist already realized that the western African and eastern South American coastlines are rather similar. Based on their congruent shape

and supported by a variety of geological evidence on both sides of the Atlantic ocean, Alfred Wegener stated his „Kontinentalverschiebungstheorie“, the theory of drifting continents (Wegener, 1912, 1915, 1929). However, without knowing suboceanic structures such as ridges and subduction zones, he could not develop a theory of Earth dynamics. Holmes (1931, 1944) first suggested thermal convection to be the fundamental process responsible for plate motion. A major breakthrough occurred between 1950 and 1965 when the ocean floors were mapped and magnetic anomalies and other seismic properties were detected.

Hess (1960, 1962) proposed the theory of seafloor spreading where ocean floors are spreading apart, propelled by thermal convection currents in the mantle, and moving away from ocean ridges. Magma from the mantle is injected into fractures in the central rift valley of the ocean ridges and becomes new oceanic crust. The convection currents in the mantle carry the continents away from the ocean ridge and toward deep-sea trenches. There subduction zones develop where the oceanic crust descends into the mantle leading to a complete regeneration of the ocean floor within a cycle of 200 to 300 million years duration. This concept has been the first global theory which explains at the same time different geodynamic phenomena (earthquake zones, orogenesis, graben formation, etc.), magmatism, metamorphism, formation of deposits, and pattern of depositional areas of sedimentary rocks.

The modern concept of plate tectonics (e.g., Hess, 1962; Vine & Matthews, 1963; Wilson, 1965; Isacks et al., 1968; Le Pichon, 1968; Morgan, 1968; McKenzie & Morgan, 1969; Dewey & Bird, 1970) has been developed based on the actualistic principle. Geologists try to adopt this concept to older orogenic areas and to reconstruct oceanic realms which have been subducted long ago. In numerous cases this is well possible but it meets with difficulties when we try to reconstruct the earliest history of Earth where this concept should not be adopted uncritically.

2. The Earth's composition

The constituent materials of the Earth are separated and segregated into layers according to density. The denser materials are concentrated near the center, the less dense near the surface. Two internal layer subdivisions are possible based on composition or physical properties (Fig. 1)

The uppermost layer of the composition-based subdivision, the Earth's crust, is composed of two distinctly different types: continental crust is with an average thickness of 30-35 km much thicker than oceanic crust with only 7 km in average, and is made up of relatively light „granitic“ rock (2.7 g/cm^3 in average) including the oldest rocks of the crust (~ 3,85 billion years). The thickness of continental crust can be up to 80 km in some mountain belts such as the Himalayas or the Andes. Oceanic crust beneath the ocean basins ranges in thickness from 3 km near the spreading axes to more than 15 km in the oldest parts and is mainly composed of dark, dense basaltic and gabbroic rocks with densities greater than continental rocks (3.0 g/cm^3 in average). It is young (180 million years of less) and relatively undeformed by folding.

The mantle comprises more than 80% of the Earth's volume. It is composed of iron and magnesium silicate rocks which in some cases can be studied in fragments brought to the surface by volcanic eruptions. The upper boundary of the mantle is defined by a discontinuity in seismic wave velocity which was discovered by the seismologist Mohorovicic and later named after him. Today this name has been shortened to Moho. Although the mantle behaves like a solid when transmitting earthquake waves, mantle rocks are able to flow at a very slow rate. The core of the Earth constitutes only 16% of Earth's volume but accounts for 32% of Earth's mass. Indirect geophysical evidence indicates that the core is mostly composed of iron with less amounts of nickel and other elements. The core is subdivided into the inner and outer core based on differences in mechanical strength. Whereas the outer core is liquid and capable of flow, the inner core is stronger and behaves like a solid.

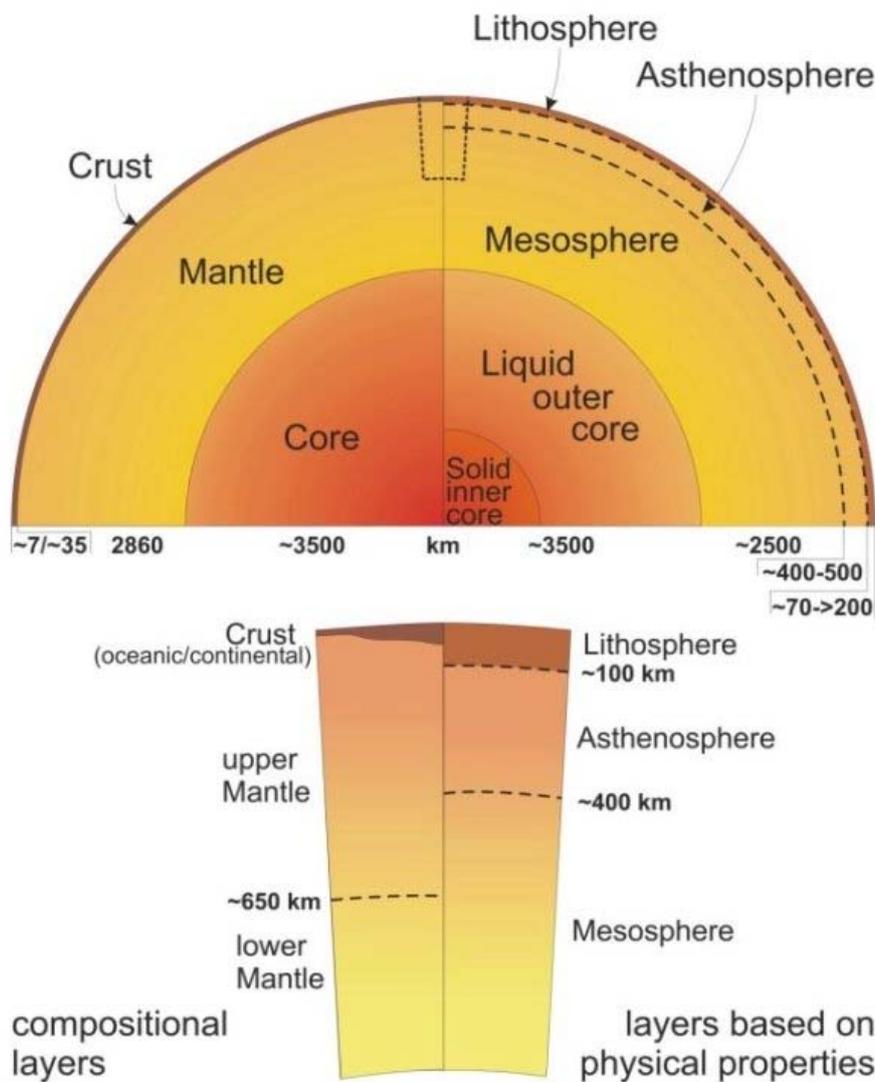


Figure 1: The layered structure of Earth.

The uppermost layer of the physical properties-based subdivision is the lithosphere where the material is solid, strong, and rigid. In the asthenosphere below the rocks lose

much of their strength and become soft plastic. This zone is easily deformed. The boundary between the two layers is not compositional but expressed by a major change in physical properties of the rock. The mesosphere is stronger and more rigid than the asthenosphere because of the high pressure which at this depth diminishes the effect of high temperature. The core of the Earth is distinct in composition and physical properties since it is mainly composed of iron in contrast to the silicate material of the mantle. Based on physical properties, the core has a solid inner part and a liquid outer core. Circulation of the liquid outer core is probably responsible for the generation of the Earth's magnetic field.

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Biographical Sketch

Martin Meschede is a professor for regional and structural geology at the university of Greifswald in Germany. He has previously held a position in Tübingen. He is a specialist in plate tectonic processes. Martin has a particular reputation for designing innovative models for subduction processes in the Caribbean. He is also interested in Neotectonics in southern Germany, has extensive experience with the Ocean Drilling Programme (ODP) and has published on the geology of Antarctica. He has also published a book on methods in structural geology.