HARTAI ÉVA,

GEOLOGY

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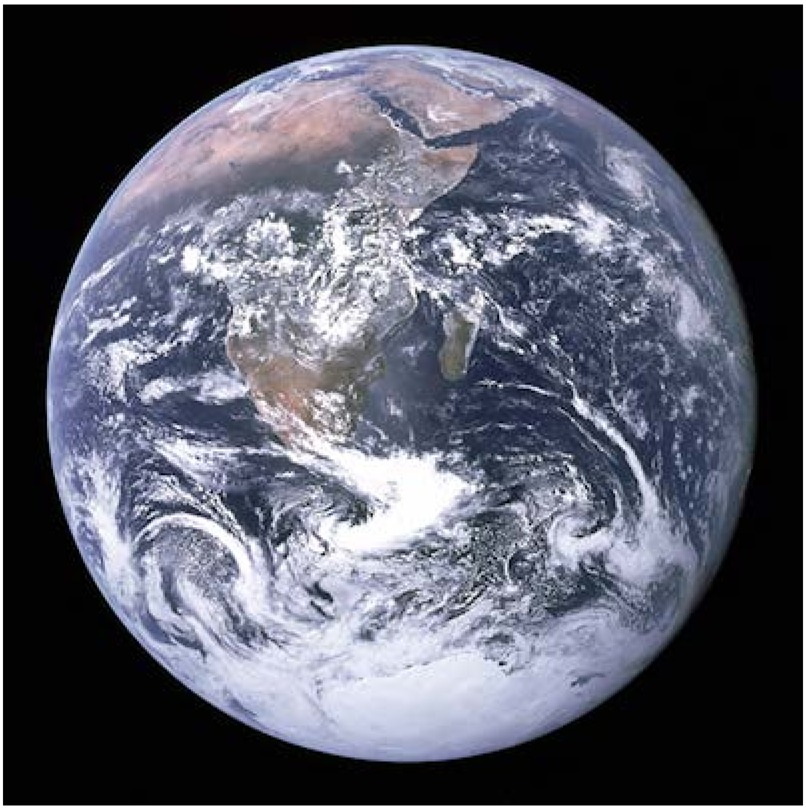
A Műszaki Földtudományi Alapszak tananyagainak kifejlesztése a
TÁMOP 4.1.2-08/1/A-2009-0033 pályázat keretében valósult meg.

II. The Earth as a Planet

1. Introduction

The Earth is a unique planet. It has an overall blue and white hue because it is surrounded by an *atmosphere* of gases. No other known planet has such kind of atmosphere. Clouds form because water evaporates from the *hydrosphere*. Only the Earth is known to have the hydrosphere in three kinds of material states: water, ice and water vapour. The third reason the Earth is special is the *biosphere*, which is the totality of the Earth's living matter. Viewed from the space, the biosphere is most dramatically revealed by blankets of green plants on some of the land masses.

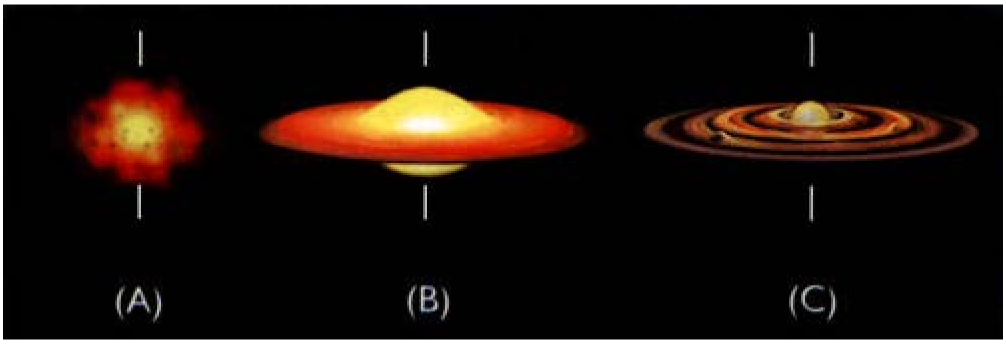


"The Blue Marble"
Our Earth, as seen by the crew of Apollo 17 on the 12th of December 1972.

2. The Origin and Structure of the Solar System

The birth of the Solar System was preceded by a supernova explosion about five billion years ago. The explosion scattered atoms of various elements everywhere through a huge volume of space. Most of the atoms were hydrogen and helium, but small percentages of all the other chemical elements were present too. The atoms formed a tenuous, turbulent, swirling cloud of cosmic gas. The gathering force of the gas was gravity, and the contracting cloud became hotter and denser. Near the center of the cloud hydrogen and helium atoms eventually became so hot that they began to fuse to form heavier elements. When the fusion of hydrogen and helium commenced, the Sun was born.

At some stage the cool outer portions of the cosmic gas cloud became compacted enough to allow solid objects to condense. The solid condensates eventually became the planets, moons and the other solid objects of the Solar System. Condensation formed innumerable small rocky fragments, but the fragments had still to somehow be joined together to form a planet. This happened by impacts between fragments drawn together by gravitational attractions. Meteorites still fall on the Earth, proving that even now some ancient, condensed, rocky fragments still exist in space. The growth process – a gathering of more and more bits of solid matter from surrounding place – is called **planetary accretion**.



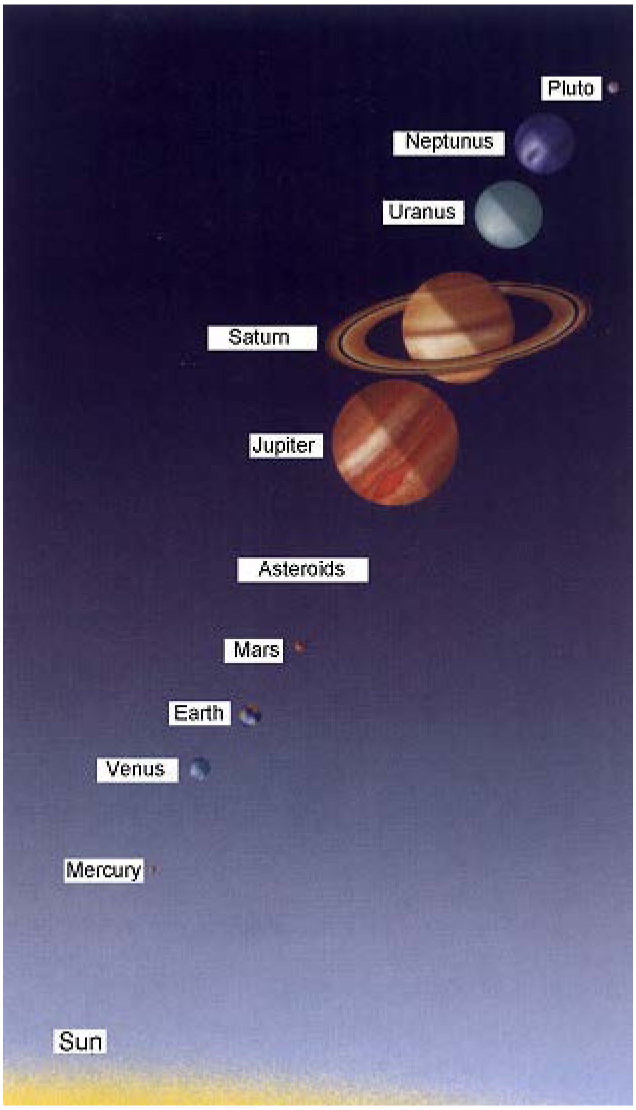
Formation of the Solar System

A: The cosmic cloud of gas and dust starts to contract. B: The contraction generates rotational movement and the rotating cloud flattens because of the centripetal forces. C: With increasing centripetal forces the flattened mass is broken into rings, and the rings contract into planets because of gravitational forces.

The formation of the Solar System can be followed in the animation below:

THE FORMATION OF THE SOLAR SYSTEM

Open video on the internet



The structure of the Solar System
The four inner terrestrial planets are small and rocky. The outer giant planets are gaseous. Outermost and smallest is Pluto, a snowball of methane, water and rock.

3. The Early Evolution of the Earth

As planetary accretion approached a climax about 4.6 billion years ago, bigger and bigger collisions meant that more and more kinetic energy was converted to heat – so much so that the terrestrial planets started to melt. The decay of the radioactive elements was also a heating factor. The planets probably did not melt completely but sufficient melting occurred that the heavier, iron-rich liquid sank into the centre of the planets, and lighter liquids, rich in light elements essential for life – such as sodium, potassium, aluminium and silicon – floated to the surface. The melting released volatile elements, and these escaped as gases, mainly water vapour, carbon dioxide, methane and possibly ammonia, that gave rise to the Earth's atmosphere. This way, the Earth became a fractionated planet.

The Formation of He Earth's Inner Structure

The formation of he Earth's inner structure

A: In the beginning the solid Earth was homogenous. B: The separation became possible by the partial melting of the Earth's mass. C: During the separation the heavier elements concentrated in the core and the lighter ones in the outer belts.

The time of continuous, massive meteorite impacts ended more than four billion years ago, and the planets cooled down, preserving the layered structure.

4. The Inner Structure of the Earth

We have information about the inner structure of the Earth from seismic waves. When an earthquake occurs, by the measurement and examination of the seismic waves we can identify differences in density and physical state inside the Earth.

Within the Earth, different layers alter one after another with increasing depth. This alteration can be recognized according to the *chemical composition* and the *physical properties*.

Layers of Differing Chemical Composition

To determine the chemical composition inside the Earth indirect measurements are used. One way to determine composition is to measure how the density of rock changes with depth below the Earth's surface. We can do this by measuring the speeds with which earthquake waves pass through the Earth, because they move more quickly through dense rocks than through less dense rocks. From such measurements we know that density increases with depth, but not smoothly. At some depths abrupt velocity increases indicate sudden increases in density. Knowing these different densities, we can estimate what the composition of the different layers must be.

The layers of different chemical composition outward from the centre of the Earth are as follows: core, mantle, and crust.

The Core

At the centre is the densest of the three layers, the **core**. It is mostly metallic iron with small amounts of nickel and other elements. The outer boundary of core is at a depth of 2,900 kilometres.

The Mantle

The thick shell of the dense, rocky matter that surrounds the core is called the **mantle**. The mantle consists of iron-magnesium-silicates and it is less dense than the core but denser than the outermost compositional layer, which also consists of rocky matter. The outer boundary of the mantle is at a depth from 8-70 km.

The Crust

The outermost compositional unit is the **crust**. While the core and the mantle have nearly constant thicknesses, the thickness of the crust is different in different places. The crust beneath the oceans, which is called **oceanic crust,** has an average thickness of about 8 km, whereas the thickness of the **continental crust** ranges from 30 to 70 km. The oceanic crust is *basalt* while the continental crust has a *granitic* composition.

The inner structure of the Earth is demonstrated in the following animation:

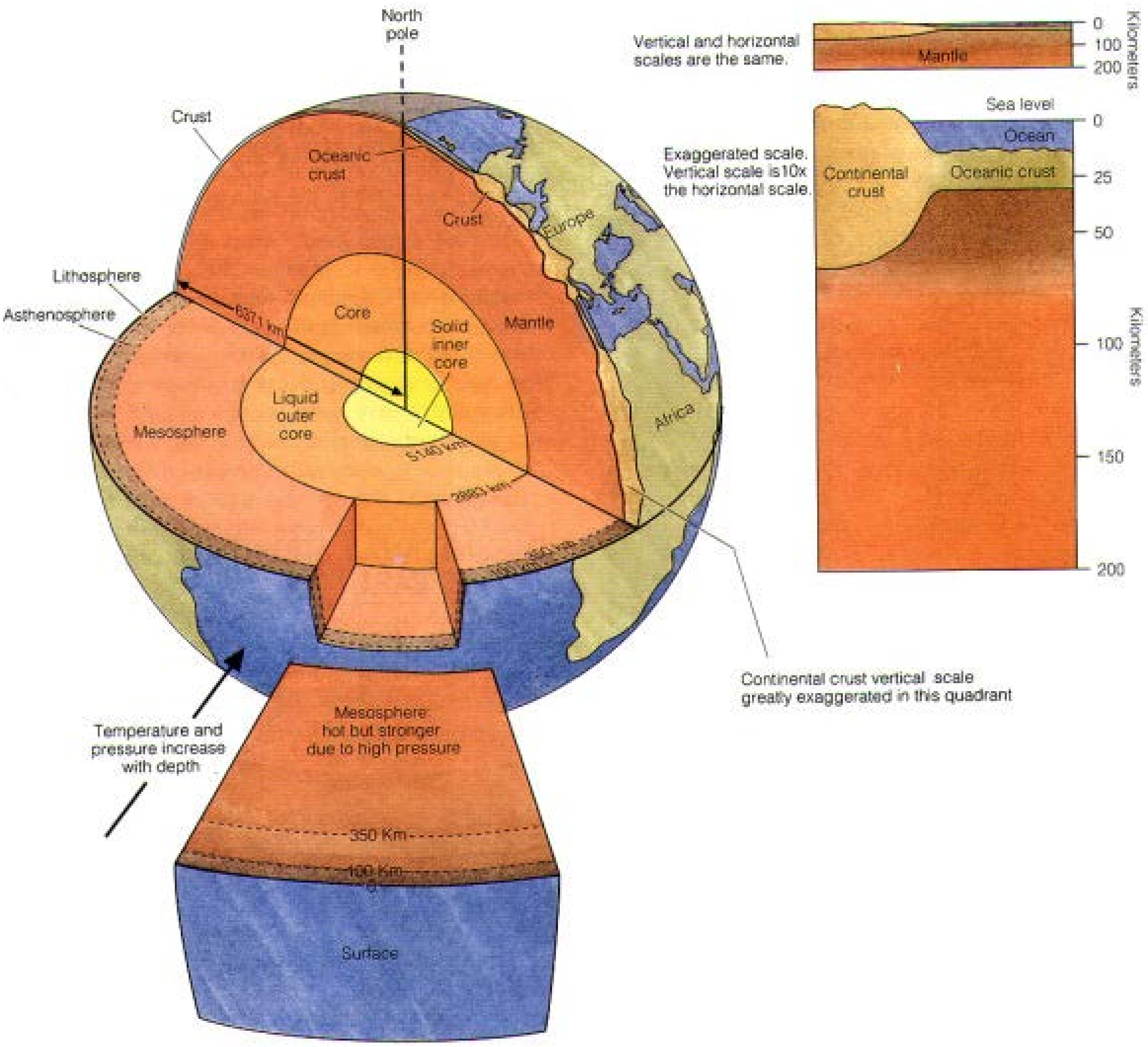
INSIDE THE EARTH

Open video on the internet

Layers of Differing Physical Properties

In addition to compositional layering, other changes occur within the earth. Most important, there are changes in physical properties such as rock strength and solid versus liquid. Except for the outer boundary of the core, the boundaries of the layers of different physical properties do not coincide with the boundaries of the layers of different chemical composition.

The layers of different physical properties outward from the centre of the Earth are as follows: inner core, outer core, mesosphere, asthenosphere, and lithosphere.



***The inner structure of the Earth* [i]**

Layers of differing chemical composition: core, mantle, crust. Layers of differing physical properties: inner core, outer core, mesosphere, asthenosphere, lithosphere. Note that the crust is a thinner layer inside the lithosphere. The oceanic crust and continental crust are different in composition.

The Inner and Outer Core

Within the core an inner region exists where pressures are so great that iron is solid despite its high temperature. The solid centre of the Earth is in the inner core. Surrounding the inner core is a zone where temperature and pressure are so balanced that the iron is molten and exists as a liquid. This is the outer core. The difference between the inner and outer cores is not one of the composition (the compositions are believed to be the same). Instead, the difference lies in the physical states of the two: one is a solid, the other is a liquid.

The Mesosphere

The strength of a solid is controlled by both temperature and pressure. When a solid is heated, it loses strength. When it is compressed, it gains strength. Differences in temperature and pressure divide the mantle and crust into three strength regions. In the lower part of the mangle, the rock is so highly compressed that it has considerable strength even though the temperature is very high. Thus, a solid region of high temperature but also relatively high strength exists within the mantle from the core-mantle boundary (at 2,883 km depth) to a depth of about 350 km and is called the mesosphere ("intermediate, of middle, sphere").

The Asthenosphere

Within the upper mantle, from 350 to between 100 and 200 km below the Earth’s surface, is a region called the asthenosphere ("weak sphere"), where the balance between temperature and pressure is such that rocks have little strength. Instead of being strong, like the rocks in the mesosphere, rocks in the asthenosphere are weak and easily deformed, like butter or warm tar. As far as geologists can tell, the compositions of the mesosphere and the asthenosphere are the same. The difference between them is one of physical properties; in this case the property that changes is strength.

The Lithosphere

Above the asthenosphere is the outermost strength zone, a region where rocks are cooler, stronger, and more rigid than those in the plastic asthenosphere. This hard outer region, which includes the uppermost mantle and all of the crust, is called the lithosphere ("rock sphere"). It is important to remember that despite the fact that the crust and mantle differ in composition, it is rock strength, not rock composition, that differentiates the lithosphere from the asthenosphere.

The difference in strength between rock in the lithosphere and rock in the asthenosphere is a function of temperature and pressure. At a temperature of 1300°C and the pressure reached at a depth of 100 km, rocks of all kinds lose strength and become readily deformable. This is the base of the lithosphere beneath the oceans, or, as it is most colloquially termed, the oceanic lithosphere. The base of the continental lithosphere, by contrast, is about 200 km deep.

BIBLIOGRAPHY:

[i] Skinner & Porter, 1995