MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
ODESSA STATE ECOLOGICAL UNIVERSITY

GUIDELINES

for the laboratory work
"**Introduction to the main rock-forming minerals and their physical and chemical properties**"
on the subject
"**Geology with Basics of Geomorphology**"

Odessa – 2024

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"**GEOLOGY WITH BASICS OF GEOMORPHOLOGY**"

for first-year students
Specialty 101 "Ecology"

«APPROVED»
at the meeting of the specialty support group
specialty 101 "Ecology"
Protocol No. __ dated "__" ________20__ year
Chairperson of the group _Chugai A.V.

«APPROVED»
at the meeting of the Department
of Hydroecology and Water Research
Protocol No. __ dated "__" __________2024
Head of the Department Loboda N.S.

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Guidelines for conducting the laboratory work "Introduction to the main rock-forming minerals and their physical and chemical properties" on the subject "Geology with Basics of Geomorphology" / Kuza A.M., Loboda N.S. / - Odessa, OSEU, 2024. - 39 p.

The guidelines are intended for first-year students of specialty 101 "Ecology", educational program "Ecology, Environmental Protection and Balanced Nature Management".

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Introduction

Mineralogy is the science of minerals, which studies the properties of minerals that make up the Earth's crust and the various processes of their formation. A mineral is a natural formation composed of one or more chemical elements, possessing specific physical properties, and remaining stable under certain natural conditions. Minerals are formed through physicochemical processes deep within the Earth and on its surface. Most minerals are solid substances (such as quartz, feldspar, etc.), but there are also liquid minerals (mercury, water, oil) and gaseous ones (carbon dioxide, hydrogen sulfide, etc.). It is one of the oldest branches of geological knowledge, originating in the Stone Age when early humans learned to distinguish and seek out stones suitable for making weapons and ornaments, such as jade, flint, etc. The first attempts to classify minerals trace back to Aristotle. The development of mineralogy is closely linked to the development of mining. Mineralogical research draws upon chemistry, crystallography, physics, and geology.

The objective of the laboratory work is to acquire initial knowledge about the chemical composition of the Earth's crust - minerals and rocks, as well as their formations, and to examine the most important patterns of geological processes, structural elements of the Earth, and the composition of the lithosphere.

As a result of completing the laboratory work, students should be familiar with minerals, their classification, properties, and practical applications.

LABORATORY WORK №4

4 INTRODUCTION TO MAJOR ROCK-FORMING MINERALS AND THEIR PROPERTIES

4.1 The distribution of minerals in the Earth

There are currently 92 chemical elements known to exist in the Earth's crust. Chemical elements have varying distributions and significance in the composition of the Earth's crust, as evidenced by Table 4.1 provided.

From the table, it can be seen that the Earth's crust consists of the 10 most abundant chemical elements, while the rest of the chemical elements together constitute about 0.5%.

Table 1 - Average Composition of the Earth's Crust (in weight %) (according to Vinogradov O.P.)

№	Chemical Elements	Weight Percentage
1	Oxygen	47.00
2	Silicon	29.50
3	Aluminum	8.05
4	Iron	4.65
5	Calcium	2.96
6	Sodium	2.50
7	Potassium	2.50
8	Magnesium	1.87
9	Titanium	0.45
10	Phosphorus	0.09
Other elements		0.43
		100%

Most chemical elements in the Earth's crust form compounds with other elements, only a few of them - such as gold, platinum, silver, copper, diamond, graphite, sulfur, and others - occur in pure native form. As a result of various chemical transformations, elements combine and form minerals that make up the Earth's crust. Hence arises the definition of the concept of "mineral."

A mineral is defined as a natural chemical compound of elements (or a native element) formed as a result of certain physicochemical processes occurring in the Earth's crust or on its surface.

Minerals in the Earth's crust do not form large independent geological bodies, but individual minerals are observed in nature, which in their pure form constitute bodies such as ice in glaciers, halite in salt deposits, calcite in marble deposits, and others. In these cases, the mentioned minerals form monomineralic rock formations.

4.2 Mineral Properties

Out of the total number (almost 2500) of known minerals, only about 50 are of significant importance, participating in the formation of rock formations; these are called rock-forming minerals. Each mineral possesses certain physical properties that arise from the characteristics of its internal structure. Physical properties enable the distinction of minerals from one another.

The physical properties of minerals include:

Color - a physical characteristic of minerals (the first thing observed by an observer). However, the same mineral species may have different colors (Fig.4.1). For example, quartz can be colored purple, dark, pink, white, or gray, but it can also be colorless and transparent. Due to color variability, color may not always be a distinctive feature of minerals. Only certain minerals have consistent coloring. For example: green - malachite, red - cinnabar, etc.

The color of minerals depends on their chemical impurities - pigments. For example, corundum (Al_2O_3) in its pure form is colorless and transparent, but when it contains Cr_2O_3 impurities, it turns red (ruby), and Ti impurities give it a blue color (sapphire).

Figure 4.1 – A variety of mineral colors

Streak color. Many minerals, when ground into powder, have a different color than their solid crystal or piece. Pyrite, for example, appears golden-yellow in its solid form but almost black as a powder. To determine the streak color of a mineral, it is repeatedly drawn across the unglazed surface of a porcelain plate (fig.4.2).

Figure 4.2 - Mineral streak colors

Luster. Most minerals exhibit a luster when viewed in reflected light. Only some, mostly amorphous ones, have a dull surface. The luster of minerals is determined by comparison with the characteristic luster of familiar substances. There are two types of luster: metallic and non-metallic.

Metallic luster - the mineral shines similarly to a polished surface of steel, silver, platinum, and other metals. Minerals such as pyrite, galena, and others have a metallic luster.

Non-metallic luster can be:

a) *Vitreous luster* - the surface of minerals shines like the surface of window glass or a bottle. Many minerals exhibit this luster, including halite, gypsum, quartz, topaz, olivine, feldspar, and others.

b) *Pearly luster* - the mineral shines like mother-of-pearl with a rainbow iridescence, which occurs when light is reflected from thin surface layers. Examples include talc, muscovite, orthoclase, anorthite, gypsum, and others.

c) *Silky luster* - characteristic of minerals with a fibrous structure resembling the sheen of silk threads, such as asbestos, satin spar, fibrous varieties of gypsum, and others.

d) *Dull luster* - minerals with a porous, earthy surface do not shine.

e) *Greasy luster* - the mineral shines like a surface smeared with grease. Minerals such as sulfur, opal, quartz in fracture, nepheline, and others exhibit this luster.

Hardness - is conveyed by the ability of minerals to resist scratching and abrasion. In determining hardness, the Moos scale is used, which includes 10 minerals. The ordinal number of the mineral on the scale determines its hardness in units. The hardness scale includes minerals arranged in increasing order of hardness (Fig.4.3):

1) Talc;
2) Gypsum;
3) Calcite;
4) Fluorite;
5) Apatite;
6) Orthoclase feldspar;
7) Quartz;
8) Topaz;
9) Corundum;
10) Diamond.

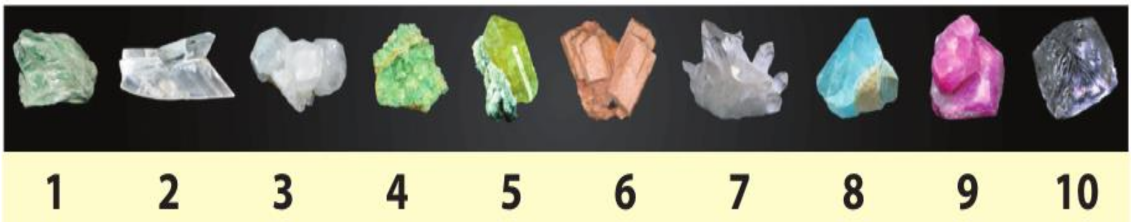

Figure 4.3 - The Moos scale of hardness

The sequence for determining the hardness of minerals is as follows: a smooth surface is selected on the mineral being tested, then the minerals of the scale are sequentially scratched on it. Suppose the first three do not leave any scratches, but the fourth (fluorite) does leave a scratch on the tested mineral. Based on this, it is determined that our mineral has a hardness of 3. If the tested mineral leaves a scratch on gypsum, which has a hardness of 2, this definitively indicates that the tested mineral has a hardness of 3.

Harder minerals have a greater density of packed atoms in their spatial lattices. They are generally more resistant to processes of solubility and chemical decomposition. This distinct property of mineral hardness significantly influences the development of the Earth's surface relief and the chemistry of surface and groundwater. Rock formations composed of harder minerals form positive elements of relief, while those consisting of relatively softer minerals create negative relief features.

Cleavage - is characteristic only of crystalline substances. Cleavage refers to the ability of crystalline minerals to split along specific planes. The directions of easiest cleavage in minerals are called cleavage planes.

Cleavage can be:

a) *Perfect cleavage* is manifested in minerals easily splitting into sheets or breaking into fragments with evenly distributed flat surfaces. The first case of perfect cleavage is typical in micas, and the second is seen in halite, calcite, adenate, and others.

b) *Good cleavage* - when minerals break into fragments with both smooth and rough surfaces upon crushing. Feldspars, hornblende, fluorite, and others exhibit this type of cleavage.

c) *Poor cleavage* - the flat surfaces of the break when minerals are crushed are barely discernible or entirely absent. Minerals such as apatite, quartz, pyrite, and others have this type of cleavage.

d) *Some minerals lack cleavage* altogether; in this case, it is referred to as complete lack of cleavage. Examples include milky-white quartz and gold.

Cleavage is closely related to the internal structure of crystals and is explained by the presence of planes between which the attractions are minimal due to the considerable distance between atoms or ions. As a result, fractures along these planes occur more easily in minerals than in any other direction. The nature of cleavage is an important distinguishing feature of minerals.

Fracture - is the surface characteristic obtained during the crushing of minerals. When minerals with perfect cleavage are broken, flat surfaces are formed. Different fracture surfaces are formed in amorphous minerals or minerals with imperfect cleavage.

Minerals are characterized by the following types of fractures:

a) *Conchoidal* - the fracture surface of the rock resembles the surface of a shell with concentric growth zones. This type of fracture is characteristic of amorphous and cryptocrystalline minerals such as obsidian, opal, quartz, and others.

b) *Earthy* - the surface is rough and porous, similar to lumps of soil. Minerals such as limonite, kaolin, chalk, bauxite, and others have this type of fracture.

c) *Granular* - crystalline aggregates of minerals, for example, marble.

d) *Fibrous (splintery*) - sharp needles are present on the fracture surface, for example, in fibrous gypsum (selenite), fibrous hornblende.

The density for different minerals varies from 0.9 to 19 (see table 4.2). The exact determination of density is possible only under laboratory conditions by weighing on hydrostatic balances and other methods. In practice, for a quick approximate determination of density, minerals are weighed by hand (assessment - "high," "medium," "low" density). The density of minerals is of great importance in the transportation by water streams. Minerals of low density are carried over long distances, while those of high density settle earlier. Consequently, during the transportation of minerals, they are sorted by density, leading to the natural enrichment and formation of placers of valuable minerals such as gold, platinum, cassiterite, wolframite, and others.

Table 4.2 - Density of Some Minerals

Minerals of low density, up to 3	Minerals of medium density, from 3 to 5	Minerals of high density, over 5
Ice 0.91	Fluorite 3.25	Galena 7.50
Gypsum 2.30	Barite 4.50	Cinnabar 8.00
Quartz 2.65		Gold 19.0

Magnetism. Some minerals possess magnetic properties, meaning they either act on a magnetic needle or are attracted to a magnet themselves. Due to this, magnetism is an important characteristic for them. Minerals characterized by magnetic properties include magnetite Fe3O4, pyrrhotite FeSnS, native platinum with iron impurities. Certain minerals exhibit specific properties; for instance, carbonates react with weak (5-10%) hydrochloric acid, producing bubbles of CO2, and many sulfides fizz with the formation of carbon disulfide, easily detectable by its characteristic odor.

Some water-soluble salts can be identified by taste. Using this characteristic, it is easy to distinguish, for example, sylvite from halite. The former has a bitter-salty taste, while the latter is simply salty.

In nature, conditions of crystallization where material flow occurs evenly from all sides are rare, so perfect crystals are seldom encountered. More commonly, minerals exist as crystalline aggregates and aggregates.

Crystalline aggregates represent the clustering of mineral grains of various shapes, depending on the internal structure of the mineral and the shape of the space in which its crystallization occurred. Among crystalline aggregates, the following forms are distinguished by shape: granular (pyrite, rock salt), columnar (selenite), acicular (hornblende), fibrous (asbestos), platy (gypsum), scaly (graphite).

Minerals in nature are found in the form of dendrites, druses, secretions, concretions, infiltrations, crusts.

Dendrites are treelike crystal growths formed during rapid crystallization or in thin cracks. Examples include ice dendrites on window glass in winter, clays, limestones, dendrites of native copper, gold, silver, and others.

Druses or crystal "children" are crystal growths attached at one end to a common base, limiting them to free ends only; druses may contain quartz, calcite, fluorite, gypsum, and others.

Secretions are voids in solid rock formations, completely or partially filled with mineral material. Large secretions with a cavity inside are called geodes. Secretions have a concentric structure, and their mineral filling occurs from the periphery to the center.

Concretions are concretions of spherical or irregularly rounded shape, formed during the deposition of mineral material around any centers of crystallization, often resulting in a radial structure. Concretions are typical for minerals such as phosphorite, pyrite, siderite, and others.

Unlike secretions, concretions grow from the center outward. Oolites resemble concretions in their structure - shallow (up to 10 mm in diameter) rounded formations with a concentric structure formed by the precipitation of mineral material from aqueous solutions.

Oolites are most often composed of calcite, manganese oxide, and brown ironstone.

4.3 Classes of Minerals

Each mineral is characterized by its chemical composition. The physical properties, practical significance, and behavior of minerals in various geological conditions primarily depend on their chemical composition. The chemical composition of minerals is expressed by ordinary chemical formulas. Knowing the chemical formula of a mineral makes it easy to predict all of its properties.

For convenience in studying and practical use, minerals, like other natural formations, are divided into classes and groups. The classification is based on chemical properties, composition, and origin of minerals. Taking into account notable features, *all minerals can be divided into nine classes*:

1) Native elements;
2) Sulfides;
3) Halide compounds;
4) Oxides and hydroxides;
5) Silicates;
6) Carbonates;
7) Sulfates;
8) Phosphates;
9) Carbon compounds.

Native Elements. Minerals in this class consist of a single chemical element. They are not widely distributed (except for graphite and sulfur) but are very important practically. Native element minerals include platinum Pt, gold Au, silver Ag, diamond C, graphite C, sulfur S, copper Cu, and others.

Sulfides. This class includes minerals that are primarily compounds of heavy metals with sulfur. They are not rock-forming minerals but are of great interest as ores of colored and black metals. The most common minerals of this class include pyrite FeS2 (iron or sulfur pyrite), galena PbS, sphalerite ZnS, chalcopyrite CuFeS2, cinnabar HgS.

Halide Compounds. Minerals in this class are salts of halogen acids (HCl, HF, etc.) in chemical terms. Their role as rock-forming minerals is small, but they are important in general geological and practical terms. Typical minerals of this class include halite (rock salt) NaCl, sylvite KCl, fluorite CaF2.

Oxides and Hydroxides. Minerals in this class are compounds of elements with oxygen and the hydroxyl group OH. They are widespread in the Earth's crust and make up about 17% of its mass. Let's consider the most important among them.

Quartz SiO2 is the most common rock-forming mineral, accounting for 12% of the Earth's crust. Chemically, it is classified as an oxide, and structurally, as a silicate. Varieties of quartz differ in color:

1) Rock crystal - colorless and transparent;
2) Amethyst - purple;
3) Morion - black;

4) Milky quartz - white;

5) Ordinary quartz - gray, and so on.

Chalcedony SiO_2 is a cryptocrystalline variety of quartz. Chalcedony usually contains various impurities, so it has many varieties, including:

1) Carnelian - contains clay-iron impurities;

2) Jasper - similar impurities but typically has a colored, even, or mottled appearance, making it widely used as a gemstone;

3) Agate - banded chalcedony.

Hematite (red iron ore) Fe_2O_3, while not significant as a rock-forming mineral, occurs as impurities in many rocks, ranging from a fraction of a percent to several percent. Uniformly dispersed particles in sedimentary rocks (clays, sand, sandstone, limestone, etc.) color these rocks red or reddish.

Magnetite (magnetic iron ore) Fe_3O_4 is a mineral in basic igneous rocks Fe_3O_4, Fe_2O_3, FeO, richer in iron than hematite, and exhibits magnetic properties.

Corundum Al_2O_3, while not significant as a rock-forming mineral, includes red corundum called ruby and blue corundum called sapphire. A fine-grained aggregate of corundum with impurities such as quartz, hematite, and others is called emery.

From the hydroxide group, the most common is goethite, or limonite $Fe_2O_3 \cdot nH_2O$, a complex mineral aggregate closely related in composition to minerals. Therefore, it can be conditionally classified as a class of water oxides. Goethite is scattered as impurities in sedimentary rocks and, depending on concentration, imparts various colors such as yellow, yellow-brown, brown, etc., often acting as cement in rocks like sandstones and conglomerates.

Opal $SiO_2 \cdot nH_2O$ is a hydrated silicon oxide. In some cases, it is a rock-forming mineral and is the main component of rocks such as geyserite, tufa, and diatomite.

Carbonates. Minerals of the carbonate class are salts of carbonic acid H_2CO_3. They are widespread in the upper parts of the Earth's crust. Representatives of carbonates include calcite $CaCO_3$, magnesite $MgCO_3$, dolomite $CaMg(CO_3)_2$, siderite $FeCO_3$, malachite $Cu(OH)_2CO_3$.

Sulfates. This class includes minerals such as gypsum $CaSO_4 \cdot 2H_2O$, and barite $BaSO_4$. Long fibrous varieties of gypsum, sometimes called selenite (moonstone), are occasionally encountered. Fine-grained masses of ordinary gypsum are called alabaster.

Barite $BaSO_4$ is characterized by high density compared to other non-metallic minerals (4300-4600) and is found among sedimentary rocks along with calcite and other minerals.

Phosphates. Phosphates are salts of orthophosphoric acid H_3PO_4. Among the many minerals in this class, apatite and phosphorite are particularly important as rock-forming minerals and raw materials for fertilizer production. Apatite $Ca(Cl,F)(PO_4)_3$ is the most common mineral in this class. Phosphorites are marine sedimentary formations, chemically similar to apatite, primarily composed of

$Ca_5(Cl,F)(PO_4)_3$ with impurities of carbonates, clays, and other substances. They usually form radially fibrous and cryptocrystalline concretions.

Silicates. Minerals of this class are the most widespread, constituting over 75% of the Earth's crust by mass. Silicates are the main rock-forming minerals and are present in most types of rocks. It is now established that in all silicates, each silicon ion $(SiO_4)_4$ is connected to four oxygen ions. The basic structural unit of silicates is the silicon-oxygen tetrahedron, with four oxygen ions positioned at the vertices and a silicon ion at the center.

The silicon-oxygen tetrahedron has four free valence bonds, through which ions of other chemical elements and silicon-oxygen tetrahedra can be attached. Silicate classification is based on the method of tetrahedron linkage. Silicon-oxygen tetrahedra can be isolated from each other or connected through shared ions via tetrahedral vertices, forming complex anionic radicals. Sometimes the tetravalent silicon ion can be replaced by a trivalent aluminum ion. Compounds in which aluminum, together with silicon, plays the role of the oxygen element, are called aluminosilicates, as proposed by Academician V.I. Vernadsky, which include feldspars, for example.

In chemical terms, silicates are salts of various silicic acids. Important silicic acids include: orthosilicic acid H_4SiO_4, metasilicic acid H_2SiO_3, and aluminosilicic acid $H_2Al_2Si_2O_8$. In aluminosilicic acid, aluminum, together with silicon, acts as the acidic element. Let's consider the main minerals of this class: olivine, augite, hornblende, feldspars, kaolin, and micas.

Olivine $(Mg,Fe)_2SiO_4$ is an iron-magnesium-rich, poor silicate, characteristic of basic and ultrabasic volcanic rocks.

Augite $Ca(Mg,Fe,Al)_2(Si,Al)_2O_6$ is a mineral of complex and variable chemical composition. In the structure of augite, aluminum occupies the center of oxygen tetrahedra, replacing silicon. It is an important rock-forming mineral found in rocks such as basalt, gabbro, and diabase.

Hornblende. Its composition is quite variable and can be expressed by the formula $(CaNa)_2(Fe^{2+},Fe^{3+},Mg,Al,Mn,Ti)$, $(Fi,OH_2)_2$.

Feldspars are aluminosilicates with many varieties, among which the main ones are orthoclase $K[Al\ Si_3O_8]$, albite $Na[Al\ Si_3O_8]$, and anorthite $Ca[Al_2Si_2O_8]$. Albite and anorthite are similar in their crystal-chemical structure and often crystallize together, forming a group of minerals called plagioclase. The content of albite (Ab) and anorthite (An) in plagioclases ranges from 0 to 100%. The composition of plagioclases is determined by the formula r. Ab q. An; r and q represent the percentage content of albite and anorthite in the plagioclase of a given composition.

Feldspars are the most common minerals in the Earth's crust (about 50%). They are the main components of rocks such as granite, syenite, diorite, gabbro, basalt, gneiss, and others.

Kaolinite $Al_4(OH)_8[Si_4O_{10}]$ is formed by the chemical decomposition of feldspars and is a component of clays. Earthy fluffy masses of kaolinite are called kaolin (china clay).

Micas are part of many volcanic and metamorphic rocks. They have perfect cleavage in one direction, which makes them easily split into very thin sheets. Muscovite and biotite have significant geological importance.

Muscovite KAl2(F,OH)2[HSiO10] is a colorless or slightly tinted transparent potassium mica. A fine scaly variety of muscovite is called sericite. Muscovite is found in granites, syenites, diorites, and mica schists.

Biotite K(Mg,Fe2+, Fe3+, Al)3(OH,F)6[Al Si3O10] is a magnesium-iron mica of greenish or brownish-black color. It occurs in granites, syenites, diorites, and mica schists.

Talc Mg(OH)2[Si4O10] is often a rock-forming mineral and is a major component of talc schists.

Serpentine Mg6(OH)8[Si4010], differs from talc only in its higher magnesium content and lower silicon content. A rock composed of serpentine is called serpentinite (from "serpens" meaning serpent), as it often has a green color. The fibrous variety of serpentine is called asbestos.

Carbon compounds. This class includes mineral formations that represent substances of animal and plant origin that have undergone physical and chemical changes. According to chemical characteristics, mineral carbon compounds can be divided into three groups: 1) hydrocarbons; 2) natural resins; 3) fossil coal.

Hydrocarbons include petroleum and mineral wax (ozocerite). The latter forms through the natural solidification of petroleum and consists of 84% carbon and 16% hydrogen.

Natural resins include amber C10H16O (fossil resins of tertiary coniferous plants) and asphalt - a product of natural solidification and oxidation of petroleum.

Fossil coal consists of altered plant remains enriched with carbon. It includes peat, lignite, bituminous coal, and anthracite. They are essentially rock formations and will be considered in the section on sedimentary rocks.

4.4 Task for laboratory work:

1. Determine the physical properties of 4-5 mineral samples using a mineral identification guide.
2. Briefly explain the theoretical part, basic principles, and definitions.
3. Describe the physical properties of two to four mineral samples.

4.5 Self-assessment questions:

1. Define the concepts of "mineralogy" and "mineral."
2. What factors determine the physical and chemical properties of rocks and minerals?
3. Provide a general overview of endogenic and exogenic processes in mineral formation.
4. How is the hardness of minerals determined? What is the Mohs scale?
5. What are cleavage and fracture? What types are encountered?

6. What forms of minerals are known in nature?
7. Mineral classes
8. Determine which class of minerals is the most common. Explain why.
9. Which minerals belong to the class of native elements?
10. Name 10 primary chemical elements that make up the Earth's crust, indicating the percentage content of the top 3 chemical elements.

TESTS:

1. Diagnostic features of minerals are:
A) characteristics specific to that mineral;
B) physical properties of minerals;
C) chemical properties of minerals;
D) origin of minerals.

2. Which chemical element of the Earth's crust has the highest percentage content:
A) silicon;
B) iron;
C) gold;
D) nickel.

3. The hardness of minerals is determined by a scale called:
A) Mohs;
B) Clarke;
C) Moho;
D) Haina.

4. Obsidian is a rock of:
A) igneous origin;
B) hydrothermal origin;
C) effusive origin.

5. Which layer of the Earth is called the "lithosphere"?
A) Earth's crust;
B) mantle;
C) core;
D) asthenosphere.

6. Halite belongs to:
A) carbonates;
B) aluminosilicates;
C) halide compounds.

7. Minerals composed of a single chemical element are called:
A) native elements;
B) silicates;
C) carbonates;
D) clarkes.

8. Limonite is a:
1. Carbonate mineral;
2. Sulfate mineral;
3. Hydroxide.

9. The most common class of minerals is:
A) carbonates;
B) silicates;
C) sulfates;
D) nitrates.

10. Formation of icicle-like structures hanging from the ceiling of a cave downward is called:
1. Stalagmite;
2. Stalactite;
3. Pegmatite.

4.6 Task for laboratory work "minerals" (for distance learning.)

The sequential number corresponds to the variant number.

Minerals should be characterized (described) according to the scheme you have in the "IDENTIFIER," which is in the GEOLOGY PRACTICUM and in the MUDL program in the laboratory work "Minerals" at the end of the topic.

Be sure to indicate which class the mineral belongs to.

Upload the work to the PROGRAM.

1. Biotite, sulfur, talc, microcline, diamond.
2. Chlorite, serpentine, labradorite, pyrite, quartz.
3. Corundum, chalcopyrite, muscovite, asbestos, topaz.
4. Kaolinite, nepheline, olivine, augite, phosphorite.
5. Garnet, orthoclase, hornblende, apatite, gypsum.
6. Siderite, halite, limonite, biotite, albite.
7. Tourmaline, opal, fluorite, calcite, talc.
8. Labradorite, limonite, anhydrite, kaolinite, chlorite.
9. Garnet, phosphorite, asbestos, anorthite, glauconite.
10. Sulfur, pyrite, labradorite, orthoclase, gypsum.

11. Halite, limonite, opal, chalcopyrite, corundum.
12. Quartz, garnet, hematite, kaolinite, graphite.
13. Halite, labradorite, fluorite, quartz, chalcopyrite.
14. Kaolinite, hornblende, tourmaline, garnet, anhydrite.
15. Gypsum, alabaster, dolomite, Iceland spar, fluorite.
16. Calcite, marcasite, limonite, corundum (red), halite.
17. Asbestos, serpentinite, garnet, phosphorite, apatite.
18. Olivine, calcite, corundum (blue), marcasite, hornblende.
19. Talc, apatite, tourmaline, anhydrite, gypsum.
20. Fluorite, limonite, corundum (fine-grained), quartz, halite.
21. Diamond, nepheline, biotite, kaolinite, serpentinite.
22. Talc, garnet, apatite, tourmaline, diamond.
23. Topaz, labradorite, microcline, muscovite, asbestos.
24. Corundum (blue), orthoclase, chlorite, muscovite, pyrite, garnet.
25. Diamond, labradorite, muscovite, kaolinite, tourmaline.

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SUPPLEMENTS

SUPPLEMENT A
MINERAL IDENTIFICATION

Mineral identification is conveniently initiated with hardness as a constant value for most minerals, independent of the size of the specimens or the grain size in the rock (Table A.1).

Table A.1 - Basic mineral properties determined by hardness

<table>
<tr><th>№</th><th>Hardness</th><th>Luster</th><th>Characteristic Features</th><th>Serial number in Table A.2</th></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td rowspan="5">1</td><td rowspan="5">Minerals with a hardness up to 2 inclusive</td><td>With metallic luster</td><td>Stains hands, not flexible</td><td>№.1</td></tr>
<tr><td rowspan="2">With vitreous or silky luster</td><td>Perfect cleavage, colorless, flexible sheets by cleavage</td><td>№.20</td></tr>
<tr><td>Green, mica-like, flexible sheets by cleavage</td><td>№.35</td></tr>
<tr><td>With greasy luster</td><td>Soap-like to the touch</td><td>№.29</td></tr>
<tr><td>Dull, white</td><td>Earthy, with water plastic</td><td>№.32</td></tr>
<tr><td rowspan="6">2</td><td rowspan="6">Minerals with a hardness above 2 up to 3 inclusive</td><td>With a greasy luster on fracture</td><td>Yellow with a shell-like fracture</td><td>№ 2</td></tr>
<tr><td rowspan="5">With a glassy or pearly luster</td><td>Green, fine grains, green streak</td><td>№. 36</td></tr>
<tr><td>Black, cleaves into thin flakes</td><td>№. 34</td></tr>
<tr><td>Light, cleaves into thin flakes</td><td>№. 33</td></tr>
<tr><td>Salty to the taste</td><td>№. 14</td></tr>
<tr><td>Effervesces with diluted hydrochloric acid</td><td>№. 16</td></tr>
</table>

Continuation of Table A.1

1	2	3	4	5
3	Minerals with a hardness **greater than 3 up to 4, inclusive**	***With metallic luster***	Golden-yellow, streak greenish-black	№ 5
		With a glassy, silky, or pearly luster	Green, mottled	№30
			Greenish-white, fibrous	№31
			White, effervesces in heated hydrochloric acid	№17
			Purple, green, blue, transparent, cubic crystals	№15
			White, blue, perfect cleavage, granular	№21
			Effervesces in hydrochloric acid when powdered	№18
			Yellowish-brown, effervesces in heated hydrochloric acid, turning yellow on the surface	№19
4	Minerals with a hardness **greater than 4 up to 5 inclusive**	***With greasy or vitreous luster***	Yellow and greenish, transparent	№22
		With dull earthy or greasy luster	Brown, opaque, granular	№23
5	Minerals with a hardness **greater than 5 up to 6 inclusive**	***With metallic or dull luster***	Black streak, magnetic properties	№10
			Yellow-brown streak, rust-yellow	№13
			Reddish streak, cherry-brown	№9
		With greasy or silky luster	Subdued sheen, translucent	№12
			Greasy, oily luster	№42

Continuation of Table A.1

1	2	3	4	5
			Greenish or brown streak, perfect cleavage, splintery fracture	№28
		With vitreous luster	Dark green, black, grayish-green streak	№27
			Gray, iridescent in blue-green and bluish tones	№41
			Greenish-gray, yellowish-green, pink, light streak	№38
			Yellowish, pink, flesh-red, rectangular fractures along cleavage	№37
			White, rhombic fractures along cleavage	№39
			Gray, dark gray, yellowish, oblique angles along cleavage	№40
	Minerals with a hardness **between 6 and 7 inclusive**	***Minerals with metallic luster***	Cubic, golden crystals, grayish-green streak. (No. 3)	№3
			Radiating growths of dark golden color	№4
		Minerals with greasy or glassy luster	Hidden crystalline structure, appearing as grains and tabular forms, weakly translucent, sometimes streaked	№7
			No cleavage, greasy luster on fracture, glassy luster on faces, conchoidal fracture	№6
			Dark green small grains.	№24
		With a dull luster	Various colors, conchoidal fracture	№8

Continuation of Table A.1

1	2	3	4	5
	Minerals with a hardness **greater than 7.**	-	Hardness 7.5, dark-red color, multifaceted	№25
		-	Green, pink, black; columnar, trigonal, prismatic crystals with longitudinal streaks	№26
		-	Hardness 9.0, barrel-shaped crystals, streaks on cleavage planes, fine-grained, dark	№11

As seen from Table A.1, minerals are divided into seven groups based on their hardness. Within each of the first six groups, minerals are further categorized into smaller subgroups based on their luster, with each mineral assigned a specific number against which the most characteristic features distinguishing that mineral from its neighbors in the subgroup are indicated.

The approximate process of identifying a mineral is as follows: first, the hardness of the mineral is determined, let's assume it is 3. Therefore, the mineral belongs to the second group based on hardness, that is, to the group of minerals with a hardness of 2-3. Then, the luster of the mineral is determined. To do this, a fresh fracture surface is required. Let's assume the mineral has a glassy luster. We refer to subgroup 2 (minerals with glassy or pearly luster). In this subgroup (see Table A.1), there are five numbers: №36, №34, №33, №14, №16, each of which has certain characteristic properties. For example, for №36, the characteristic features are green color and green streak; for №34, black color and the ability to cleave into thin sheets; for №33, light color and cleavage into thin sheets; for №14, salty taste; for №16, effervescence with weak hydrochloric acid.

It turns out that the identified mineral is not salty and does not cleave into sheets, but effervesces vigorously with weak hydrochloric acid on the fresh surface. A mineral with such properties has №16. Next, we proceed to Table A.2, where the main rock-forming minerals are classified into mineralogical classes, and under this number, we find that this mineral is calcite. By determining all the other properties of the mineral according to the scheme indicated in Table A.2, we finally confirm the correctness of our characterization. A complete mineral characterization according to this scheme includes: name, chemical composition, hardness, luster, color, streak color, cleavage and fracture, crystal form, specific gravity, mode of occurrence in nature, and specific diagnostic properties.

Table A.2 - Key to Rock-Forming Minerals

S/N	Mineral, formula	Crystal form	Hardness / Specific gravity, g/cm3	Hardness Luster (L.) Color (C.) Streak color (SC.)	Cleavage and fracture	Diagnostic features	Origin	Practical
1	2	3	4	5	6	7	8	9
I Native elements								
1	Graphite, C	Hexagonal plates and flakes	1.0 / 2.2	L. – Metallic, greasy C. – Steel-grey to black SC. – Greyish-black, lustrous	Fine-grained, perfect cleavage in one direction	Greasy to the touch, stains hands, writes on paper.	Forms in igneous rocks, during reducing processes at high temperatures. Can be a product of coal metamorphism.	Manufacture of pencils, crucibles, electronic devices and more
2	Sulfur, S	Truncated tetrahedra, tetragonal crystals	1.5 / 2.0-2.1	L. – Greasy C. – Yellow SC. – Weak, pale-yellow	Conchoidal, earthy, imperfect cleavage	Soft, yellow to greenish-brown color. Becomes charged when rubbed, flammable.	Forms during the decomposition of sulfurous compounds in the presence of organic matter. Emanates from volcanic vents with vapor and hydrogen sulfide. Can be produced from	Used in rubber, chemical, textile (bleaching fabrics) industries, medicine, electrical engineering.

							the decomposition of sulfides.	
			II. Sulfides					
3	Pyrite (iron sulfide), FeS2	Cubic crystals	6.0-6.5 4.9-5.2	L. – Strong metallic C. – Straw-yellow, golden SC. – Greenish-black	Uneven, conchoidal, imperfect cleavage	Differs from chalcopyrite by its straw-yellow color, high hardness, and crystal form with striations on the faces.	Forms in contact-metamorphic rocks, from the decomposition of animal and plant remains in sedimentary rocks, during hydrothermal processes.	Production of sulfuric acid.
4	Marcasite (spear pyrite), FeS2	Radial-rayed aggregates, tabular or spear-shaped crystals and comb-like twins	6.0-6.5 4.5-4.9	L. – Metallic, dull C. – Pale greenish-yellow SC. – Greenish-gray	Uneven	Greenish tint on fresh fracture, crystals different from pyrite.	Forms from surface acidic and low-temperature hydrothermal solutions. Common in sedimentary rocks.	Production of sulfuric acid.
5	Chalcopyrite (copper pyrite), CuFeS2	Tetrahedra (individual crystals are rare)	3.5-4.0 4.1-4.3	L. – Strong metallic, sometimes with iridescent tarnish C. – Brass-yellow, greenish-	Uneven, very imperfect cleavage	Has a blue, pinkish-purple tarnish; distinguished from pyrite by hardness and color	The mineral has magmatic, hydrothermal origins. Found in cavities within pegmatites	The most important copper ore.

				golden SC. – Greenish- black				
				III. Oxides				
6	Quartz (Transparent rock crystal, violet amethyst, smoky quartz) Chemical Formula: SiO2	Elongated prismatic crystals with pyramidal terminations. Prism faces exhibit cross striations.	<u>7,0</u> 2,6	H. - Glassy on faces, greasy on fracture. C. - White, milky, pink, smoky, black. S. - No streak.*	Fracture: Conchoidal, no cleavage.	The characteristic features include the crystal shape, hardness, absence of cleavage, conchoidal fracture, and greasy luster.	The mineral originates from both magmatic and hydrothermal processes. It is commonly found in the cavities of pegmatites. During exogenic processes, it forms through the dehydration and recrystallization of silicon dioxide.	Transparent varieties are used in optical production and jewelry making, while massive ones find applications in metallurgical and glass industries.
7	Chalcedony, SiO2	Chalcedony does not form crystals.	<u>6,5</u> 2,6	B. - Cloudy, greasy, matte, waxy C. - Light gray, blue, smoky R. - Does not leave streaks	Conchoidal, no cleavage	Differs from similar opal and cryptocrystalline fluorite by hardness.	Forms during the crystallization of silicon dioxide, precipitates from low-temperature hydrothermal solutions.	Utilization of banded varieties (agate) in jewelry making, precision mechanics, and horology.
8	Flint SiO2 Al2O3	Does not form	<u>7,0</u>	B. – Matte,	There is no	Opaque,	Formed during	Used as an

		crystals".	2,6	hazy K. – From yellow to black, diverse R. – Doesn't take risks	cohesion, shell fracture	sparks when struck against steel, emits a distinctive odor.	sediment diagenesis, rock catagenesis, and weathering.	abrasive, in lighters.
9	Hematite (iron luster, cryptocrystalline, dull brown iron ore), Fe_2O_3	Flakes, plates, and rosettes	<u>5,5-6,5</u> 4,9-5,3	B. – Metallic in crystalline forms, metallic and dull in earthy forms K. – From reddish-brown to iron-black P. – Cherry-red, brown	Shell-like or earthy, no cohesion	Cherry-red and brown streak.	Forms in metamorphic rocks as a product of iron hydroxide dehydration. Sometimes - during hydrothermal processes and as a result of oxidation of magnetic iron ore.	High-quality iron ore.
10	Magnetite (magnetic iron ore), Fe_2O_4	Octahedral crystals, sometimes with streaks on the edges	<u>5,5-6,5</u> 4,9-5,2	B. – Metallic, dull K. – Iron-black P. – Black	Granular, imperfect cohesion	Strong magnetic properties (affects the compass needle).	A rock-forming mineral in basic igneous rocks. Also forms during contact metamorphism and hydrothermal processes.	High-quality iron ore.
11	Corundum	Uneven,	<u>9,0</u>	B. – Glassy	Barrel-shaped	High hardness.	Occurs in	Used for

	(red - ruby, blue - sapphire, dark fine-grained - whetstone),	occasionally on the rhombohedron, imperfect cohesion	3,9-4,0	K. – Blue, gray, brown P. – No streak or gives a white streak, scratches porcelain plate	and plate-like crystals, solid mass		metamorphic rocks, pegmatite veins, basic and alkaline igneous rocks.	metal polishing, as a whetstone (whetstone), transparent varieties - in jewelry.
Hydroxides								
12	Opal, $SiO_2 \cdot nH_2O$	Does not form crystals	5,5-6,5 2,2-2,3	B. – Greasy, dull, weakly glassy, pearlescent K. – White, yellow, gray, blue, semi-transparent P. – No streak or gives a white streak	Shell-like, no cohesion	Differs from chalcedony in lower hardness and greasy luster.	Forms from aqueous solutions of silica under near-surface conditions.	Noble opal - a gemstone.
13	Limonite (brown iron ore), $Fe_2O_3 \cdot nH_2O$	Does not form crystals	4,0-5,5 3,6-4,0	B. – Dull, semi-metallic K. – Rusty-yellow, brown, dark-brown P. – Yellowish-brown,	Earthy.	Rusty-yellow streak.	Forms in the weathering crust from other iron compounds, precipitates at the bottom of water bodies from solutions of various iron salts with the	Common iron ore.

				rusty-yellow			help of bacteria.	
IV. Halogen compounds								
14	Halite (rock salt), NaCl	Cubic crystals	2,5 2,1	B. – Glassy, greasy K. – White, colorless, bluish, pink, gray P. – White	Very perfect cleavage in three directions along the faces of the cube	Salty to taste, very perfect cleavage along the cube	Lagoonal-marine chemical sediment.	Used in chemical and food industries, metallurgy.
15	Fluorite (fluorspar), CaF_2	Cubic, octahedral crystals	4,0 3,0-3,2	B. – Glassy K. – Purple, yellow, green, pink, colorless P. – White, colorless	Perfect cleavage	Crystal form, weak glassy luster, cleavage, and hardness.	Forms during hydrothermal processes, sometimes in pneumatolytic veins together with beryl, tourmaline, topaz, and other minerals.	Production of hydrofluoric acid, use in metallurgy as a flux, transparent varieties - in optics.
V. Carbonates								
16	Calcite (limestone spar, transparent variety – Icelandic spar), $CaCO_3$	Rhombohedral and scalenohedral crystals	3,0 2,7	B. – Glassy, pearly K. – White, gray, yellow, blue, transparent P. – White	Very perfect cleavage in three directions along the rhombohedron	Perfect cleavage along the rhombohedron, low hardness, effervesces with dilute hydrochloric acid.	Forms during hydrothermal processes, as well as during weathering and sediment deposition.	Utilized in the production of lime; transparent varieties are used in optics.
17	Magnesite (magnesium spar), $MgCO_3$	Rhombohedral crystals are rare, occurs mainly in	3,5-4,5 2,9-3,1	B. – Glassy, silky, dull K. – White, gray,	Chalky or earthy in cryptocrystalline varieties, perfect	In powder, resembles chalk. Effervesces with heated	Forms during the metamorphism of basic	Refractory building material; in powdered

		massive form.		yellowish, creamy, brown P. – White	cleavage in crystalline forms.	hydrochloric acid.	magnesium-rich rocks, during hydrothermal processes and diagenesis of limestones, and through sedimentary accumulation. It is a product of weathering of magnesium-rich rocks.	form, it is used in medicine.
18	Dolomite (bitter spar), $CaCO_3 \cdot MgCO_3$	Distorted rhombohedral crystals are rare, occurs mainly in massive form.	<u>3,5-4,0</u> 2,8-2,9	B. – Glassy, pearly K. – White, yellow, gray, greenish P. – White	Perfect cleavage in three directions along the rhombohedron.	Effervesces in powder form with hydrochloric acid.	It forms as a product of the diagenesis of limestones under the influence of magnesium solutions. It is also formed during the metamorphism of sedimentary rocks.	It is used as a flux in metallurgy and as a building material.
19	Siderite (iron spar), $FeCO_3$	Flat and distorted rhombohedral crystals	<u>3,5-4,5</u> 3,7-3,9	B. – Glassy, pearly K. – Gray, pea-yellow, brown P. – White, sometimes	Perfect cleavage in three directions.	Decomposes with effervescence in heated hydrochloric acid, turning yellow	Forms during hydrothermal and metasomatic processes (due to solutions containing iron acting on	Valuable iron ore.

				brownish.		due to the formation of ferrous chloride.	limestones). It is also a product of sedimentary accumulation.	
VI. Sulfates								
20	Gypsum (light spar, white – alabaster, fibrous – selenite), $CaSO_4 \cdot 2H_2O$	Tabular, platy crystals, twins resembling "swallowtail", rosettes	2,0 2,3	B. – Glassy with a pearly sheen, silky in fibrous varieties, dull K. – Colorless (transparent), white, pink, yellow, gray P. – White	Prickly in fibrous varieties, very perfect cleavage in one direction.	Crystal form with very perfect cleavage in one direction and low hardness (can be scratched with a fingernail).	Chemical sediment.	Used in construction, sculptural work, and medicine.
21	Anhydrite (anhydrous gypsum), $CaSO_4$	Small tabular crystals	3,0-3,5 2,8-3,0	B. – Glassy, with a pearly sheen K. – White, grayish, blue, pink P. – White	Granular, perfect cleavage in three mutually perpendicular directions	Cannot be scratched by a fingernail like gypsum, and unlike calcite, does not react with acids.	Forms through sedimentary processes.	Used in the production of special cement, artistic products.
VII. Phosphates								
22	Apatite (fluorapatite and chlorapatite), $Ca_5(F,Cl)$ $[PO_4]_3$	Hexagonal prisms, sometimes tabular crystals	5,0 3,2	B. – Glassy on faces, greasy on fracture, fine-grained masses	Uneven, conchoidal, imperfect cleavage	Characterized by crystal habit and a hardness of 5. Insoluble in hydrochloric acid.	A rock-forming mineral in igneous rocks, also formed at the contact of volcanic rocks	Utilized in the production of mineral phosphorus fertilizers.

				exhibit strong sugary luster K. – Sometimes colorless, green, yellowish, white, bluish-green, and brownish-green P. – White			with limestones.	
23	Phosphorite, Ca5(F,Cl)[PO4]3 with impurities of clay and sand.	Does not form crystals.	5,0 3,2	B. – Dull, earthy K. – Pale yellowish, gray, brown P. – Gray, weak	No cleavage	Characteristic nodules, concretions with a radial structure, emits a characteristic odor.	Formed by sedimentary processes from phosphorus residues of ancient organisms.	Utilized in the production of mineral phosphorus fertilizers.
VIII. Island Silicates (Orthosilicates)								
24	Olivine (peridot), (Mg,Fe)2 [SiO]4	Crystals are rare, usually grains	6,5-7,0 3,3-4,1	B. – Glassy, transparent K. – Olivine-green, bottle-green, green, brownish, transparent P. – Does not leave streak	Uneven, imperfect cleavage	Characteristic olive-green color, clear cleavage, grainy texture.	A rock-forming mineral in ultramafic and mafic volcanic rocks.	Transparent varieties - chrysolites - are used in jewelry making, olivine rocks (dunites) - as a building material, in the chemical

								industry.
25	Garnet (almandine, andradite, uvarovite), R"3R"'2 [SiO4]3; R"3 – Mg, Ca, Mn, Fe; R"'2 – Al, Fe	Isometric polyhedra	7,0-7,5 3,5-4,3	B. – Glassy, sometimes greasy K. – Dark red, brownish P. – Does not leave streak	Uneven, conchoidal, imperfect cleavage	Isometric crystal form, coloring, high hardness.	Forms during metamorphic, sometimes magmatic processes.	Used as a grinding abrasive material, transparent varieties - in jewelry making.
	Ring silicates							
26	Complex borosilicate Na(Li,Al)3 Al6[(OH)4 (BO3)3 Si6O18]	Triangular elongated hexagonal prismatic crystals with longitudinal striations	7,0-7,5 3,0-3,2	B. – Glassy K. – Green, pink, brown, black, transparent P. – White or does not leave streak	Prickly, no cleavage	Prismatic trigonal crystal form, longitudinal striations, hardness, no cleavage.	Found in granite rocks and pegmatite veins, sometimes in contact-metamorphic rocks.	Used in radio engineering, transparent varieties - gemstones.
	Chain Silicates (Pyroxenes)							
27	Augite, Ca(Mg,Fe,Al)[(SiAl)2O6]	Octahedral prismatic, small columnar crystals	6,5 3,3-3,6	B. – Glassy K. – Green, brown, black P. – Light, grayish-green	Uneven, cleavage visible on prism faces at angles close to right angles.	Differentiated from hornblende by crystal shape, cleavage, and hardness.	A rock-forming mineral in mafic volcanic and metamorphic rocks.	Used in radio engineering, transparent varieties - gemstones.
	Ribbon Structures Silicates (Amphiboles)							
28	Hornblende, General formula of amphiboles R7(OH)2 [Si2O11]; R – Ca, Mg, Fe, Na	Columnar or hexagonal prismatic crystals, radiating growth	5,5-6,0 3,1-3,5	B. – Silky on cleavage planes, resembling the luster of horn material	Prickly, perfect cleavage in two directions at an angle of 124°	Crystal form (acicular, prismatic), cleavage at an angle of 124°.	A rock-forming mineral in igneous and metamorphic rocks.	Used in radio engineering, transparent varieties - gemstones.

				K. – Grayish and dark green, black P. – Greenish or brown				
Sheet Silicates								
29	Talc, $Mg_3(OH)_2[Si_4O_{10}]$	Very perfect in one direction, splits into thick, non-elastic flakes	1.0 . 2.7-2.8	B. – Greasy on cleavage planes, pearly K. – White, yellowish, greenish, bluish P. – White	Sheet-like and scaly	Greasy to the touch, very soft, flakes flexible but not elastic.	Product of metamorphism of magnesian rocks.	Used in rubber, paper industries, medicine, fire-resistant material.
30	Serpentine (serpentine), $Mg_6(OH)_8[Si_4O_{10}]$	Fibrous and platy crystals, fine grains	3.0-4.0 2.5-2.7	B. – Greasy, waxy, silky K. – Ranges from light green, bluish to dark green with yellow spots (resembling snake skin) P. – White, greenish	Earthy in massive forms, scaly in fibrous varieties	Serpentine is distinguished by its coloration, lack of cleavage, and weak greasy luster.	Product of hydrothermal metamorphism of ultrabasic igneous rocks.	Used as a decorative material.
31	Asbestos, $Mg_6(OH)_8[Si_4O_{10}]$	Fibrous crystals	2.5-3.0 2.22	B. – Silky K. – Greenish-yellow, almost white	Perfect cleavage in one direction in fibrous varieties	Asbestos has a fibrous structure and silky luster.	Product of hydrothermal metamorphism of ultrabasic igneous rocks.	Asbestos is used in the manufacture of fireproof fabrics,

				P. – Does not produce streaks				cardboard, and gaskets.
32	Kaolinite (kaolin), $Al_4(OH)_8[Si_4O_{10}]$	Crystals are extremely rare, usually earthy masses.	1,0-2,0 2,6	B. - Dull, matte, greasy, pearly in flakes K. - White, slightly yellowish or grayish R. - White	Earthy, dense, with very perfect cleavage in one direction	Greasy to the touch, soft, swells considerably in water.	Product of hydrothermal alterations and surface weathering of feldspars and other aluminosilicates.	I am a ceramicist, used in construction, paper industry, fireproof material.
33	Muscovite (white potassium mica), fine-flaky - sericite, $KAl_2[AlSi_3O_{10}](OH,F)_2$,	Tabular, platy crystals reaching large sizes.	2,0-3,0 2,7-3,1	Б. – Vitreous, iridescent K. – Colorless with a slight yellowish, pinkish, or grayish hue, transparent P. – Non-scratch	Very perfect cleavage in one direction	Ability to split into thin, elastic flakes and scales, light coloration.	A rock-forming mineral of igneous rocks of metamorphic origin.	Used as electrical insulation and refractory material.
34	Biotite (black iron-magnesium mica), $K(Mg,Fe)_3 [AlSi_8O_{10}] (OH,F)_2$	Tabular hexagonal, platy crystals	2,0-3,0 3,0-3,1	B. - Glassy, iridescent K. - Transparent, black or dark green, brown R. - Does not give streaks.	Very perfect cleavage in one direction	Greenish-brown coloration, cleaves into elastic sheets, opaque in thick flakes.	A constituent of igneous and metamorphic rocks.	Used as an electrical insulating and refractory material.

35	Chlorite, (Fe,Mg)5 Al(OH)8 [AlSi3O10]	Tabular, flaky crystals forming aggregates of solid masses.	2,0-2,5 2,6-2,8	B. – Vitreous, pearly K. – Light and dark grass-green, violet, pink P. – White, light greenish, or non-receptive to scratches	Very perfect cleavage in one direction	Capable of splitting into flexible, resilient flakes, characteristic green color, low hardness	Product of metamorphic transformations of biotite, augite, and hornblende	Chlorites with high iron content (shamozite) are used as iron ore.
36	Glauconite (from the group of hydrous phyllosilicates), K(Fe,Mg)3 (OH)2 [AlSi3O10]· nH2O	Small (up to 1 mm) grains and nodules	2,0-3,0 2,2-2,8	B. – Dim, glassy, oily K. – Dark green (almost black-green) P. – Somewhat greenish	Grainy, uneven	Dark green hue, graininess.	Sediments of marine origin.	Utilized for water softening.
Framework silicates (aluminosilicates)								
37	Orthoclase, K2O · Al2O2 · 6SiO2	Prismatic pinacoidal crystals	6,0 2,6	B. – Glassy, iridescent K. – White, creamy, bluish-gray, pink, red P. – Does not scratch	Perfect cleavage in two directions at right angles	Rectangular fractures, high hardness, perfect cleavage.	Rock-forming mineral of acidic, intermediate, and alkaline igneous rocks. Product of high-temperature hydrothermal alteration of	Pale-colored varieties are used in porcelain and faience industry.

							rocks.	
38	Microcline, Composition analogous to orthoclase	Prismatic crystals, similar to orthoclase crystals	6,0 2,6	B. – Glassy or weakly iridescent on cleavage faces K. – Creamy, greenish-gray, pink, green R. – Light	Perfect cleavage in two directions at nearly right angles	Differs from orthoclase in cleavage (angle between cleavage planes is less than right by 20°).	Rock-forming mineral of intermediate, alkaline, igneous rocks. Also forms by metamorphic processes.	Utilized in porcelain and faience industry.
39	Albite (sodium plagioclase), Na(AlSi3O8)	Tabular plate-like crystals, twinning	6,0 2,6	Б. – Glassy, iridescent K. – White, bluish-white R. – White	Uneven, perfect cleavage in two directions at oblique angles	White color, sometimes with fine streaks on cleavage planes, high hardness.	Forms through magmatic and metasomatic hydrothermal processes (rock-forming mineral).	Has no industrial significance.
40	Anorthite or anorthite (calcium plagioclase), Ca(Al2Si2O8)	Tabular crystals (sometimes encountered)	6,0-6,5 2,7	Б. – Glassy, iridescent K. – Gray, white, bluish, yellowish R. – White	Distinct cleavage in two directions	Similar to albite, differing only in cleavage.	Rock-forming mineral of basic igneous rocks.	Has no industrial significance.
41	Labradorite (calcium-sodium plagioclase), (Ca,Na) [(Al,Si) AlSi2O8]	Tabular crystals with distinct streaks on cleavage planes	6,0 2,7	Б. – Glassy, iridescent K. – Dark gray, with shimmers (iridescence)	Perfect cleavage in two directions	Distinctive feature – iridescence.	Rock-forming mineral of alkaline igneous rocks.	Labradorite - precious decorative material.

				R. – White				
42	Nepheline (eleolite) "oily stone", $KNa_3[AlSiO_4]_4$	Small prismatic crystals (sometimes encountered)	5,5-6,0 2,7	Б. – Glassy on faces, greasy on fracture K. – Gray, pink, yellowish-brown, colorless R. – Does not scratch or scratches white	Flatly-convex, imperfect cleavage.	Differs from orthoclase and plagioclase by its greasy luster, imperfect cleavage. Differs from quartz by its hardness and luster.	Rock-forming mineral of alkaline igneous rocks.	Used in glass industry, for producing soda, alumina, pigments.
Minerals that do not have geological significance but are included in the hardness scale.								
Native elements								
43	Diamond, C	Eight and twelve-sided crystals (of various shapes)	10,0 3,5	Б. – Hard diamond K. – Transparent, colorless, yellow, blue, black R. – Does not scratch	Perfect cleavage in four directions (along the octahedron)	Differs from quartz by perfect cleavage, high hardness, and crystal form.	Product of crystallization of ultra-basic and basic magmas in explosion pipes.	Used in jewelry making, for manufacturing and grinding drill bits.
Insular silicates								
44	Topaz, $Al_2(FOH)_2[SiO_4]_3$	Prismatic crystals	8,0 3,3-3,6	Б. – Glassy K. – Colorless, blue, yellowish, pink, purple	Uneven, perfect cleavage in one direction	Differs from quartz by greater hardness, perfect cleavage,	Product of crystallization of acidic magma in pegmatites and processes of autometamorphism	Used as gemstone, as an abrasive material, in the production of precision

				R. – Does not scratch		and stronger luster.	(greisens).	instruments.