Lecture. Origin and structure of the Earth

1. Materialist hypotheses of the origin of the Earth.
2. Form, structure and physical properties of the Earth.
3. Earth's crust, its structure and physical properties.
4. Thermal features of the Earth.

Literature:

1. Zaritsky P.V., Tikhonenko D.G., Gorin M.O., Andreev V.V., Degtyarev V.V. Geology with the basics of mineralogy: a textbook, ed. P.V. Zaritsky, D.G. Tikhonenko. Kharkiv: Maidan, 2012. S. 35–45.

2. Kanivets V.I., Parkhomenko M.M. General and Quaternary geology and geomorphology: a textbook. Chernihiv: Desna polygraph, 2015. P. 7–10; 12–15.

3. Kratenko L. Ya. General Geology: Textbook, 2nd ed. Dnipropetrovsk: NMU, 2008. S. 21–56.

4. Tikhonenko D..G., Degtyarev V.V., Shchukovsky M. A., Yazykova

A. G. and others. Geology with the basics of mineralogy: a textbook, ed. D. G. Tikhonenko. Kyiv: Higher Education, 2003. P. 9–22.

5. Bilenko D. K. Fundamentals of geology and mineralogy. Kyiv: Higher School, 1973. P. 14–35.

6. Tolstoy M. P. Geology with the basics of mineralogy. Moscow: Higher school. 1991. S. 7–32.

7. Gursky B. N., Gursky G. V. Geology. Minsk: Higher school. 1985. S.18–27.

8. Gnatenko O. F., Kapshtyk M. V., Petrenko L. R., Vitvitsky S.V. Soil science with the basics of geology: a textbook. Kyiv: Oranta, 2005. S. 17–22.

1. Materialist hypotheses of the origin of the Earth.

Earth is one of the small planets of a small star - the Sun, which is part of the Galaxy - a huge cluster of 100 billion stars. But there are other galaxies united in a larger stellar association - the Megagalaxy.

Our galaxy has a spiral thickened shape with sleeves. Most of the stars are located in the main zone and therefore there is the well-known Milky Way, a cluster of an infinite number of stars.

Earth is one of the inner planets of the solar system (Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune), the third planet from the Sun. The average radius of its orbit is 150 million km (light covers this distance in 8 minutes and 12 seconds).

The earth reaches moderately warm sunlight. Under these conditions, the Earth's atmosphere cooled rapidly. Water was formed from water vapor, and the hydrosphere emerged - the Earth's water shell, which is not found in other planets. The sun gave birth to life, which later contributed to the enrichment of the Earth's atmosphere with oxygen. With the flowering of life, the biosphere emerged and man appeared, and with it the noosphere - an area of human activity, which is an important geological force.

The question of the origin of the Earth - one of the most important and quite complex, as to date, existing hypotheses have not given a comprehensive answer.

The first scientific hypothesis about the origin of the solar system belongs to the German philosopher I. Kant, which he proposed in 1755. According to I. Kant's hypothesis, the Earth and other planets of the solar system were formed from primary dusty matter, which was in chaotic motion. According to the law of gravity, these different sized particles began to move. Heterogeneous star clusters formed, which, in turn, began to attract smaller ones. Thus, separate large clusters were formed, which became separate stars.

According to the hypothesis of the French mathematician and astronomer Pierre-Simon Laplace (1796), the planets were formed from sparse matter, from a hot nebula in the center of which the Sun arose. Cooling and compaction led to an increase in the speed of rotation and separation from the nebula of a series of rings that rotated constantly, on which later formed planets.

According to both Kant and Laplace, the Earth, like other planets, underwent a warming stage during compaction and subsequent cooling, so this hypothesis is often combined into one Kant-Laplace.

In the early twentieth century. these hypotheses have ceased to satisfy scientists because science has not discovered hot gas nebulae in the universe. They were changed by the ideas of Multon, Chamberlain, Jeans and Jeffries about the collision of the Sun with other cosmic bodies, but according to modern views, the probability of such a collision is extremely small.

According to O. Schmidt's hypothesis (1944), the Earth and other planets of the solar system were formed from interstellar meteorite dust, which was captured by the Sun as it passed through it. According to this hypothesis, the Earth originated as a cold body, and the source of its internal energy - the processes of radioactive decay of elements and various chemical reactions.

Academician V.G. Fesenkov (1960) believed that the Sun and planets were formed due to the accumulation of gas-dust nebula. Given that the age of the Sun is very close to the age of the Earth, he assumed that the Sun and the planets formed simultaneously. In the distant past, several billion years ago, the Sun emerged, like other stars, from local condensation in a gas-dust environment that was in constant motion. Continuing to form in the star and intensively decreasing, the Sun had to reduce a significant amount of matter approximately in the equatorial plane, which due to very rapid rotation could not concentrate in a single body. Other planets were formed from such a gas-dust mass.

The latest advances in cosmochemistry confirm the obvious genetic unity of the material composition of the entire solar system. The Earth, taking shape as a separate planet, began to warm up (due to radioactive decay (first Pu 244, Cm 248, and later U 235, U 238, Th 232, K 40)).

This caused the melting of iron first, then silicates. Heavy liquid iron sank to the center of our planet and formed its core. From the silicate shell (mantle) as a result of zone melting formed the lithosphere, the oceans and the atmosphere, ie the earth's crust.

2. Form, structure and physical properties of the Earth.

The size of the land is S = 510 million km^2, m = 5.98 × 10^{21} tons, V = 1083320 million km^3, R = 6371 km, p = 5.52 g / cm^3. The Earth is dominated by water - 361 million km^2, land - 149 million km^2 (70.8 and 29.2 %).

The earth has the shape of a geoid, which is slightly flattened from the poles, with an equatorial radius of 6378.2 km and polar - 6356.9 km, with differences in the earth's terrain of about 20 km (between oceanic depressions more than 11 km deep and the highest mountains above 8 km.)

The structure of the Earth: internal (lithosphere, mantle, core) and external (atmosphere, hydrosphere, biosphere).

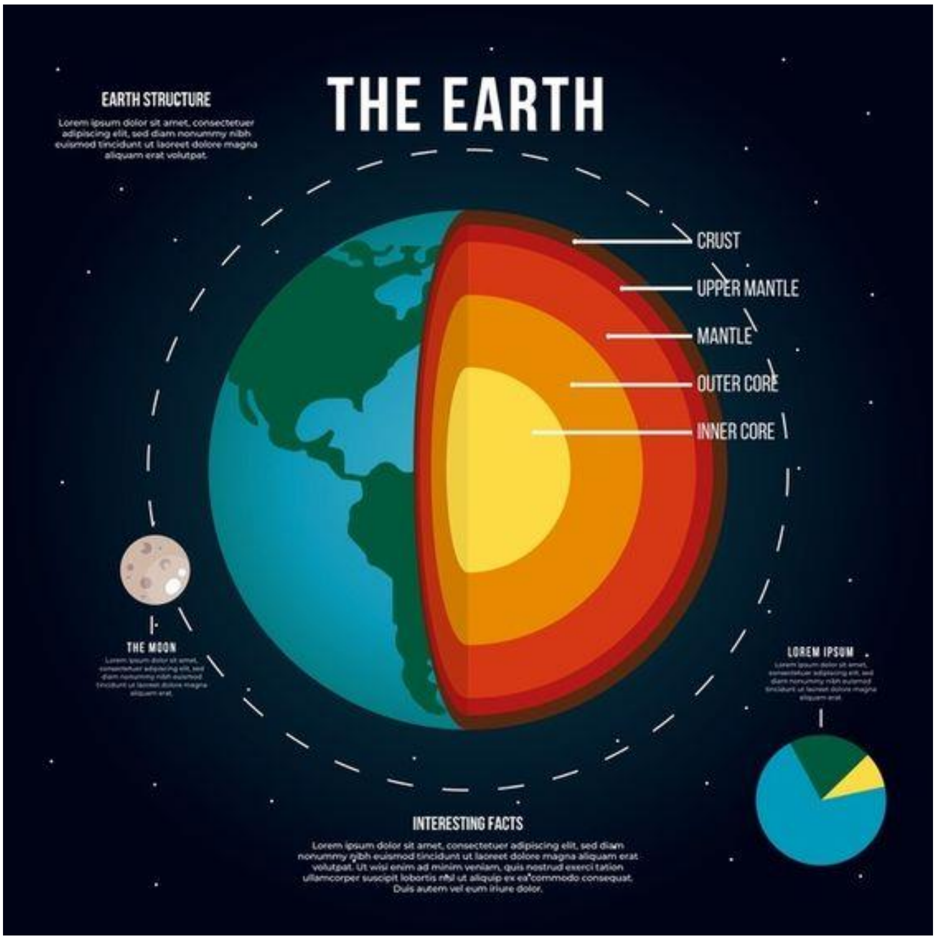

Fig. 1. The internal structure of the Earth

The earth consists of rocks, minerals and crystals formed as a result of geological processes: endogenous (crystals, minerals, rocks); exogenous (relief, soil-forming rocks, soils).

The lithosphere (Earth's crust) is a solid part of the mantle (900 km), which is called the Earth's rock shell. The lithosphere is divided into moving plates American, Eurasian, African. Indo-Australian, Antarctic, Pacific. The thickness of the crust varies from 5 to 60 km (on the continents - 40-50 km, in the seas and oceans - 6-10 km). The earth's crust consists of igneous (granites, syenites, diorites, gabbro, liparites, basalts), sedimentary (sands, clays, sandstones, limestones) and metamorphic (crystalline shales, marble, quartzite) rocks. The lithosphere of solid elements contains the most silicon and aluminum, so the earth's crust is abbreviated as sial (Sial).

The mantle - lies beneath the earth's crust and extends to a depth of 2900 km - to the Earth's core. Geophysical studies have established the heterogeneity of the structure and composition of the mantle, so it is divided into two parts - the upper and lower. In the depths of the mantle are the centers of strong earthquakes and volcanic foci. Upper mantle: roughness 900–1000 km, composed of heavier rocks: peridotites, eclogites, dunites, ultrabasalts. The chemical composition of the upper magma is dominated by silicon, magnesium, so it is called Sima (Sima). Lower mantle: its thickness (roughness) is 1900 km. Of the chemical elements in it in the first place iron (about 50 %), then nickel, cobalt, decreases the amount of silicon, aluminum. It is called Nifesima.

The core - the central part of the Earth, starting from a depth of 2900 km is very dense. Up to a depth of 5120 km, the density is the same, and deeper - greatly increases, so it is divided into two parts: the *outer core* is at a depth of 2900 km.

The substance is in a liquid state, more precisely in a state of plasma, increases the number of heavy elements, and quantitatively predominates iron, nickel, called Nife II *(Nife II)*. *The inner core* at a depth of 5120 consists of iron, nickel, cobalt, chromium, copper, phosphorus, carbon, sulfur and possibly platinum, with about 90 % iron, 9 % nickel, and all other metals up to 1 %. Called the inner nucleus of Nife I *(Nife I)*.

The structure of the Earth is quite schematic. In fact, it is more complicated; each geosphere is divided into smaller layers with different composition of chemical elements. Undoubtedly, these geospheres differ in the physical state of matter, which is associated with changes in pressure and temperature. Of these geospheres, the upper mantle is important, which determines the development of the earth's crust.

The atmosphere is the air envelope of the Earth, which is connected to it by gravity and participates in its diurnal and annual rotation. The boundary of the Earth's atmosphere is located at an altitude of up to 3000 km (at this altitude its density is equal to the density of interplanetary gas).

The lower layer of the atmosphere adjacent to the lithosphere and hydrosphere is called the *troposphere.* The thickness of the troposphere is 8–18 km; it depends on the season and latitude: it increases in summer and with approach to the equator. The temperature of the troposphere decreases with rising upwards: at the poles at an altitude of 9 km - 500, at the equator at an altitude of 17 km - 900. In the troposphere meteorological phenomena occur: clouds are formed, air currents occur, precipitation falls.

The troposphere is called the nitrogen-oxygen shell because it consists mainly of nitrogen and oxygen, which are here in a physical mixture. Nitrogen in this mixture by weight is 78.08 %, oxygen - 20.95 %, and the rest - 0.97 % is argon, neon, xenon, krypton, helium, hydrogen and carbon dioxide.

In addition to the troposphere, the atmosphere includes *the stratosphere* (11–25 km), *the mesosphere* (25–80 km), *the thermosphere* (80–800 km), and *the exosphere* (more than 800–1000 km).

In the troposphere as a result of gravity the air is denser. Here, due to heating from the sun, there is the greatest force of movement of air masses. Higher gravity decreases. The lightest gas - hydrogen forms the outermost shell of the atmosphere.

Hydrosphere - a set of water on the Earth's surface and in the surface of the earth's crust (oceans, seas, rivers, lakes, swamps, springs, perennial glaciers of mountainous and polar countries).

The hydrosphere, unlike other geospheres, does not form a continuous shell around the Earth. It occupies 70.8 % of the earth's surface. The average depth of the hydrosphere is 3.8 *km*, and the largest - 11022 *m* (Mariana Trench in the Pacific Ocean). The area of the Pacific Ocean is larger than the area of all continents - it is equal to 180 million square meters. km.

Seawater is salty: the average amount of salts in it is 3.5 %, so its density is 1.03 g / cm^3. The largest percentage in seawater are chloride compounds; then sulfides, and very few carbonates. Carbonates predominate in river water. The carbonates introduced into the ocean by river waters are rapidly absorbed by marine organisms and deposited on the seabed in the form of lime silt and limestone. In the depths of the oceans, the pressure reaches 1000 *atm*, as in the sedimentary zone. The average temperature on the surface of the oceans is + 17.4 ^{0}C.

The biosphere is a zone of active life of organisms (plants, animals, humans) that inhabit the Earth and the entire space in which life is widespread. The biosphere includes the troposphere, hydrosphere and upper lithosphere.

The boundaries of the biosphere are changing due to the movement of land and sea boundaries and climate change.

The amount of organic matter per unit surface of the Earth varies in different places. It is believed that 75 % of organic living matter is water, 23 % - dry organic matter and 2 % - unburned ash. The dry organic part contains approximately 50 % of carbon extracted from air carbonic acid and sea water.

Man plays an exceptional role in the biosphere. It changes nature, uses its riches, improves it: irrigates deserts, drains swamps, paves canals, develops productive forces, and so on.

3. Earth's crust, its structure and physical properties.

The Earth's crust is the uppermost layer of the lithosphere, which is the product of physicochemical evolution of the upper mantle during geological time. The Earth's crust - the transformed lithosphere - is the product of the interaction of the lithosphere with the atmosphere, hydrosphere and biosphere on the one hand, and the mantle - on the other.

In the process of geological history, the earth's crust gradually thickened and differentiated into oceanic and continental types. The upper part of the earth's crust is called the weathering crust. It is formed due to changes in rocks under the influence of mechanical and chemical action on them of various atmospheric factors, animals and plants. This process causes the destruction of rocks and their complete disintegration. Due to the activity of plant and animal organisms on the surface of the weathering crust humus is formed, ie the soil is formed.

There are three layers in the structure of the earth's crust: sedimentary, granite and basaltic.

The sedimentary layer consists of soft and mostly loose rocks formed by the deposition of matter by water and wind, as well as glaciers on the Earth's surface. Sedimentary rocks have a layered structure, their density varies from 1 to 2.65 g /cm^3. The thickness of the sedimentary layer varies from a few meters to 10-15 km. On the Earth's surface there are areas where the sedimentary layer is absent.

The granite layer is composed mainly of igneous and metamorphic rocks with an average silica content of more than 60 % and a density of 2.6–2.8 g /cm^3. The thickness of the granite layer is different. Its greatest power (50-70 km) under modern mountain ranges (Pamirs, Alps). Under oceanic depressions, such as the bottom of the Atlantic and Indian Oceans, this layer is either completely absent or its thickness is insignificant.

The basalt layer lies under the granite layer and has a thickness of 5–30 km. In terms of chemical composition and physical properties, the substance of this layer is close to basalts, ie to the main rocks, in which silica is contained much less than in granites. The density of the substance of the basalt layer increases to 3.32 g /cm^3. The lower limit is considered to be the limit of the earth's crust, which is sometimes called the limit of Mokhorovichich (the Yugoslav scientist who first established it).

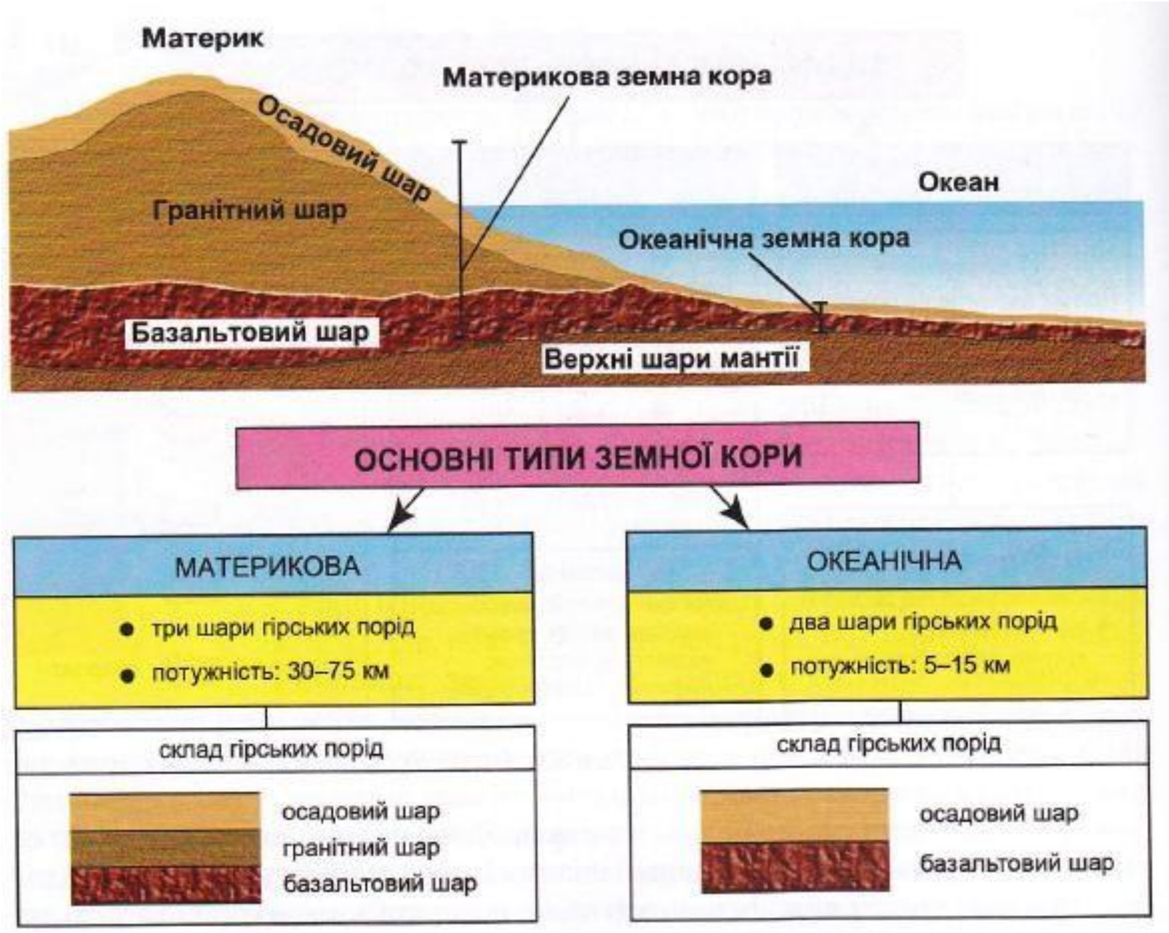

Fig. 2. The structure of the earth's crust

4. Thermal features of the Earth

Heat is of great importance in the life of our planet. The thermal regime of the Earth is due to two factors - the radiation of the Sun and the heat of the earth's interior. On the Earth's surface, the main source of heat is the Sun. Every minute 1 cm^2 of the Earth's surface receives about 8.13 J of heat (1.94 cal). The amount of solar heat is several thousand times greater than the heat that comes from the bowels of the Earth.

A third of the sun's radiant energy, which reaches the Earth's surface, is reflected into outer space. The amount of solar heat that enters the Earth and the amount of reflected energy are not the same for different latitudes. They depend on the nature of the distribution of water and land, on air and ocean currents, on the features of relief and vegetation.

Under the influence of solar heat, various processes take place: water cycle, weathering of rocks, soil formation and others. Thanks to solar energy, an organic world has emerged and is evolving.

The internal heat of the Earth (thermal field) is associated with sources of internal energy. It manifests itself on the surface in the form of volcanic eruptions, earthquakes, crustal movements, and others. Thus, deep heat is a catalyst for the intensity of all endogenous processes occurring in the bowels of the Earth.

The boundary of the distribution of zones of influence of external and depth factors of the thermal field is a layer *of constant temperature,* the depth of which in different regions of the planet varies considerably. Numerous studies in mines and wells have shown that below the *constant temperature* layer there is a natural increase in temperature with depth. However, the rate of change of this temperature in different regions of the Earth is not the same. This velocity is measured by the magnitude of **the geothermal gradient,** the essence of which is an increase in temperature by 1 ^{0}C with depth. The magnitude of this increase is small and is hundreds and thousands of degrees. Based on this, the geothermal gradient is mostly measured in ^{0}C per 100 m, which averages 3.3 ^{0}C. The second indicator that measures the rate of temperature rise with depth is **the geothermal degree.** *The geothermal degree* is the inverse of *the geothermal gradient*, the physical essence of which is the difference in depth, which corresponds to an increase in temperature by 1 ^{0}C. On average, it is assumed that the temperature rises by 10 C every 33 m.

The rate of temperature rise with depth in different regions of the planet can vary 10-20 times. Thus, in southern California, the geothermal degree is 4 m, and in Alabama - 137 m. The minimum increase in temperature with depth is characteristic of regions with the development of ancient geological structures (platforms), and the maximum - mobile folded regions and especially areas with young volcanism.

The inconsistency of the rate of temperature rise with depth is explained by the change in the thermal conductivity of rocks and the uneven flow of heat from the depth. An indisputable factor in the formation of the Earth's internal heat is both the radioactive decay of chemical elements and the gravitational separation of the substance of the Earth's core.

The Earth's thermal field, especially its deep component, plays an extremely important role in geological processes, as a result of which significant masses of igneous and metamorphic rocks and various mineral ores are formed. Phenomena such as earthquakes, volcanic eruptions, crust formation in the earth's crust, etc. are connected with the internal thermal energy of the Earth. Based on the study of the thermal field, a method of search and exploration of minerals was developed, which was called **thermometry.**

Questions for self-preparation

1. Briefly describe the position of the Earth and the solar system in space.
2. What is the essence of the cosmological hypotheses of Kant, Laplace, Schmidt, Fesenkov?
3. Which planets belong to the terrestrial planets?
4. Give a general description of the planet Earth (shape, size, structure).
5. Name and describe the outer spheres of the Earth.
6. Name and describe the inner spheres of the Earth.
7. Earth's crust, its structure and physical properties.
8. What is called a geothermal degree and a geothermal gradient?