English for Mining

Engineers

***(англійська мова***

***за професійним спрямуванням)***



***Міністерство освіти і науки України***

**Житомирський державний технологічний університет**

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Навчальний посібник **«**English for Mining Engineers» (англійська мова за професійним спрямуванням) призначений для здобув. вищ. освіти факультету гірничої справи, природокористування та будівництва, спеціальності 184 «Гірництво», освітньо-професійної програми «Гірництво», освітньо-кваліфікаційного рівня «бакалавр», які володіють основами лексичного і граматичного мінімуму і бажають вдосконалити володіння професійною і загально-технічною термінологією, виробити навички професійно-спрямованого мовлення.

Посібник складається з трьох розділів. Перший розділ «Basic Coursе» містить 11 уроків, які охоплюють актуальні теми, пов’язані з проблемами, розвитком та майбутнім гірничої промисловості. Другий розділ розроблено для закріплення граматичного матеріалу та третій розділ «Glossary of Geological Terms» містить глосарій гірничих термінів.

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ПЕРЕДМОВА

Навчальний посібник *«English for Mining Engineers*» призначений для аудиторної та самостійної роботи здобувачів вищої освіти, які навчаються за напрямом «Гірництво» за спеціальностями “Розробка родовищ та видобування корисних копалин”, “Маркшейдерська справа». Він також є корисним для широкого кола осіб, які самостійно вивчають гірничу термінологію англійською мовою. Головною метою посібника є: підготовка студентів до читання професійно орієнтованої літератури; удосконалення навичок усного мовлення і формування навичок групового спілкування у формі дискусії із загальнодоступних та поглиблених професійних проблем у межах знань студентів зазначеної спеціальності; засвоєння необхідного лексичного мінімуму, який має сприяти здійсненню професійної комунікації та діяльності; розуміння основних проблем гірництва. Посібник дозволяє сформувати вміння, що необхідні для самостійної роботи з оригінальними професійно спрямованими англомовними джерелами.

Навчальний посібник складається з трьох розділів. Перший розділ «Basic Coursе» містить 11 уроків для аудиторного засвоєння та для індивідуального опрацювання. Уроки охоплюють актуальні теми сьогодення, пов’язані з розвитком, сучасним станом, проблемами та майбутнім гірничої промисловості. Другий розділ розроблено для закріплення граматичного матеріалу та третій розділ «Glossary of Geological Terms», містить глосарій гірничих термінів. В частині «Additional Reading» запропоновано додатковий матеріал до уроків основного розділу.

Уроки містять: нову лексику; тематичні тексти (переважно декілька взаємодоповнюючих текстів різного ступеня складності) чи діалоги; ряд практичних завдань для закріплення лексико- граматичних явищ; додаткові тексти для самостійної роботи; ситуації для обговорення у класі.

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## PART I BASIC COURSE

# UNIT I. THE STRUCTURE OF THE EARTH

#### Science Vocabulary

|  |  |
| --- | --- |
| the Earth | земля, земна куля |
| layer | шар, пласт, нашарування |
| inner core | внутрішнє ядро |
| outer core | зовнішнє ядро |
| mantle | мантія |
| crust | земна кора |
| solid | твердий |
| to be made up of | складатися з |
| immense | неосяжний, величезний, безмірний |
| thickness | товщина |
| semi-molten | напіврозтоплений |
| to melt | топити, розчинити, танути |
| tectonic plates | тектонічні плити |
| earthquake | землетрус |
| volcano | вулкан |
| boundary | межа, кордон |
| to be broken up into | розбиватися на |
| convection currents | конвекційні потоки |
| radioactive decay | радіоактивний розпад |
| plate tectonics | тектоніка плит |
| plate boundary | межа плит |
| to erupt | вивергатися |
| surface | поверхня |
| to cool | охолоджувати |
| to solidify | тверднути, затверднути |
| igneous rock | магматична порода |
| chain | ланцюг |
| to force below | вдавлювати донизу |
| subduction zone | зона субдукції |

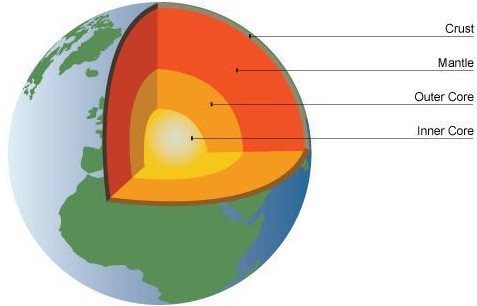
|  |  |
| --- | --- |
| to trigger | приводити в дію спусковий механізм |
| crack | тріщина. щілина |
| to squash | роздавити, розчавити |

***Read and translate the text***

### THE STRUCTURE OF THE EARTH I

The Earth consists of four concentric layers: *inner core*, *outer core*, *mantle* and *crust*.

1. **The inner core** is in the centre and is the hottest part of the Earth. It is solid and made up of iron and nickel with temperatures of up to 5, 500° C. With its immense heat energy, the inner core is like the engine room of the Earth.
2. **The outer core** is the layer surrounding the inner core. It is a liquid layer, also made up of iron and nickel. It is still extremely hot, with temperatures similar to the inner core.
3. **The mantle** is the widest section of the Earth. It has a thickness of approximately 2,900 km. The mantle is made up of semi-molten rock called magma. In the upper parts of the mantle the rock is hard, but lower down the rock is soft and begins to melt.
4. **The crust** is the outer layer of the earth. It is a thin layer between 0-60 km thick. The crust is the solid rock layer upon which we live.



### II

The crust is made up of **tectonic plates**, which are in constant motion. Earthquakes and volcanoes are most likely to occur at plate boundaries.

There are two different types of crust: **continental crust**, which carries land, and **oceanic crust**, which carries water.

The Earth's crust is broken up into pieces called **plates**. Heat rising and falling inside the mantle creates **convection currents** generated by radioactive decay in the core. The convection currents move the plates. The movement of the plates, and the activity inside the Earth, is called **plate tectonics**.

Plate tectonics cause earthquakes and volcanoes. The point where two plates meet is called a **plate boundary**. Earthquakes and volcanoes are most likely to occur either on or near plate boundaries.

The Earth's plates move in different directions.

Tensional margins

At a tensional or **constructive boundary** the plates are moving **apart**. The plates move apart due to convection currents inside the Earth.



*The Helgafjell volcano on Westman Island, Iceland*

### III

As the plates move apart (very slowly), magma rises from the mantle. The magma erupts to the surface of the Earth. This is also accompanied by earthquakes.

When the magma reaches the surface, it cools and solidifies to form a new crust of **igneous rock**. This process is repeated many times, over a long period of time.

Eventually the new rock builds up to form a volcano. Constructive boundaries tend to be found under the sea, e.g. the Mid Atlantic Ridge. Here, chains of underwater volcanoes have formed along the plate boundary. One of these volcanoes may become so large that it erupts out of the sea to form a volcanic island, e.g. the Westman Islands near Iceland.

Compressional boundary

At a compressional or **destructive boundary** the plates are moving **towards** each other. This usually involves a continental plate and an oceanic plate.

The oceanic plate is denser than the continental plate so, as they move together, the oceanic plate is forced underneath the continental plate. The point at which this happens is called the **subduction zone**. As the oceanic plate is forced below the continental plate it melts to form magma and earthquakes are triggered. The magma collects to form magma chamber. This magma then rises up through cracks in the continental crust. As pressure builds up, a volcanic eruption may occur. Also the oceanic plate is pushed underneath the continental plate, causing mountains and possibly volcanoes to form along the destructive plate boundary.



*A view of the Himalayas from Gorak Shep*

### IV

As the plates push together, the continental crust is squashed together and forced upwards. This is called **folding**. The process of folding creates **Fold Mountains**. Fold Mountains can also be formed where two continental plates push towards each other. This is how mountain ranges such as the **Himalayas** and the **Alps** were formed.

1. ***Use the dictionary and write down transcriptions of the words given below.***

surrounding, approximately, layer, earthquake, volcano, accompanied, solidifies, boundaries, underneath, mountains.

1. ***Give English equivalents to the following Ukrainian words and word combinations. Make up your own sentences*.**

складатися з…, машинне відділення, твердий пласт, різні типи, зростання і падіння, траплятися, окремо рухатися, магматичне вогнище, донизу.

1. ***Match the definitions.***
   1. subduction zone
   2. igneous rock
   3. decay
   4. earthquake
   5. crack
   6. layer
   7. volcano
      1. The process or result of being gradually decomposed;
      2. The process in which one tectonic plate moves beneath another and sinks into the mantle at a convergent plate boundary;
      3. A narrow opening;
      4. Resulting from, or produced by the action of great heat with rocks, it could also mean formed from lava/magma;
      5. Single thickness of some material covering a surface;
      6. Vent or fissure on the surface of a planet (usually in a mountainous form) with a magma chamber attached to the mantle of a planet or moon, periodically erupting forth lava and volcanic gases onto the surface;
      7. A shaking of the ground, caused by volcanic activity or movement around geologic faults.
2. ***Fill in the blanks with the proper words. Change the form if necessary.***

#### destruction/destructive/destroy

* 1. The fire was a vengeful act of .
  2. The building was by fire.
  3. Emotions can become if they are suppressed and denied.
  4. All the files were deliberately .
  5. Indiana tornado deals death and .
  6. The grand of nature are the winds and the waves.

**divide/division/divisible**

1. The cells began to out of control.
2. They agreed on of profits.
3. The war children from their parents.
4. Every particle of matter is infinitely .

**earthly/earthy/earthen**

1. It is a sermon against our obsession with pursuits...
2. Critics were impressed by the movie's realism.
3. Her only furniture was an crock or two.
4. I see no reason why he shouldn't come.
5. ***Match the synonyms.***

|  |  |
| --- | --- |
| immense | dissolve |
| melt | eruptive |
| break up | refrigerate |
| erupt | vast |
| cool | harden |
| crack | fracture |
| igneous | split up |
| solidify | become active |

1. ***Put 7 – 10 questions to the text.***
2. ***Control points.***
   1. What concentric layers of the Earth do you know?
   2. What are convection currents?
   3. Give short information about the tensional margins.
   4. Tell a few words about the compressional boundary.
3. ***Read the text from Additional reading. Speak on the Structure of the Earth.***

### ADDITIONAL READING

The Earth has three major layers. All known life exists on the solid outer layer, called the crust. Beneath the crust is the mantle, a gooey, hot layer of magma and other semi-solid rocks and minerals. Movement in the mantle leads to tectonic activity, such as volcanic eruptions and earthquakes, on the crust.

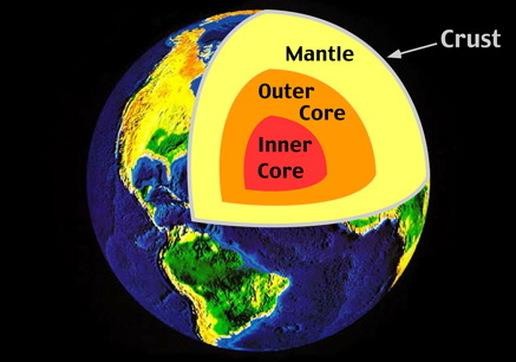
The core, beneath the mantle, is the deepest and hottest layer of the Earth. It is made almost entirely of metal. The core is made of two layers: the outer core, which borders the mantle, and the inner core. The inner core is shaped like a ball.

Scientists say the outer core is made mostly of iron and nickel. Iron and nickel are two important metals found everywhere on the planet. (On the surface of the Earth, these metals are found in solid form.) Iron and nickel in the outer core form an alloy, or a mixture of metallic elements. The outer core is approximately 2,300 kilometers (1,430 miles) thick. The alloy of the outer core is very hot, between 4,000 and 5,000 degrees Celsius (7,200 and 9,000 degrees Fahrenheit). The inner core is made mostly of iron. It is approximately 1,200 kilometers (750 miles) thick. Although the iron is extremely hot— between 5,000 and 7,000 degrees Celsius (9,000 and 13,000 degrees Fahrenheit)—the pressure from the rest of the planet is so great that the iron cannot melt. For this reason, the inner core is mostly solid.

Because the Earth has a ball of metal in the middle of it, the entire planet is magnetic. Scientists believe the liquid outer core is what controls the Earth’s magnetic field. The magnetic field acts almost like a bubble. It protects the planet from charged particles floating around in the solar system, such as those from the sun. The magnetic North and South Poles are opposing sides of Earth’s big magnet.

The hard, metallic material in the core is balled up in the center of the Earth because it's the heaviest material on the planet. When Earth was formed about 4.5 billion years ago, all the heavier substances sank toward the middle. The lighter and less dense material, such as air and water, stayed closer to the crust.

Inside the core, the metals are constantly moving. The core of the Earth rotates regularly. Some scientists say the inner core actually rotates faster than the rest of the planet! As the liquid outer core moves, it can change the location of the magnetic North and South Poles.



# UNIT II. CHANGES OF ROCKS

#### Science Vocabulary

|  |  |
| --- | --- |
| pumice | пемза |
| melting | плавлення |
| to descend | спускатися; сходити (вниз); знижуватися |
| igneous | вивержений; пірогенний; вулканічного походження |
| morphing | процес трансформування |
| weathering | вивітрювання, ерозія |
| erosion | ерозія; роз'їдання, витравлення, поступове руйнування |
| sediment | осадова порода |
| sedimentary rock | осадова порода |
| metamorphic rock | метаморфічна порода |
| fossil | cкам'янілість; (викопні рештки) |
| squeezing | стискання; здавлювання |
| to trap in | поглинати, затримувати, відокремлювати |
| liquid | рідкий |
| pressure | тиск, стискання |
| to accumulate | нагромоджувати(ся); акумулювати(ся);  скупчувати(ся) |
| molten | розтоплений, литий |

***Read and translate the text***

### CHANGES OF ROCKS

A rock is a solid, inorganic, naturally-formed substance without a particular atomic structure or chemical composition. It's probably easier to just remember that rocks are made up of two or more minerals. Examples of rocks include granite, limestone, marble, pumice, obsidian, sandstone, shale and slate. Each of these rocks consists of several different minerals, which are mixed up inside the rock through a variety of geologic processes.

The way rocks change depends on various processes that are always taking place on and under the earth's surface. Now let's take a closer look at each of these processes.

*Heat & Pressure*

What happens to cookie dough when you put it in the oven? The heat of the oven produces changes in the ingredients that make them interact and combine. Without melting the dough, the heat changes it into a whole new product — a cookie.

A similar process happens to rocks beneath the earth's surface. Due to movements in the crust, rocks are frequently pulled under the surface of the earth, where temperatures increase dramatically the farther they descend. Between 100 and 200 kilometers (62 and 124 miles) below the earth's surface, temperatures are hot enough to melt most rocks. However, before the melting point is reached, a rock can undergo fundamental changes while in a solid state — morphing from one type to another without melting.

An additional factor that can transform rocks is the pressure caused by tons of other rocks pressing down on it from above; heat and pressure usually work together to alter the rocks under the earth's surface. This kind of change, which results from both rising temperature and pressure, is called metamorphism, and the resulting rock is a metamorphic rock.

*Melting*

What happens to a chocolate bar when it gets very hot? It melts.

The same thing happens to a rock when it is heated enough. Of course, it takes a lot of heat to melt a rock. The high temperatures required are generally found only deep within the earth. The rock is pulled down by movements in the earth's crust and gets hotter and hotter as it goes deeper. It takes temperatures between 600 and 1,300 degrees Celsius (1,100 and 2,400 degrees Fahrenheit) to melt a rock, turning it into a substance called magma (molten rock).

*Cooling*

What would you do to turn a melted chocolate bar back into a solid? You'd cool it by putting it into the refrigerator until it hardens.

Similarly, liquid magma also turns into a solid rock when it is cooled. Any rock that forms from the cooling of magma is an igneous rock. Magma that cools quickly forms one kind of igneous rock, and magma that cools slowly forms another kind.

When magma rises from deep within the earth and explodes out of a volcano, it is called lava, and it cools quickly on the surface. Rock formed in this way is called extrusive igneous rock. It is extruded or pushed out of the earth's interior and cools outside of or very near the earth's surface. What if the magma doesn't erupt out of a volcano, but instead gets pushed slowly upward toward the earth's surface over hundreds, thousands, or even millions of years? This magma will also cool, but at a much slower rate than lava erupting from a volcano. The kind of rock formed in this way is called intrusive igneous rock. It intrudes, or pushes, into the earth's interior and cools beneath the surface.

*Weathering & Erosion*

All objects on the earth's surface are exposed to the wind, along with many other elements — water, the sun, temperature changes. Over time, these factors wear objects down and break them apart. The resulting bits and pieces of material are called sediment. Sediment is then transported by wind and water, often ending up far from where it started. These processes of breakdown and transport due to exposure to the environment are called weathering and erosion. Weathering and erosion affect all rocks on the earth's surface.

*Compacting & Cementing*

What happens to a loose pile of garbage when it's put into a compactor? The squeezing of the machine produces a solid cube of compacted garbage.

The same thing happens to sediment formed from the weathering and erosion of rock. Over time, sediment accumulates in oceans, lakes, and valleys, eventually building up in layers and weighing down the material underneath. This weight presses the sediment particles together compacting them. Water passing through the spaces in between the particles helps to cement them together even more. This process of compacting and cementing sediment forms sedimentary rock.

### TYPES OF ROCKS

All rock (except for meteorites!) that is on Earth today is made of the same stuff as the rocks that dinosaurs and other ancient life forms walked crawled or swam over. While the stuff that rocks are made from stays the same, the rocks do not. Over millions of years, rocks are recycled into other rocks. Moving tectonic plates help to destroy and form many types of rocks. The three main types, or classes, of rock are sedimentary, metamorphic, and igneous and the differences among them have to do with how they are formed.

*Sedimentary rocks* are formed from particles of sand, shells, pebbles, and other fragments of material. Together, all these particles are called sediment. Gradually, the sediment accumulates in layers and over a long period of time hardens into rock. Generally, sedimentary rock is fairly soft and may break apart or crumble easily. You can often see sand, pebbles, or stones in the rock and it are usually the only type that contains fossils.

Examples of this rock type include conglomerate and limestone.

*Metamorphic rocks* are formed under the surface of the earth from the metamorphosis (change) that occurs due to intense heat and pressure (squeezing). The rocks that result from these processes often have ribbon like layers and may have shiny crystals, formed by minerals growing slowly over time, on their surface.

Examples of this rock type include gneiss and marble.

*Igneous rocks* are formed when magma (molten rock deep within the earth) cools and hardens. Sometimes the magma cools inside the earth, and other times it erupts onto the surface from volcanoes (in this case, it is called lava). When lava cools very quickly, no crystals form and the rock looks shiny and glasslike. Sometimes gas bubbles are trapped in the rock during the cooling process, leaving tiny holes and spaces in the rock.

Examples of this rock type include basalt and obsidian.

1. ***Use the dictionary and write down transcriptions and translations of the words given below.***

Sedimentary rocks, weathering, erosion, igneous rocks, magma, melting, metamorphic rocks, rock cycle, tectonic plate

***Give English equivalents to the following Ukrainian words and word combinations. Make up your own sentences*.**

вивітрювання, вивержена порода, осад, цементація, відкладання, галька.

1. ***Match the definitions*.**

|  |  |
| --- | --- |
| weathering | melted rock that is beneath the surface of the earth |
| sedimentary rock | magma or melted rock that rises to the surface |
| deposition | tiny pieces of ground up rock found on the bottom of a slow moving river |
| lava | when rock fragments are moved by water or wind |
| magma | to push together by applying a great deal of pressure |
| sediment | when rocks are broken down into smaller fragments by freezing, thawing, or rain |
| igneous rock | to cause small particles to stick together |
| transportation | when rock fragments are laid down in a new location |
| metamorphic rock | rock formed by the cooling and hardening of hot liquid rock |
| compacting | rocks formed from sediments that have been compacted and cemented together |
| cementation | rock formed when sedimentary or igneous rocks are changed by heat and pressure |

1. ***Fill in the blanks with the proper words. Change the form if necessary.***

#### weathering/to weather/weathered

* 1. Soon the bricks of an old farmhouse vanished into thin air.
  2. is the breaking down of rocks, soil and minerals as well as artificial materials through

contact with the Earth's atmosphere, biota and waters.

* 1. The man a serious illness and lived on for two or three years.

#### deposition/to deposit/deposit

1. As more mud was on top, the downward pressure increased.
2. Farmers detected an oil not far from the village.
3. The other is the linking of polyhedral building units from solution and of the newly formed solid.
4. ***Fill in the blanks using vocabulary from the text. Change the form if necessary.***

*Lava change igneous rocks density erosion arrange weathering sedimentary mineral deposit*

* 1. occur in a wide variety of forms and in different shapes and sizes.
  2. Extrusive rocks occur as .
  3. During metamorphism, the original rock .
  4. The of a rock can also be changed do to the immense pressure.
  5. Sometimes rock crystals will be in layers or bands.
  6. A rock is composed of geologically altered materials, which is formed by the build up and condensation of and particle matter by the action of water.
  7. and is the breakdown of rock due to exposure to the atmosphere and due to the differences in conditions from where rock had formed and surfaced.

1. ***Match the synonyms.***

|  |  |
| --- | --- |
| density | erosion |
| deposition | conveyance |
| cementation | hardness |
| transportation | sedimentation |
| weathering | thawing |
| melting | bonding |

***Put 10 key questions to the text describe main types of rocks and their changes under different conditions*.**

1. ***Control points:***
   1. Changes of rocks as a nature process.
   2. Main changes of rocks
   3. Types of rocks
   4. Connection between changes of rocks under certain conditions and their types
2. ***Look at the list of words below and classify each word as a product or process of the Rock Cycle. Put a check in the appropriate column to show if the word is a product or process. Use the following chart to describe the main processes of rock cycle and types of rocks*.**

|  |  |  |
| --- | --- | --- |
| **PARTS OF ROCK CYCLE** | **PRODUCT** | **PROCESS** |
| *Weathering* |  |  |
| *Metamorphism* |  |  |
| *Melting* |  |  |
| *Magma* |  |  |
| *Igneous Rocks* |  |  |
| *Cooling/Solidification* |  |  |
| *Sediment* |  |  |
| *Transportation/Erosion* |  |  |
| *Sedimentary Rocks* |  |  |
| *Deposition* |  |  |
| *Compaction/Cementation* |  |  |
| *Heat* |  |  |
| *Metamorphic Rocks* |  |  |
| *Lava* |  |  |
| *Eruption* |  |  |
| *Pressure* |  |  |

**UNIT III. ROCKS TYPES**

#### Science Vocabulary

|  |  |
| --- | --- |
| coherent | зчеплений, з’язаний, зцементований |
| pertain to | мати відношення до чогось |
| aggregate | сукупність, скупчення; агрегат (скупчення, зрощення мінералів, які складаютьгірську породу) |
| interlocking | взаємозв'язані, зв'язані один з одним |
| igneous rocks | магматичні породи |
| deposit | поклад; родовище; відкладення |
| sedimentary rocks | осадові породи |
| metamorphic rocks | метаморфічні породи |
| intrusive | інтрузивний, плутонічний |
| extrusive | екструзивний, вулканичний |
| solidification | застигання, затвердіння |
| debris | уламковий матеріал |
| tear ( tore , torn ) | рвати, розривати, відривати |
| pyroclastic | пірокластичний |
| vent | вхідний чи вихідний отвір |
| mafic | мафічні, темні породи |
| felsic | кислі гірські породи |
| silicic ( siliceous) | кремнієвий |
| silica | кварц |
| grain | зерно; кристал; гранула; піщинка; крупинка |
| nucleation | утворення центрів кристалізації, нуклеація |
| viscosity | вязкість, липкість, клейкість; тягучість |
| tungsten | вольфрам |
| uranium | уран |
| granite | граніт |
| diorite | діорит, діоритовий |
| chromium | хром |
| platinum | платина |
| gabbro | габро |
| clastic | уламковий, відламковий уламкове родовище, кластичний (про породу) |
| precipitate | осад; осідання (грунту); осідати, осаджуватися ; опадати |
| denudation | денудація, ерозія |
| bedding | залягання |
| boulder | галька |
| silt | мулисті відкладення; шлам |
| siltstone | алеврит |
| pebble | булижник, гравій |
| chert | кремінь, крем'янистий сланець, роговик (гірська порода) |
| cave | печера; порожнина, улоговина; карстове утворення |
| foliated | листуватий, розділений, шаруватий (про породу) |
| non-foliated | нешаруватий |
| [gneiss](http://geology.com/rocks/gneiss.shtml) | гнейс |
| [phyllite](http://geology.com/rocks/phyllite.shtml) | філіт |
| [schist](http://geology.com/rocks/schist.shtml) | сланець |
| [slate](http://geology.com/rocks/slate.shtml) | глинистий сланець |
| [hornfels](http://geology.com/rocks/hornfels.shtml) | роговик |
| [marble](http://geology.com/rocks/marble.shtml) | мармур |
| [quartzite](http://geology.com/rocks/quartzite.shtml) | кварцит |
| [novaculite](http://geology.com/rocks/novaculite.shtml) | новакуліт |
| soapstone | мильний камінь, стеатит |

***Read and translate the text***

### TYPES OF ROCKS

Rock: any naturally formed, firm and coherent aggregate of minerals that constitutes part of the Earth. Despite considerable diversity, we can classify all rocks into three types, according to how they formed:

* 1. Igneous rocks (from Latin "ignis" meaning "pertaining to fire") are formed by cooling and solidification of molten rock material and typically represented by an interlocking aggregate of silicate minerals.
  2. Sedimentary rocks (from Latin "sedimentum" meaning "settle") are formed from particles of pre-existing rocks by cementation or other processes at the Earth's surface.
  3. Metamorphic rocks (from Greek "meta" meaning "change" and "morpho" meaning "form") are formed within the Earth's crust by solid- state transformation of pre-existing rock (igneous, sedimentary or even metamorphic) as a result of high temperature, high pressure or both.

Within each group, rocks share common origins, but do not necessarily look alike. Difference is a clue to how and where a rock formed.

****

### IGNEOUS ROCKS

**Igneous rock** (etymology from Latin *ignis*, fire) is one of the three main [rock](http://en.wikipedia.org/wiki/Rock_%28geology%29) types (the others being [sedimentary](http://en.wikipedia.org/wiki/Sedimentary_rock) and [metamorphic rock](http://en.wikipedia.org/wiki/Metamorphic_rock)). Igneous rock is formed by [magma](http://en.wikipedia.org/wiki/Magma) (molten rock) being cooled and becoming solid. They may form with or without [crystallization](http://en.wikipedia.org/wiki/Crystallization), either below the surface as [intrusive](http://en.wikipedia.org/wiki/Intrusion) ([plutonic](http://en.wikipedia.org/wiki/Plutonic)) rocks or on the surface as [extrusive](http://en.wikipedia.org/wiki/Extrusive_%28geology%29) ([volcanic](http://en.wikipedia.org/wiki/Volcanic_rock)) rocks. This magma can be derived from partial melts of pre-existing rocks in either the [Earth'](http://en.wikipedia.org/wiki/Earth)s [mantle](http://en.wikipedia.org/wiki/Mantle_%28geology%29) or [crust](http://en.wikipedia.org/wiki/Crust_%28geology%29). Typically, the melting is caused by one or more of three processes: an increase in temperature, a decrease in pressure, or a change in composition. Over 700 types of igneous rocks have been described, most of them formed beneath the surface of the Earth's [crust](http://en.wikipedia.org/wiki/Crust_%28geology%29). These have diverse properties, depending on their composition and how they were formed. Two types of igneous rocks can form from magma:

1. Intrusive (Plutonic) igneous rocks are produced by cooling and crystallization of magma beneath the Earth's surface. The resulting igneous body may represent solidification of a magma chamber or reservoir in which magma would have been stored during movement toward the surface.
2. Extrusive (Volcanic) igneous rocks are produced rapid cooling and crystallization of magma on the Earth's surface. Volcanoes represent the vents from which molten silicate material, solid rock debris, and gases escape from the subsurface. The volcanic products may be coherent (lava) or fragmented (pyroclastic) material. Pyroclasts are produced when the erupting magma is torn apart by violent explosions within the volcanic vent.

Magmas are composed of the major elements (O, Si, Al, Mg, Fe, Ca, Na and K) that form the Earth. The dominant component of most magmas is silicon dioxide (silica), which constitutes 35-79% of the liquid. Magmas are grouped into compositional categories based on silica content: ultramafic (245% silica), mafic (45-52% silica), intermediate (53-65% silica), and felsic or silicic (>65% silica).

**Texture of igneous rocks** refers to variations in the sizes and shapes of mineral grains in a rock, and the type of relationships between the grains. Texture is determined by:

1. **Rate of Cooling** - a primary control on texture, determines the relative rate of crystal nucleation and growth:
   1. slow cooling - few large crystals produced by growth rate greater than nucleation rate;
   2. rapid cooling - many small crystals produced by nucleation rate greater than growth rate;
   3. quench - glass produced where ions have no time to organize into crystals.
2. **Magma composition and Temperature** - control magma density and magma viscosity (or its internal resistance to flow)
   1. high silica melts are viscous and crystallize at low temperatures (<850ûC). Ions have difficulty migrating through liquid and organizing into crystals;
   2. low silica melts are fluid (low viscosity) and have high temperatures (850û-1200ûC). Ions easily migrate through liquid and organize into crystals;
   3. higher silica content, the higher the viscosity;
   4. higher temperature, the lower the viscosity.
3. **Gas content of magma** - High gas content reduces viscosity, leading to larger crystals even at low temperatures. Igneous rocks make up approximately 95% of the upper part of the Earth's crust, but their great abundance is hidden on the Earth's surface by a relatively thin but widespread layer of [sedimentary](http://en.wikipedia.org/wiki/Sedimentary_rock) and [metamorphic](http://en.wikipedia.org/wiki/Metamorphic_rock) rocks.

Igneous rocks are **geologically important** because:

their minerals and global chemistry give information about the composition of the mantle, from which some igneous rocks are extracted, and the temperature and pressure conditions that allowed this extraction, and/or of other pre-existing rock that melted;

their absolute ages can be obtained from various forms of [radiometric dating](http://en.wikipedia.org/wiki/Radiometric_dating) and thus can be compared to adjacent geological [strata](http://en.wikipedia.org/wiki/Stratum), allowing a time sequence of events;

their features are usually characteristic of a specific tectonic environment, allowing tectonic reconstitutions (see [plate tectonics](http://en.wikipedia.org/wiki/Plate_tectonics));

in some special circumstances they host important mineral deposits ([ores](http://en.wikipedia.org/wiki/Ore)): for example, [tungsten](http://en.wikipedia.org/wiki/Tungsten), [tin](http://en.wikipedia.org/wiki/Tin), and [uranium](http://en.wikipedia.org/wiki/Uranium) are commonly associated with [granites](http://en.wikipedia.org/wiki/Granite) and [diorites](http://en.wikipedia.org/wiki/Diorite), whereas ores of [chromium](http://en.wikipedia.org/wiki/Chromium) and [platinum](http://en.wikipedia.org/wiki/Platinum) are commonly associated with [gabbros](http://en.wikipedia.org/wiki/Gabbro).



### SEDIMENTARY ROCKS

**Sedimentary rocks** are types of [rock](https://en.wikipedia.org/wiki/Rock_(geology)) that are formed by the [deposition](https://en.wikipedia.org/wiki/Deposition_(sediment)) of material (pre-existing rocks or pieces of once-living organisms) at the [Earth](https://en.wikipedia.org/wiki/Earth)'s surface and within bodies of water. Sedimentary rocks have also been found on [Mars](https://en.wikipedia.org/wiki/Mars). [Sedimentation](https://en.wikipedia.org/wiki/Sedimentation) is the collective name for processes that cause [mineral](https://en.wikipedia.org/wiki/Mineral) and/or [organic](https://en.wikipedia.org/wiki/Organic_matter) particles ([detritus](https://en.wikipedia.org/wiki/Detritus)) to settle and accumulate or minerals to [precipitate](https://en.wikipedia.org/wiki/Precipitation_(chemistry)) from a [solution](https://en.wikipedia.org/wiki/Solution). Particles that form a sedimentary rock by accumulating are called [sediment](https://en.wikipedia.org/wiki/Sediment). Before being deposited, sediment was formed by [weathering](https://en.wikipedia.org/wiki/Weathering) and [erosion](https://en.wikipedia.org/wiki/Erosion) in a source area, and then transported to the place of deposition by [water](https://en.wikipedia.org/wiki/Water), [wind](https://en.wikipedia.org/wiki/Wind), [ice](https://en.wikipedia.org/wiki/Ice), [mass movement](https://en.wikipedia.org/wiki/Mass_wasting) or [glaciers](https://en.wikipedia.org/wiki/Glacier), which are called agents of [denudation](https://en.wikipedia.org/wiki/Denudation).

Sedimentary rocks cover 75% of the Earth's surface. Though, the sedimentary rock cover of the continents of the [Earth's crust](https://en.wikipedia.org/wiki/Crust_(geology)) is extensive, but the total contribution of sedimentary rocks is estimated to be only 8% of the total volume of the crust. Sedimentary rocks are only a thin layer over a crust consisting mainly of [igneous](https://en.wikipedia.org/wiki/Igneous_rock) and [metamorphic rocks](https://en.wikipedia.org/wiki/Metamorphic_rock). Sedimentary rocks are deposited in layers as [strata](https://en.wikipedia.org/wiki/Stratum), forming a structure called [bedding](https://en.wikipedia.org/wiki/Bed_(geology)). The study of sedimentary rocks and rock strata provides information about the subsurface that is **useful** for [civil engineering](https://en.wikipedia.org/wiki/Civil_engineering), for example in the construction of [roads](https://en.wikipedia.org/wiki/Road), [houses](https://en.wikipedia.org/wiki/House), [tunnels](https://en.wikipedia.org/wiki/Tunnel), [canals](https://en.wikipedia.org/wiki/Canal) or other structures. Sedimentary rocks include common types of rocks such as chalk, limestone, sandstone, clay and shale. **Sedimentary rocks are also important sources** of [natural resources](https://en.wikipedia.org/wiki/Natural_resource) like [coal](https://en.wikipedia.org/wiki/Coal), [fossil fuels](https://en.wikipedia.org/wiki/Fossil_fuel), [drinking water](https://en.wikipedia.org/wiki/Drinking_water) or [ores](https://en.wikipedia.org/wiki/Ore).

The study of the sequence of sedimentary rock strata is the main source for scientific knowledge about the [Earth's history](https://en.wikipedia.org/wiki/History_of_the_Earth), including [palaeogeography](https://en.wikipedia.org/wiki/Palaeogeography), [paleoclimatology](https://en.wikipedia.org/wiki/Paleoclimatology) and the [history of life](https://en.wikipedia.org/wiki/Evolutionary_history_of_life). The [scientific discipline](https://en.wikipedia.org/wiki/List_of_academic_disciplines) that studies the properties and origin of sedimentary rocks is called [sedimentology](https://en.wikipedia.org/wiki/Sedimentology). Sedimentology is a part of both [geology](https://en.wikipedia.org/wiki/Geology) and [physical geography](https://en.wikipedia.org/wiki/Physical_geography) and overlaps partly with other disciplines in the [Earth sciences](https://en.wikipedia.org/wiki/Earth_science), such as [pedology](https://en.wikipedia.org/wiki/Pedology_(soil_study)), [geomorphology](https://en.wikipedia.org/wiki/Geomorphology), [geochemistry](https://en.wikipedia.org/wiki/Geochemistry) and [structural geology](https://en.wikipedia.org/wiki/Structural_geology).

Based on the processes responsible for their formation, sedimentary rocks can be subdivided into **four groups**: clastic sedimentary rocks, biochemical (or biogenic) sedimentary rocks, chemical sedimentary rocks and a fourth category for "other" sedimentary rocks formed by impacts, [volcanism](https://en.wikipedia.org/wiki/Volcanism), and other minor processes.

Four basic processes are involved in the formation of a **clastic sedimentary rock**: weathering (erosion) caused mainly by friction of waves, transportation where the sediment is carried along by a current, deposition and compaction where the sediment is [cemented](http://geomaps.wr.usgs.gov/parks/misc/glossaryc.html#cementation) , forming sedimentary rock. Clastic sedimentary rocks may have particles ranging in size from microscopic clay to huge boulders. Their names are based on their clast or grain size. The smallest grains are called [clay](http://geomaps.wr.usgs.gov/parks/misc/glossaryc.html#clay), then [silt](http://geomaps.wr.usgs.gov/parks/misc/glossarys.html#silt), then [sand](http://geomaps.wr.usgs.gov/parks/misc/glossarys.html#sand). Grains larger than 2 [millimeters](http://geomaps.wr.usgs.gov/parks/misc/metric.html) are called pebbles. Shale is a rock made mostly of clay, siltstone is made up of silt-sized grains, sandstone is made of sand-sized clasts, and conglomerate is made of pebbles surrounded by a [matrix](http://geomaps.wr.usgs.gov/parks/misc/glossarymn.html#matrix) of sand or mud.

**Biochemical (or biogenic) sedimentary rocks** form when large numbers of living things die, pile up, and are compressed and cemented to form rock. Accumulated carbon-rich plant material may form coal. Deposits made mostly of animal shells may form limestone, coquina, or chert.

**Chemical sedimentary rocks** are formed by chemical precipitation. The stalactites and stalagmites you see in caves form this way, so does the rock salt that table salt comes from. This process begins when water traveling through rock dissolves some of the minerals, carrying them away from their source. Eventually these minerals can be redeposited, or precipitated, when the water evaporates away or when the water becomes over-saturated with minerals.

### C:\Users\Asus\Desktop\Гірництво\Ст.21 над MetamorphicRocks.jpg

### METAMORPHIC ROCKS

Metamorphic rocks started out as some other type of rock, but have been substantially changed from their original igneous, sedimentary, or earlier metamorphic form. Metamorphic rocks form when rocks are subjected to high heat, high pressure, hot, mineral-rich fluids or, more commonly, some combination of these factors. Conditions like these are found deep within the Earth or where tectonic plates meet. Exposure to these extreme conditions has altered the mineralogy, texture and chemical composition of the rocks. The amount of heat and pressure determines the final state of metamorphic rocks, as does their specific mineral contents.

In metamorphic rocks some or all of the minerals in the original rock are replaced, atom by atom, to form new minerals.

There are two basic types of metamorphic rocks. **Foliated metamorphic rocks** such as [gneiss](http://geology.com/rocks/gneiss.shtml), [phyllite](http://geology.com/rocks/phyllite.shtml), [schist](http://geology.com/rocks/schist.shtml), and [slate](http://geology.com/rocks/slate.shtml) have a layered or banded appearance that is produced by exposure to heat and directed pressure. **Non-foliated metamorphic rocks** such as [hornfels](http://geology.com/rocks/hornfels.shtml), [marble](http://geology.com/rocks/marble.shtml), [quartzite](http://geology.com/rocks/quartzite.shtml), and [novaculite](http://geology.com/rocks/novaculite.shtml) do not have a layered or banded appearance.

**Foliated metamorphic rocks** have very obvious bands of layers that formed as a result of a more rapid cooling or higher pressure. Some examples of foliated metamorphic rocks include gneiss, schist, slate and soapstone.

Different degrees of pressure and heat result in unique forms of foliated rock. When submitted to light pressure and low heat, metamorphic rock forms slate, which is a fragile rock that tends to break at the joints of layers. This produces thin, flat rocks.

Slightly higher pressures and temperatures produce phyllite, which is a harder rock that often has a shiny appearance. Phyllite often includes deposits of micas, which follow the direction of folliation, giving it its shiny appearance.

Still greater pressures result in the formation of schist. Schist has a larger grain than phyllite, but it shares phyllite's shiny luster from large mica deposits. These deposits are often larger in schist than in phyllite.

The greatest pressures and heats form gneiss. Gneiss has alternating bands of dark and light rock, which are formed when pressures form large mineral deposits into thinner bands. Gneiss has coarser bands than other foliated metamorphic rocks. Unlike phyllite and schist, gneiss contains very little mica. However, gneiss often contains quartz and feldspar.

**Non-foliated metamorphic rocks** do not have a platy or sheet- like structure. There are several ways that non-foliated rocks can be produced. Some rocks, such as limestone are made of minerals that are not flat or elongate. No matter how much pressure you apply, the grains will not align!

Generally speaking, non-foliated metamorphic rocks were created under extremely high temperatures and very low, even amounts of pressure. These rocks typically cooled very slowly, allowing the minerals within them to form large, uniform crystals that are tightly packed together.

Different types of rocks and minerals can form non-foliated metamorphic rocks. Quartzite is made of metamorphosed sandstone, while marble is formed from limestone that was metamorphosed. Hornfels have no specific composition while amphibolites are formed from hornblende and plagioclase.

Although non-foliated rocks may have small bands of different colors, the crystals that form them generally have no visible organization.

**What are Metamorphic rocks used for?** Slate is most often used as a roofing material, decorative gardening stone, the base for tables. Marble is another one of the metamorphic rocks and is a metamorphosed limestone. Marble remains a popular building and sculpture material today. It can also be ground down to make cleaning products or soaps. Schist is another metamorphic rock that is formed from either mud or shale. It is used for paving and occasionally

sculpture. However, schist is formed at a much higher temperature than slate is. It is a fairly weak rock so it does not make for a good building material.

1. ***Use the dictionary and write down transcriptions and translations of the words given below.***

constitute, cementation, luster, pressure, evaporate, abundance, dissolve, equivalent, elongate, eruption, extract, determine

1. ***Give English equivalents to the following Ukrainian words and word combinations. Make up your own sentences.***

коефіцієнт,швидкість, інтенсивність; дебріс (уламки); величина, кількість; твердий, тверде тіло; зовнішній вигляд

1. ***Match the definitions*.**
   1. texture
   2. sediment
   3. pedology
   4. liquid
   5. matter
   6. metamorphic rock
   7. sedimentary rock
   8. igneous rock
   9. extrusive rock
   10. intrusive rock
       1. Sedimentary or igneous rock altered by great heat or pressure, e.g. limestone changed to marble.
       2. The term for a rock formed when molten rock cools and hardens.
       3. Volcanic, igneous rock cools on the surface as lava.
       4. The scientific study of soils, including their origins, characteristics, and uses.
       5. Rock formed from accumulated sediments. Examples are clay, sandstone, and limestone.
       6. Igneous rock forms when molten rock cools underground. The distinctive physical composition or structure of something, especially with respect to the size, shape, and arrangement of its parts: the texture of sandy soil; the texture of cooked fish.
       7. Solid fragments of inorganic or organic material that come from the weathering of rock and are carried and deposited by wind, water, or ice.
       8. Having a flowing quality; fluid.
       9. That which occupies space and has mass; physical substance.
2. ***Match the synonyms.***

|  |  |
| --- | --- |
| to accumulate | liquid |
| to deposit | volcanic |
| fluid | to collect |
| igneous | firm |
| solid | matter |
| weathering | erosion |
| substance | to put or set down |

1. ***Fill in the blanks with the proper words. Change the form if necessary.***

#### sediment/sedimentation/sedimentary

* 1. is a material that settles to the bottom of a liquid; lees.
  2. Sandstone is a rock.
  3. Rock formed by .

#### deposit/deposition

1. can include layers of sand and mud.
2. They examined the of sand and gravel on the river bed.
3. I over $3,000 this afternoon.

#### compress/compression/compressibility/compressible

1. Some materials easily.
2. The author 80 years of history into 15 pages.
3. Paper is a packing material.
4. is a force that tends to shorten or squeeze something, decreasing its volume.
5. Properties to be tested are: , water absorption and porosity.

#### nuclear/nucleus/nucleation

1. is a central or fundamental part or thing around which others are grouped; core.
2. When a radioactive element gives off a neutron, for example, we call this a event.
3. is the initial process that occurs in the [formation of a crystal](http://www.britannica.com/science/crystallization) from a solution, a liquid, or a vapor.
4. ***Put 7 – 10 key questions to the text*.**
5. ***Indicate the category of the words: Element or Rock?***

[tungsten](http://en.wikipedia.org/wiki/Tungsten), [tin](http://en.wikipedia.org/wiki/Tin), [gabbro](http://en.wikipedia.org/wiki/Gabbro), [uranium](http://en.wikipedia.org/wiki/Uranium), [granite](http://en.wikipedia.org/wiki/Granite), [diorite](http://en.wikipedia.org/wiki/Diorite), [platinum](http://en.wikipedia.org/wiki/Platinum),[chromium](http://en.wikipedia.org/wiki/Chromium).

1. ***Make a list of chemical elements used in this chapter. Restore the context they are used in*.**
2. ***Say the following in English and Ukrainian:***

O, Si, Al, Mg, Fe, Ca, Na and K

1. ***Control points:***
   1. Name the sciences which are closely related to the Earth study. What does each of these sciences study?
   2. Speak about Igneous rocks; their types. Texture and geological significance.
   3. What are Sedimentary rocks? Four types of sedimentary rocks.
   4. What are Metamorphic rocks? Foliated and Non-foliated metamorphic rocks.
   5. What are mentioned above types of rocks used for?
   6. Speak on the scientific theory of plate tectonics.

### ADDITIONAL READING

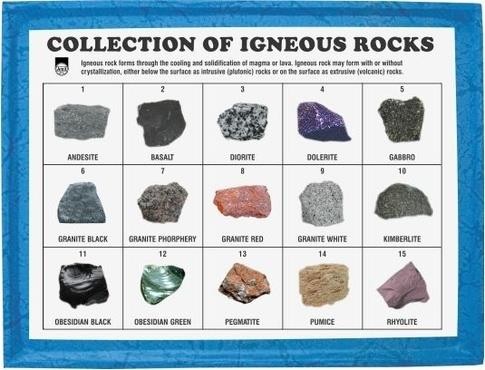
### IGNEOUS ROCK CLASSIFICATION

Igneous rocks are grouped on the basis of texture and mineral assemblage. Compositional categories based on silica content also apply to magma types that cool to form different types of volcanic rocks: komatiite (ultramafic), basalt (mafic), andesite (intermediate) and rhyolite (felsic). If the same magma cools to form intrusive igneous rock, the corresponding rock names are peridotite (komatiite), gabbro (basalt), diorite (andesite) and granite (rhyolite). Differences in magma composition are reflected by the mineral assemblage, or variety and abundance of different minerals, in an igneous rock.

1. Ultramafic rocks include peridotite (olivine-pyroxene rock), dunite (olivine rock) and pyroxenite (pyroxene rock). These rocks are predominantly intrusive in nature throughout Earth history. Volcanic equivalents, known as komatiites, primarily existed during early Earth history, and there are no known modern examples. The Earth's mantle is thought to be composed of peridotite.
2. Mafic rocks are black, dark gray or dark green in color, and composed primarily of olivine, feldspar (calcium plagioclase) and pyroxene. Basalt, aphanitic but locally porphyritic or vesicular mafic volcanic rock, is the most abundant igneous rock of the Earth's crust, forming the ocean floor and volcanic oceanic islands. Gabbro is the phaneritic intrusive equivalent of basalt, and composes the deeper ocean crust.
3. Intermediate rocks are medium-gray color, and composed of amphibole and feldspar (intermediate plagioclase) together with some pyroxene and biotite. Andesites, locally porphyritic, are intermediate volcanic rocks found in volcanic chains on continental margins and in island arcs above subduction zones. Diorite is the phaneritic intrusive equivalent of andesite, and comprises many of the batholiths found associated with subduction processes.
4. Felsic rocks are light-colored, locally glassy (obsidian), and composed of quartz and potassium feldspar with minor sodium plagioclase, biotite and amphibole. The volcanic rock, rhyolite, characterizes continental volcanoes and is typically associated with extremely explosive volcanic activity. The explosive nature of rhyolite volcanism reflects the magma's high viscosity and gas content relative to mafic or even intermediate magmas. Granite is the phaneritic intrusive equivalent of rhyolite, and comprises many of the batholiths found within continental crust. Pegmatite is extremely coarse-grained granite, that forms from residual, water-rich magmatic fluids.

In addition to composition, pyroclastic rocks are further subdivided according to fragment size and type:

1. tuff is a pyroclastic volcanic rock consisting of broken crystals and pieces of volcanic glass less than 2 mm in diameter. Welded tuffs occur where particles were hot enough to fuse together after coming to rest.
2. volcanic breccia is a pyroclastic volcanic rock composed of consolidated, angular volcanic particles greater than 2 mm in diameter.



# UNIT IV. MINERALS: TYPES AND PROPERTIES

#### Science Vocabulary

|  |  |
| --- | --- |
| property | властивість, якість |
| artificial | штучний; синтетичний |
| to imply | 1. мати на думці (на увазі); натякати 2. містити в собі; значити, мати значення |
| silicate minerals | силікатні мінерали |
| distinction | 1. різниця; розбіжність; відмінність 2. характерна ознака, особливість, 3. розрізнення, розпізнавання |
| abundant | поширений, рясний, багатий (на щось – in) |
| to evaporate | 1. випаровувати(ся), згущати(ся) 2. перетворювати(ся) на пару |
| cleavage | 1. розщеплення 2. розходження; розкол 3. *гірн*, шаруватість, кліваж, спайність |
| luster (lustre) | блиск, глянець; лиск |
| streak | смужка (нерівна) ; жилка, прожилок |
| density | густота, щільність |
| scratching | скрипіння; дряпання |
| mica | слюда |
| to extract | здобувати, одержувати, видаляти, вилучати |
| hardness | твердість; щільність; цупкість; міцність, жорсткість |
| decompose | розкладати(ся); гнити; розчиняти(ся) |
| fracture | тріщина; надлом, злом; розрив |

***Read and translate the text***

### MINERALS: TYPES AND PROPERTIES

Did you know that even though thousands of minerals have been named, only about a dozen are common in the Earth’s crust? Sophisticated laboratory equipment exists for determining the exact chemical composition of minerals, yet sometimes the most essential tools in geology are a magnifying lens and a penknife. Using just these tools, scientists can identify about 90% of what they encounter in the field.

*A mineral* is a naturally occurring inorganic solid with a definite crystalline structure and fixed chemical composition. This implies that a mineral must be found in nature. Artificial substances, including synthetic crystals, are not minerals. It is also important to note that minerals are *inorganic* having little or no carbon. There are some minerals such as Calcite (CaCO3) or Diamonds C where the distinction is hard to make. All minerals are characterized by a definite crystalline structure. Two compounds of the same chemical composition may have different crystalline structures and would therefore be different minerals. In a similar manner each mineral has a fixed chemical composition. Two crystals of the same structure would be different minerals if their chemical compositions were not the same.

There are over 1,500 known minerals, each of which is defined by physical properties dictated by its crystal structure and chemical composition. Of these numerous mineral *species* (a mineral distinguished from others based on unique physical and chemical properties) only a handful are common and just a few are important *rock forming* (most abundant constituents of rock) minerals.

Minerals are divided into different groups based on their chemistry.

*Silicate minerals*

The most common mineral group on Earth is the silicate minerals, which all have the elements silica and oxygen as their main ingredients. Most silicate minerals form when molten rock cools, either at or near the Earth’s surface or deep underground.

*Non-silicate minerals*

There are many different groups of other minerals that are known as non-silicate minerals. Some of these groups form when magma cools, while others form when water evaporates away leaving mineral crystals behind, or when other minerals decompose. Properties of Minerals

Minerals are classified by their chemical composition and crystal structure. These two features occur on a microscopic level, but we can see them in other ways because they determine a mineral’s observable physical properties. In other words, what appears to us on the outside is determined by what’s on the inside.

The seven physical properties of minerals are:

* crystal form
* hardness
* fracture or cleavage
* luster
* color
* streak
* density.

Let’s see how each one helps identify a mineral.

*Crystal form* is the outward expression of the orderly arrangement of atoms inside the mineral. What you are seeing is the actual arrangement and structure of the atoms in that mineral. For example, look at some everyday table salt, which is a combination of sodium and chlorine. Normally, what you see is a salt cube, but if you were to break this cube down into smaller parts, it would simply break into smaller and smaller cubes because that is how the atoms are arranged.

*Hardness* is how resistant a mineral is to scratching, not how easily it breaks. Hardness depends on the bonds within the mineral, so the stronger the bonds, the harder the mineral. Mineral hardness is measured on the Mohs scale of hardness, which compares the hardness of different minerals.

Diamond is considered the hardest mineral, so it’s a 10 on the Mohs scale of hardness. Talc has a very weak bond between its atoms, and so it’s a 1 on the Mohs scale of hardness. If it helps, you can think of the hardness of talc in relation to the hardness of your fingernail, which is about a 2.5.

*Fracture and cleavage* describe how a mineral breaks. Some minerals break very nicely along smooth planes, and this is called cleavage. Minerals break this way because their atoms are arranged so that they break apart from each other along these planes. Mica is an example of a mineral that has cleavage. If a mineral fractures, it breaks in uneven ways that are not flat or parallel. Again, these minerals break like this because that’s how their atoms are arranged.

*Luster* is how reflective a mineral is. Minerals are usually either classified as having metallic luster, which is very shiny or reflective, or non-metallic luster, which is not shiny and is very dull.

Some minerals can be identified by their color, but some minerals, such as quartz, come in many colors. *Streak* is often a better way to identify a mineral, which is the color that shows up when a mineral is scraped across an unglazed porcelain plate. However, minerals with non-metallic luster all have a white streak, so this is really only helpful for minerals with a metallic luster.

Finally, the *density* is how tightly packed the material of the mineral. Minerals that are denser have more tightly packed atoms than those that are less dense.

Minerals are in just about everything. That computer you’re using? It’s full of them. Do you have any jewelry? All of those stones and the gold or silver that they are made of are minerals. The copper wiring in your house, the aluminum foil in your kitchen drawer, the nails holding your pictures on the wall, those are all minerals!

Precious stones and gemstones are things that you are likely quite familiar with. They are rubies, diamonds, emeralds and the like. Metals, like gold, silver, copper, lead, iron, zinc and aluminum are extracted from ore, and the process of extracting these minerals is called metallurgy. Fossil fuels, like coal and petroleum, are also minerals that you are probably quite familiar with. These power our cars and heat our homes.

*Minerals are inorganic compounds that are classified by their physical properties. The physical properties of minerals define their unique features, such as color, luster and density. While minerals do have unique properties, they must all be solid, naturally formed, have a unique chemical composition and have a crystalline structure.*

*Minerals are not evenly distributed across Earth, nor are they shared equally once they have been extracted from the ground. Because so many types of minerals are important in our everyday lives, they are in high demand and can cause conflict between those who can afford them and those who can’t.*

1. ***Use the dictionary and write down transcriptions and translations of the words given below.***

Mineral, fracture, luster, hardness, distributed, gemstones, metallurgy, copper, streak, cleavage

1. ***Give English equivalents to the following Ukrainian words and word combinations. Make up your own sentences*.**

Алмаз, кристалічна структура, твердий (властивість), мінерал, щільність, блиск, видобувати, силікатні мінерали, хімічний склад, розщеплення

1. ***Match the definitions*.**

|  |  |
| --- | --- |
| hardness | is the color of the powder left on a streak plate(piece of unglazed porcelain) when the mineral is  scraped across it |
| cleavage | refers to how light is reflected  from the surface of a mineral |
| minerals | the outward expression of the orderly arrangement of atoms  inside the mineral |
| density | ability to resist scratching |
| luster | inorganic compounds that are  classified by their physical properties |
| crystal form | is how tightly packed the materia  l of the mineral |
| silicate minerals | ability of a mineral to break  along preferred planes |
| streak | minerals, which all have the elements silica and oxygen as  their main ingredients |

1. ***Fill in the blanks with the proper words. Change the form if necessary*.**

#### define/definition

* 1. People themselves by the choices they make.
  2. At that time, there were two competing proposals for how to a standard unit of measure, or meter.
  3. We need a better of these terms.
  4. At last all minerals were according to their properties.

#### hardness/hard/dense/density

1. Diamonds are forever, and so is their extreme .
2. We were put to finish the examination in one hour.
3. There is some mistake about the of the times.
4. These coastal forests harbor a broad cross-section of wildlife species.
5. Instead, it is a measurement used by brewers to track the of certain ingredients.
6. ***Fill in the blanks using vocabulary from the text. Change the form if necessary*.**

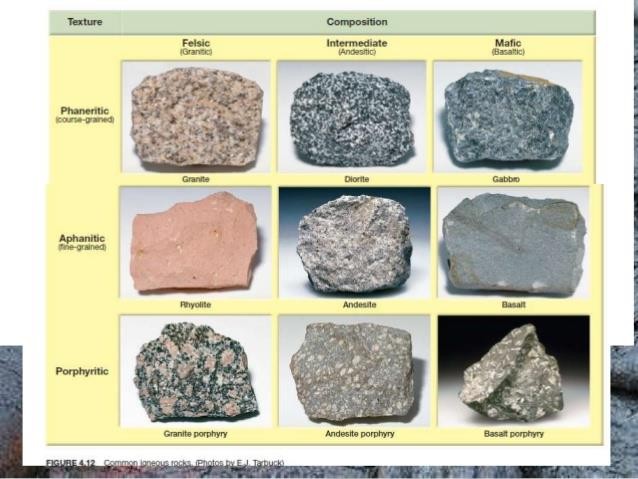
*Reflect inorganic chemical streak color lattice cleavage occur mineral hardness*

* 1. are naturally , , uniform materials that have definite and physical properties.
  2. Most minerals have a distinctive that can be used for identification.
  3. The of metallic minerals tends to appear dark because the small particles of the absorb the light hitting them.
  4. is a measure of the mineral’s resistance to scratching.
  5. Different break in different ways showing different types of .
  6. This is called the crystal .
  7. The mineral does not light like a metal.

***Match the synonyms.***

|  |  |
| --- | --- |
| molten | segmentation |
| cleavage | scattering |
| luster | sop up |
| distribution | density |
| hardness | liquid |
| streak | brilliancy |
| absorb | distinctive |
| distinguished | stripe |

1. ***Put 10 key questions to describe main types of minerals and their properties*.**
2. ***Prepare a report about minerals and their properties using key-points in the previous task and chart in annex 1 “Mineral Properties”.***



**UNIT V. WHAT IS LAND SURVEYING**

#### Science Vocabulary

|  |  |
| --- | --- |
| surveying | геодезія, зйомка (знімання) |
| large-scale | великомасштабний |
| measurement | вимірювання; вимір; розмір |
| mapping | креслення, нанесення на мапу (на карту); картографія |
| application | застосування, використання |
| plane surveying | горизонтальна зйомка  місцевості; топографічна зйомка без урахування кривизни |
| geodetic surveying | геодезична зйомка; зйомка рахуванням кривизни; вища геодезія |
| curvature | кривизна, згин |
| equipment | устаткування, обладнання; оснащення (дія) |
| acquisition | придбання, здобуття |
| plot | план, схема, графік, креслення; наносити дані |
| chart | схема, таблиця, діаграма, графік, карта, план; складати схему, карту; креслити графік |
| to stakeout | встановлення меж земельного наділу; провішувати лінію; застовпити |
| to delineate | встановлювати межі; окреслювати; креслити; намічати |
| sewage system | система каналізації |
| pipeline | трубопровід, нафтопровід |
| handheld tablet | планшет портативний для вводу координат |
| GPS receiver | GPS приймач |
| landing site | посадкова площадка |
| Landsat (land satellite) | штучний супутник для зйомки |
| spacecraft | поверхні Землі |
| inventory | матеріальні цінності; запаси |

******

***Read and translate the text***

### What is Land Surveying

**Surveying** has been traditionally defined as the science of making relatively large-scale, accurate measurements of the Earth’s surfaces; mapping relative positions above, on or under the surface of the ground. Surveying includes the determination of the measurement data, the reduction and interpretation of the data to usable form or establishing such positions from a technical plan.

Thus, surveying has two similar but opposite functions: (1) the determination of existing relative horizontal and vertical position, such as that used for the process of mapping, and (2) the establishment of marks to control construction or to indicate land boundaries.

Of course, the surveyor must be familiar with mathematics, especially the application of trigonometry. Most traditional surveying is *plane surveying,* which does not take into account the curvature of the earth. For most surveying projects, the curvature of the earth is slight enough that the effects can be ignored, greatly simplifying the calculations involved. For projects involving greater distances, the curvature of the earth must be taken into account; this is *geodetic surveying*, an application of geodesy.

In general, the work of a surveyor can be divided into five parts:

* 1. Research analysis and decision making; selecting the survey method and equipment, most likely corner locations, and so on.
  2. Field work or data acquisition; making measurements and recording data in the field.
  3. Computing or data processing; performing calculations based on the recorded data to determine locations, areas, volumes, and so on.
  4. Mapping or data representation; plotting measurements or computed values to produce a map, plоt, or chart, or portraying the data in numerical or computer format.
  5. Stakeout. Setting monuments and stakes to delineate boundaries or guide construction operations.

Surveying plays an extremely important role in many branches of engineering. As such, surveyors use elements of **mathematics** (**geometry** and **trigonometry**), **physics**, **engineering** and the **law**. For example, surveys are required to plan, construct, and maintain highways, railroads, buildings, bridges, tunnels, canals, land subdivisions, sewage systems, pipelines, etc. All engineers must know the limits of accuracy possible in construction.

Many improvements and refinements have been incorporated in all the basic surveying instruments. These have resulted in increased accuracy and speed of operations and opened up possibilities for improved methods in the field. Important technological developments starting in the late 20th century include the use of satellites as reference points for geodetic surveys and electronic computers to speed the processing and recording of survey data. Surveying equipment includes **total stations**, robotic total stations, GPS receivers, prisms, **3D scanners**, radios, handheld tablets, digital levels, and **surveying software**. Progress continued into the space program where new equipment and systems were needed to supply precise control for missile alignment and moon mapping of proposed landing sites. Electronic distance-measuring (EDM) equipment, laser devices, north- seeking gyroscopes, improved aerial cameras, inertial and Doppler surveying systems, remote sensors, and various-sized computers are but a few products of today’s technology now being directly applied in modern surveying with terrific impact. Landsat spacecraft provide images of global coverage for down-to-earth projects such as land cover inventories, natural resource mapping, water quality assessment, and flood control.

1. ***Use the dictionary and write down transcriptions and translations of the words given below.***

Spacecraft, require, speed, refinement, processing, alignment, gyroscope, record, software

1. ***Give English equivalents to the following Ukrainian words and word combinations. Make up your own sentences.***

Підтримувати, установлювати, маркшейдерська справа, гірнича геометрія, високоточне устаткування, оцінка якості води, повінь, застосовувати, впливати

1. ***Match the definitions.***
   1. surveying
   2. GPS
   3. mapping
   4. plot
   5. stakeout
   6. EDM
   7. plane surveying
   8. geodetic surveying
      1. The surveying of areas of limited size, making no corrections for the earth’s curvature;
      2. A radio system that uses signals from satellites to tell you where you are and to give you directions to other places;
      3. A branch of applied mathematics that is concerned with determining the area of any portion of the earth's surface, the lengths and directions of the bounding lines, and the contour of the surface and with accurately delineating the whole on paper;
      4. The surveying of the earth's surface, making allowance for its curvature and giving an accurate framework for smaller-scale surveys;
      5. An area of land that has been measured and is considered as a unit;
      6. To mark the location or limits of with stake;
      7. Can be used to place objects or points in three dimensions in relation to the unit;
      8. The act or operation of making maps.
2. ***Match the synonyms.***

|  |  |
| --- | --- |
| accurate | position |
| construct | precise |
| define | plotting |
| mapping | analysis |
| survey | build |
| computing | determine |
| location | processing |

1. ***Fill in the blanks with the proper words. Change the form if necessary.***

#### supply/supplier

* 1. Administration of the organization must the workers with uniforms.
  2. A large number of are active in the international coal market.
  3. America has a 300-year of coal.
  4. The brain requires a constant of oxygen.

#### survey/surveyor

1. Geological Survey is a document reporting the results of a .
2. The teacher is doing a of the literature on the subject.
3. Geological experts were commissioned the land.
4. is a person whose job is to survey buildings or land.
5. The land worked by triangulating the plot.

#### locate/location/locator/locatable

1. Surveyors are working the boundaries of the property.
2. These popular apartments are centrally .
3. These explored fragments of cultural entities are not clearly geographically .
4. Deposits of oil, gas, coal, phosphate, sodium, potassium, and oil shale on the land cannot be staked, that is why they are not .
5. A surveyor should determine the exact of the site.
6. This is a lovely for a house.
7. A person who determines or establishes the boundaries of land or a mining claim is called .
8. ***Put 7 – 10 key questions to the text*.**
9. ***Control points:***
   1. Give the definition of the term *surveying.* Speak on the functions of surveying*.* The role of surveying in engineering and modern industry.
   2. What is the main difference between *plain surveying* and *geodetic surveying*?
   3. What are the functions of surveyors? What does the work of surveyor implies?
   4. New technological developments in surveying.

# UNIT VI. OPEN-CAST MINING

#### Science Vocabulary

|  |  |
| --- | --- |
| open-pit mining | гірнича розробка відкритим способом |
| elimination | усунення, відсів |
| deposit | поклад, відкладати; родовище |
| tunneling | прокладання тунелів |
| dimension | величина, ступінь |
| quarry | кар’єр, відкрита розробка |
| to avert | запобігати (небезпеці, хворобі,тощо) |
| foliation | розшарування, розщеплення |
| shear | зріз, зсув |
| haul road | шлях буксирування |
| waste dump | гірничий цикл завантаження- обкатки-розвантаження; звалище |
| sulfide-minerals | сульфідні мінерали |
| de-watering | зневоднення, осушування |

******

***Read and translate the text***

### OPEN-CAST MINING

Open-pit mining, also known as open cast mining, open-cut mining, and strip mining, means a process of digging out rock or minerals from the earth by their elimination from an open pit or borrow. The word is used to distinguish this type of mining from extractive methods that need tunneling into the earth. Open-pit mines are used when deposits of commercially helpful minerals or rock are found close to the surface; that is, where the overburden (layer material covering the valuable deposit) is comparatively thin or the material of interest is structurally inappropriate for tunneling. For minerals that happen deep underneath the surface - where the overstrain is solid or the mineral happens as veins in hard rock - underground mining methods take out the precious material.

Open-pit mines that manufacture building materials and dimension stone are usually referred to as quarries. People in few of the English-speaking countries are not likely to make a difference among an open-pit mine and other kinds of open-cast mines, like quarries, borrows, placers, and strip mines.

Open-pit mines are characteristically engorged until either the mineral resource is exhausted, or a mounting ratio of overburden to ore makes more mining uneconomic. When this occurs, the exhausted mines are at times converted to landfills for disposal of solid wastes. Nevertheless, some form of water control is normally required to keep the mine pit from becoming a lake.

Open сut mines are dug on benches, which portray vertical levels of the hole. These benches are normally on four meter to sixty meter intervals, relying on the size of the machinery that is being utilized. A lot of quarries do not use benches, as they are normally shallow.

Most walls of the pit are normally dug on an angle less than vertical, to avert and lessen damage and hazard from rock falls. This relies on how weathered the rocks are, and the kind of rock, and also how a lot of structural weaknesses happen within the rocks, like a fault, shears, joints or foliations.

The walls are stepped. The inclined part of the wall is called the batter, and the flat part of the step is called as the bench or perm. The steps in the walls help avert rock falls continuing down the entire face of the wall. In some instances additional ground support is needed and rock bolts, cable bolts and concrete are utilized. De-watering bores might be used to ease water pressure by drilling horizontally into the wall, which is frequently sufficient to cause failures in the wall by itself.

A haul road is located at the side of the pit, forming a ramp up which trucks may drive, taking ore and waste rock.

Waste rock is piled up at the surface, near the edge of the open cut. This is known as the waste dump. The waste dump is also tiered and stepped, to lessen degradation.

Ore which has been processed is called as tailings, and is normally slurry. This is pumped to a tailings dam or settling pond, where the water fades away. Tailings dams may frequently be toxic due to the presence of unextracted sulfide minerals, few types of toxic minerals in the gangue, and frequently cyanide which is utilized to treat gold ore via the cyanide leach method.

1. ***Use the dictionary and write down transcriptions and translations of the words given below.***

open-cast mining, elimination, deposit, dimension, quarry, drilling, exhausted mines, foliation

1. ***Give English equivalents to the following Ukrainian words and word combinations. Make up your own sentences.***

метод добування; свердління, буріння; шахта; рідкий цемент; використати, утилізувати; обробляти; перенапружувати; яма, котлован; розробка відкритим способом; жильна порода; поглинати; хвостова дамба

1. ***Match the definitions*.**
   1. Open-pit mining is ….
   2. Open-pit mines are usually ….
   3. Open-cast mining may include …
   4. The exhausted mines are containers …
   5. Ore which has been processed is …
      1. … borrows, placers, quarries and strip mines;
      2. … quarries;
      3. … of solid wastes;
      4. … normally slurry;
      5. ... a process of digging out rock or minerals from the earth by their elimination from an open pit or borrow.
2. ***Fill in the blanks with the proper words. Change the form if necessary.***

#### mining/mine

1. is profitable and perspective nowadays.
2. Open-cast means a process of digging out rock or minerals from the earth by their elimination from an open pit or borrow.
3. Open-pit may be referred to quarries. watered/de-watering/watering
4. bores might be used to ease water pressure by drilling horizontally into the wall.
5. Violets need  .
6. To have a rich harvest you should keep your kale yard .

#### exhausted/exhausting

1. The job of a surgeon is extremely .
2. mines are at times converted to landfills for disposal of solid wastes.
3. After a hectic day Andrew was completely .
4. ***Match the synonyms*.**

|  |  |
| --- | --- |
| open-cast mining | to concern |
| to distinguish | to prevent |
| to avert | dehydration |
| to eliminate | to discern |
| de-watering | mining |
| extractive | open-pit mining |
| to refer | to remove |

1. ***Put 7-10 key questions to the text.***
2. ***Control points*.**
   1. The peculiarities of open-cast mining.
   2. The difference between open-pit mines and quarries, borrows, placers, and strip mines.
   3. Find the information about open-cast mining in Ukraine.
3. ***Read the texts from Additional reading.*** *Describe briefly each of the forms of mining.* ***Speak on the:*** *Environmental Risks of mining; how they arise and how their effects can be mitigated.*

### ADDITIONAL READING

### OPEN-CAST MINING

Open-pit mining, open-cut mining or open-cast mining is a surface mining technique of extracting rock or minerals from the earth by their removal from an open pit or borrow. The result of using this technique is a huge visible scar on the earth surface. Here is a list of 5 incredible open-pit mines.

* 1. Mirny Mine, Russia − Mirny Mine is an inactive diamond mine in Mirny, Eastern Siberia. It is the largest open diamond mine in the world and the second largest excavated hole in the world. It is 525 meters (1,722 ft) deep and has a diameter of 1,200 m (3,900 ft). The airspace above the mine is closed for helicopters because of incidents in which they were sucked in by the downward air flow!
  2. Bingham Canyon Mine, United States – The Bingham Canyon Mine, also known as the Kennecott Copper Mine, is an open-pit mine located in southwest of Salt Lake City, Utah. It is the largest and deepest excavated hole in the world: it is 0.6 miles (0.97 km) deep, 2.5 miles (4 km) wide! It was designated a National Historic Landmark in 1966.
  3. Kalgoorlie Super Pit (Super Pit gold mine), Australia – Australia’s largest open-cut gold mine. The pit is oblong in shape and is approximately 3.5 kilometres long, 1.5 kilometres wide and 570 metres deep. At these dimensions, it is large enough to be seen from space.

The Big Hole (Kimberley Mine), South Africa – An open-pit and underground mine in Kimberley, South Africa, and claimed to be the largest hole excavated by hand. It was open in 1871 and closed in 1914. Its 43-year lifetime, the 50,000 workers who used picks and shovels shifted 22.5 million tonnes of earth, yielding almost 3 tonnes of diamonds. It is 463 metres (1,519 ft) wide and was excavated to a depth of 240 metres (790 ft), but then partially infilled with debris reducing its depth to about 215 metres (705 ft). Since then it has accumulated about 40 metres (130 ft) of water, leaving 175 metres (574 ft) of the hole visible.

* 1. Diavik Diamond Mine, Canada – An active diamond mine that has become an important part of the regional economy, employing 700 and producing 1,500 kg (3,300 lb) of diamonds a year. Located on a small 20 square km island, it is just 220 km (140 mi) from the Arctic Circle and during the winter the water around it freezes over.

# UNIT VII. UNDERGROUND MINING

#### Science Vocabulary

|  |  |
| --- | --- |
| underground mining | підземна розробка |
| precious | дорогоцінний |
| to extract | вилучати |
| to facilitate | полегшувати |
| feasible way | доступний спосіб |
| copper | мідь |
| zinc | цинк |
| tin | олово |
| lead | свинець |
| sedimentary | осадовий |
| metamorphic | метаморфічний |

******

***Read and translate the text***

### UNDERGROUND MINING

Underground mining is carried out when the rocks, minerals, or precious stones are located at a distance far beneath the ground to be extracted with surface mining. To facilitate the minerals to be taken out of the mine, the miners construct underground rooms to work in. The mining company selects the best feasible way to get the minerals extracted out. Most mining is carried out using continuous mining that employs a continuous mining mechanism to cut the coal deposits from the walls. This means there is less of blasting and drilling and utilizes fewer miners down in the mines. It is safer than the yester year techniques of mining.

This kind of mining is done when the rock or mineral is on the side of a mountain. This makes it an easy, cheaper way to mine. Minerals that are mined with draft mining are gold, coal etc. with slope mining, the coal or mineral bed is located very deep and parallel to the ground. It is called a slope mine because the shafts are slanted. Shaft mining has a vertical man shaft, a tunnel where men travel up and down in an elevator. Shrinkage stoping is a flexible mining method for narrow ore bodies that need no backfill during stoping. Long wall mining consists of multiple coal shearers mounted on a series of self-advancing hydraulic ceiling supports. Retreat mining is the last phase of a common type of coal mining technique referred to as room and pillar mining. Retreat mining is a process that recovers the supporting coal pillars, working from the back of the mine towards the entrance, hence the word retreat. Room and pillar mining advances inward, away from the entrance of the mine. Other underground mining methods include Hard rock mining, bore hole mining, drift and fill mining, long hole slope mining, sub level caving and block caving.

Two prominent ways through which underground mining is done are:

#### Underground mining (hard rock)

Underground hard rock mining refers to various undergrounmining techniques used to excavate hard minerals, mainly those containing metals such as ore containing gold, silver, iron, copper, zinc, nickel, tin and lead, but also involves using the same techniques for excavating ores of gems such as diamonds. In contrast soft rock mining refers to excavation of softer minerals such as salt, coal, or oil sands.

#### Underground mining (soft rock)

Underground mining (soft rock) refers to a group of underground mining techniques used to extract coal, oil, shale and other minerals or geological materials from sedimentary ("soft") rocks. Because deposits in sedimentary rocks are commonly layered and relatively less hard, the mining methods used differ from those used to mine deposits in igneous or metamorphic rocks. Underground mining techniques also differ greatly from those of surface mining.

1. ***Use the dictionary and write down transcriptions and translations of the words given below.***

underground mining, feasible way, coal deposits, shaft mining, retreat mining, excavation, shale, precious stones, drilling.

1. ***Give English equivalents to the following Ukrainian words and word combinations. Make up your own sentences.***

Гірська порода; дорогоцінне каміння; відбирати; вилучати; доступний спосіб; руда; розробка відкритим способом; розробка підземним способом; магматичні породи; осадові породи; метаморфічні породи; розшарований; поклади; дорогоцінний камінь; робота з закладкою.

1. ***Match the definitions:*** 
   1. Underground mining methods are…
   2. Underground mining (soft rock) is …
   3. Retreat mining is …
   4. Underground mining (hard rock) means …
   5. Shrinkage stoping is…
      1. … a group of underground mining techniques used to extract coal, oil shale and other minerals or geological materials from sedimentary ("soft") rocks.
      2. … a flexible mining method for narrow ore bodies that need no backfill during stoping.
      3. … a process that recovers the supporting coal pillars, working from the back of the mine towards the entrance, hence the word retreat.
      4. **…** hard rock mining, bore hole mining, drift and fill mining, long hole slope mining, sub level caving and block caving.
      5. … various underground mining techniques used to excavate hard minerals, mainly those containing metals such as ore containing gold, silver, iron, copper, zinc, nickel, tin and lead, but also involves using the same techniques for excavating ores of gems such as diamonds.
2. ***Match the synonyms*:**

|  |  |
| --- | --- |
| drilling | to dig out |
| sedimentation | valuable |
| to excavate | deposition |
| precious | to improve, to help |
| slope | boring |
| to facilitate | accessible |
| feasible | declivity |

1. ***Fill in the blanks with the proper words. Change the form if necessary*.**

#### sedimentary/sedimentation/sediments

* 1. Deposits in rocks are commonly layered.
  2. Sand and clay originated by .
  3. Such as gypsum, rock salt and chalk have great practical value.

#### recover/recovery

1. His from pleurisy for such a short time was a real wonder.
2. Retreat mining is a process that the supporting coal pillars, working from the back of the mine towards the entrance, hence the word retreat.
3. People in Los Angeles will never from the last earthquake.

#### mined/mining

1. company selects the best feasible way to get the minerals extracted out.
2. Underground techniques also differ greatly from those of surface mining.
3. Granite, gabbro and basalt are in Zhytomyr Region.
4. ***Put 7-10 key questions to the text.***
5. ***Control points:***
   1. Fundamentals of underground mining.
   2. Compare the methods of soft rock and hard rock underground mining.
   3. Other underground mining methods.

### ADDITIONAL READING

# UNDERGROUND MINING DEVELOPMENT

# Underground mining has been around for centuries; its techniques improving over years of developing new processes and technologies. At the surface, mining may seem as simple as digging tunnels or shafts. Earth excavation, however, is both dangerous and difficult to execute properly without the right types of processes in place. Underground mine development seeks to refine approaches and ensure safety while acquiring needed materials.

# Depending on the mining techniques used, some underground mining projects may increase or reduce productivity. Careful consideration should be given to factors such as: size, shape, orientation of ore body, strength of rock materials, and all depths involved.

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# How Are Underground Mines Created?

# Underground mining has changed a lot over the years, since the 19th century when men started using shovels to tote canaries and make sure that the air underground was not toxic. The modern mines feature extensive water-drainage and ventilation systems including high-tech communication networks with computerized machines in order to reduce the number of humans that are required underground.

# Most mines normally have crucial components in common such as ventilation shafts and clear toxic fumes for blasting and drilling, access shafts to help lower equipment and workers and escape routes. They also contain ore-transportation tunnels, communication systems that can send information back and forth from deep within the earth and recovery shafts that can carry excavated ore back to the surface. However, no two mines are usually alike, and technological advances and application on the design and mining methods have greatly changed. These also rest on considerations such as:

# The composition of the rocks,

# The ore being mined

# The orientation of the ore deposit,

# Simple economics

# The geological features found underground, and

# The determination of hard or soft mining.

# Hard-Rock Underground Mining

# There are some hard-rock underground mines and soft-rock underground mines. For instance, coal deposits are usually found in soft sedimentary rocks, while gold deposits live in metamorphic igneous hard rocks, and so does copper, diamond, silver, zinc and nickel.

# Block caving

# This is a common hard-rock mining method that’s typically used to mine low-grade ore. It is a process where drilling a section of the ore at the very bottom of the deposits is done before blasting to make the roof collapse. The gravity then takes over as the ore above the blast collapses and any succession support is withdrawn. This collapsed ore is then hauled out of the mine for further processing.

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## Soft-Rock Underground Mining

For coal, uranium, salt, oil shale and phosphate you will be forced to mine in soft rocks. This is where they live and the two main methods are longwall and room and pillar mining procedures. Most of the coal is extracted using room and pillar approaches.

**Room and Pillar Mining**

This is used for seams and it is a relatively gentle and flat dipping process. The ‘room’ and ‘large’ pillars are mined for coal and left behind to support the weight of the rock layers and overburden above.

This type of the mining process is traditionally used for underground mining in Colorado and [results in at least 75% recovery of coal seam](https://www.dep.pa.gov/Business/Land/Mining/Pages/Underground-Coal-Mining.aspx).

**Longwall Mining**

This refers to a mechanized method of coal mining where the coal shearer is mounted between a self-advancing hydraulic roof and conveyor system. The machine then moves along the panel of coal to about 820 feet. This is almost completely automated. While the coal is removed and transported through the conveyer, the roof supports are also removed, thus allowing the roof to collapse into the void. [This method results in at least 90% of coal mining](https://www.dep.pa.gov/Business/Land/Mining/Pages/Underground-Coal-Mining.aspx) but it is likely to cause the surface subsidence features.

## Common Parts Of The World Where Underground Mining Is A Large Industry

There are many industries in the world relying on the supply of mineral commodities from underground mining, and the dependency on high-tech industries. Coal is actually one of the leading global energy resources. Additionally, the mining sector is quite pivotal to the economy of the world, and the revenue for the top 40 global mining companies represents a majority of the whole industry. This amounted to approximately [650 billion US dollars in the year 2020.](https://www.statista.com/topics/1143/mining/)

The top areas of the world contributing largely to underground mining include:

* The US – primarily Colorado
* Australia
* Brazin
* Canada
* China,
* Russia
* South Africa
* The EU

## Company Requirements Before Starting Underground Mining

Companies wishing to get involved in underground mining should first ensure they fulfill the following requirements;

* Specific mile plan for operations
* Bonding, patterns and reclamation plans
* Acquired permits for water pollution – this should include discharge permit, discharge pollutant elimination system, stormwater pollution prevention, a countermeasure plan and spill prevention control.
* Air quality permits
* Artificial pond permits
* Hazardous materials waste permits
* Water rights
* Well-drilling permits
* Right of way authorizations, access and road use authorizations

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## AMS Providing Underground Mining Services

We are experts in construction, maintenance, and rehabilitation for mining projects of all sizes. We work to ensure that each mining project is given the opportunity to capitalize on the advantages of different types of mining approaches, techniques, and much more.

Our [AMS contractor services](https://americanmineservices.com/) are in high demand, helping contractors to improve processes, facilitate oversight, and provide oversight for a number of different mining projects.

* Underground Development
* Contract Operations and Training
* Equipment and Facility Installation
* Mine Rehabilitation
* Mine Sealing
* Drill and Blast
* Rock Excavation
* Ground Support
* Tunneling
* Highwall Work

**MINE TUNNELING**

The [mining industry](https://www.energy.gov/eere/amo/mining-industry-profile) is expansive with many different approaches depending on the needs of each project. It may not seem obvious, but the general public requires many kinds of materials, minerals, and other components derived from the Earth for everyday living. One example might be zinc which is frequently used in household items, cosmetics, and more. Depending on the types of material mined, there are various methods for extraction. Mine tunneling is one such method and one that dates back centuries.

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## Different Types Of Mining

Mining operations are essential due in part to the many variant products we require for everyday use. Mining, without a doubt, is a key component of our lives. But how do mining operations work and what are the [different types of mining](https://americanmineservices.com/different-types-of-mining/)?

Mining methods include:

* Surface mining
* Underground mining
* Placer mining
* In-situ mining

When we talk about underground mining, operations may also include more specific approaches such as Room and Pillar Mining, Block Cave Mining, and Longwall Mining.

### Tunneling Systems Used In Mining

Mining tunnels are essential to access, extract and transport underground ores. What are underground ores? Ores are just another way of framing materials that are naturally occurring solid materials. Some of the more important ore deposits include copper, silver, and iron. Underground mining is focused on finding the ore through cost-effective measures and increasing efficiencies that would otherwise be offset by open pit sources.

It’s important that material extraction also has as little waste as possible. In order to access underground mines, entryways are created through horizontal and vertical tunnels, sometimes referred to as:

* [Adit](https://en.wikipedia.org/wiki/Adit) – entrance to underground mine
* [Shaft](https://www.britannica.com/technology/shaft-excavation) – vertical access hole that stretches down to the location of an ore
* [Decline](https://en.wikipedia.org/wiki/Underground_hard-rock_mining) – can sometimes be a spiral tunnel that helps to access ores

Mine tunnels are used to help access deeply buried ores in a more effective manner than surface or open-pit mines techniques.

## Mining Techniques For Tunnel Construction

The most crucial aspect of mine tunneling is its use and ability to properly function. It requires attention to construction and engineering to ensure safety measures are taken at every step of mine development. Not only are mine tunnels needed to extract materials and even precious metals, but their access points require keeping equipment and, most especially, miners safe.

Excavating earth materials and dirt in order to construct a mine tunnel underground means dealing with unstable materials. As with most mine operations, there is some level of danger. In fact, in August 2022, [10 miners in a Mexican mine operation](https://www.business-humanrights.org/en/latest-news/mexico-ten-miners-still-trapped-in-coal-mine-after-tunnel-collapse-caused-three-shafts-to-flood/) were trapped in a mine tunnel for three days underground due to flash flooding.

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### What Keeps Tunnels from Collapsing?

Earth materials are inherently compressive. Moving materials for mine tunneling is no easy feat and requires sound planning and execution. Everything must be taken into consideration including the weight of the soil and rock being moved. Building a tunnel through ground materials disrupts how these sediments exist naturally. For mine construction, this means replacing existing support with an alternative. For this reason, mine tunneling uses materials such as concrete and steel to ensure reinforcement for the newly constructed tunnel.

The shape of the tunnel also matters as it can help distribute equilibrium to ensure that the tunnel does not collapse. For the engineers working with tunnels, much of their techniques and approaches don’t differ all that widely from budget engineering. They consider statics which is used to describe how the following forces can interact and distribute equilibrium. This considers all of the following:

* **Tension** – used to describe the expansion and pulling on existing materials
* **Compression** – used to describe how materials are shortened and squeezed
* **Shearing** – causes part of the materials to slide past one another in different directions
* **Torsion** – twisting of material

As mentioned, mine tunnels should consider reinforcement materials such as masonry, steel, iron, and concrete. Mine tunneling must also consider how to withstand loads placed on them.

## Mine Tunneling & Construction

Depending on where a tunnel is built, mine experts must consider the types of materials that the tunnel will pass through. For example, mine tunneling through software will require a different technique compared with tunneling through rocks like shale, chalk, and even sandstone.

Planning for mine tunneling is critical. Engineers and mine service providers should conduct a thorough analysis, research, and other items to determine how a tunnel project will be put together. Assessment for risks should always be conducted. Engineers and mine tunneling experts should consider many different factors including:

* Soil and rock types
* Weak beds and zones, including faults and shear zones
* Groundwater helps to reveal flow patterns and even pressure
* Hazardous items such as heat, gas, and fault lines

More importantly, mining construction companies should consider the fact that a tunnel may very well pass through multiple types of material and encounter hazardous zones. With mine tunnel planning can help decrease risks of delay and other liabilities that can occur after a project is already underway.

After the planning phase, mine tunneling experts should then focus on excavation plans and construction to ensure the proper execution of mine tunnels. Tunnels are constructed through a very particular process that involves blasting, boring, and even digging by hand.

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## Future Of Mine Tunneling

As mining operations become more complex and advance with new tools, engineers continue to approach tunnels that are both larger and longer. [Advanced imaging technology](https://science.howstuffworks.com/engineering/structural/tunnel.htm) can help mine construction companies more reliably scan products inside the earth by computing sound waves traveling through the ground. These types of tools can help clarify a tunnel’s potential environment by giving a better picture of rock and soil types and other faults or fissures that may interfere with the production of a mine tunnel.

Rather than use concrete or steel to reinforce exclusive, there are new ways of creating concrete using resin and other polymers.

## AMS Mine Construction Company

Now that the tunnel has been secured and is stable, you can then begin the next explosion of the process. Additional calculations and measurements must be made in order to ensure the safe and effective construction of mine tunnels. For [underground mining development information go here](https://americanmineservices.com/underground-mining-development/).

AMS has over 50 years of experience in evaluating, designing, and constructing mines and tunnels for a variety of construction needs nationwide. Some projects that we’ve recently been awarded are the [Crystal Creek dam improvement](https://americanmineservices.com/crystal-creek-dam-improvements/) project and the [Fort Dodge Wall structure solicitation](https://americanmineservices.com/ams-has-been-awarded-fort-dodge-wall-structure-solicitation/). [Contact us](https://americanmineservices.com/contact/) with any inquiries.

# UNIT VIII. MINE MANAGERS

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#### Science Vocabulary

|  |  |
| --- | --- |
| manager | керівник |
| to be responsible for | бути відповідальним |
| supervising | контроль, нагляд |
| overseeing | здійснення нагляду, контролю |
| tunneling | прокладання тунелю |
| checking | перевірка |
| inspecting | обстеження, огляд |
| to carry out | здійснювати |
| duty | обов’язок |
| hiring staff | наймання штату працівників |
| liaising | підтримування зв’язку |
| negotiating | ведення переговорів |
| supplier | постачальник |
| contractor | підрядчик |
| stakeholder | пайовик, партнер |
| guidelines | офіційні нормативи |
| maintenance | підтримка |
| emergency | непередбачений випадок |
| current state | сучасний стан |
| to gain | заробляти, довіряти |
| to appoint | призначити, затвердити |
| to keep up | підтримувати, продовжувати |
| to keep out | усувати, уникати |
| the most critical thing | найбільш важлива річ |
| to conduct the meetings | проводити зустрічі |
| original capacity | початковий обсяг |
| to achieve | досягати, отримувати |
| subsidence | осідання (порід) |
| environmental impacts | вплив на навколишнє середовище |
| reducing injury rates | зниження рівня травматизму |
| improvement | поліпшення, вдосконалення |
| frustration | розчарування |
| to increase productivity | підвищити продуктивність |
| to decrease/ reduce our unit costs | зменшити собівартість |

***Read and translate the text***

### MINE MANAGERS

Mine managers are responsible for planning, organizing and supervising the activities of a mine. They are responsible for planning future mine production, overseeing the development and tunneling of the mine, checking the quality of stone, rock and minerals and inspecting the mine for danger. Mine managers also carry out generic management duties, such as hiring staff, organizing staff training, overseeing financial administration, and liaising and negotiating with suppliers, contractors and other stakeholders. They also ensure occupational health and safety guidelines are followed, which includes planning and overseeing maintenance of the mine and developing emergency response plans.

#### An Interview

***Australian Mining:*** *What are your primary roles and responsibilities in your job? Give us a day in your working life.*

**John Turner:** My primary role is to oversee and manage the safe and efficient operation of what is a large and busy mine. The mine is managed in accordance with its management operating system which is Mandalong's "Business Management Framework".

A typical day consists of starting early and getting up to date with the current state of operations and any issues that may require further actions by others or me. From there it is attending review and planning meetings in line with the Business management Framework and working with members of the Mandalong's Senior Management Team to ensure the mine is working as efficiently as possible.

***AM:*** *What training/education did you need for your job?*

**JT:** I studied Mining Engineering at The University of New South Wales (UNSW), graduating in 1986.

***AM:*** *How did you get to where you are today? Give us a bullet point career path.*

**JT:** Studied Mining Engineering at UNSW 1982 to 1985. During this time gained experience in both underground and open cut coal mining during university vacations.

Commenced work as a miner with Allied Constructions in 1985.

In 1987 employed as a junior mining engineer and worked at Angus Place Collieries.

Undermanagers Certificates of Competency and commenced as an Undermanager in 1992 and then later as a Senior Mining Engineer in 1997.

Appointed as Mine Manager of Centennial Coal's Mandalong Mine in 2006 and I’m currently in that position.

***AM:*** *What tools and/or software do you use on a daily basis?*

**JT:** Main tools are an office, laptop and a phone - even when off site it is easy to keep up to date with activities at the mine. We use the Pulse System for the majority of management tasks and, by necessity, know enough about the various Microsoft Office applications to keep out of trouble.

But the most critical thing is having an office or meeting rooms to conduct the meetings that are critical to efficient planning and performance review.

***AM:*** *What is the one thing that you are most proud of in your professional life?*

**JT:** I am lucky to have been the Mine Manager of Mandalong as it has grown from its original capacity of 3.5 mtpa (million tonnes a year) to its current production levels of up to 5.5 mtpa. The fact that we can achieve those levels of production from a mine that has been designed to minimize subsidence and other environmental impacts makes me very proud.

***AM:*** *Biggest career challenge?*

**JT:** Reducing Injury rates - I have seen a major improvement in safety over my time in the industry, but injury rates are still too high despite a lot of effort to identify and act on the causes.

***AM:*** *What is your biggest frustration in your job?*

**JT:** My biggest frustration is trying to get everything done and still spend enough time underground to ensure that I really understand what is going on, to keep track of standards, to understand opportunities for improvement etc.

***AM:*** *What is the biggest challenge facing your business?*

**JT:** Our biggest challenge is to continue to increase productivity and decrease our unit costs. There have been major increases in a lot of our inputs costs due to competition for labor and equipment, new taxes etc. and at the same time we are looking at significant reductions to coal price so we must reduce our cost per tonnes to ensure the mine generates an acceptable return on the major investment.

***AM:*** *Is there anything else about your job you want Australia to know about?*

**JT:** Mandalong shows that high production levels can be achieved with a minimal impact to the environment, and I am very proud to be part of that achievement.

1. ***Use the dictionary and write down transcriptions of the words given below*.**

supervising, negotiating, supplier, guidelines, maintenance, emergency, efficient, Business Management Framework, issue, further, ensure, Allied Constructions, colliery, majority, minimize, identify, significant reductions, acceptable, Australia.

1. ***Give English equivalents to the following Ukrainian words and word combinations. Make up your own sentences*.**

Перевірка якості каменю, породи і мінералів; переговори з постачальниками, підрядниками та іншими зацікавленими сторонами; забезпечити охорону здоров’я і безпеку; наглядати за безпекою та ефективною діяльністю; планувати зустрічі відповідно до…; ефективно наскільки це можливо; призначений директором шахти; навіть, коли знаходишся за межами шахти; щоб уникнути неприємностей; щоб забезпечити шахту.

1. ***Match the definitions*.**
   1. capacity
   2. manager
   3. inspecting
   4. mine
   5. framework
   6. open cut
   7. tool
   8. subsidence
   9. equipment
   10. challenge
       1. Look at (someone or something) closely, typically to assess their condition or to discover any shortcomings;
       2. An essential supporting structure of a building, vehicle, or object;
       3. An excavation made in the open rather than in a tunnel;
       4. The ability to hold, receive or absorb;
       5. The necessary items for a particular purpose;
       6. A call to someone to participate in a competitive situation or fight to decide, who is superior in terms of ability or strength;
       7. The gradual sinking of landforms to a lower level as a result of earth movements, mining operations, etc.;
       8. An excavation in the earth for extracting coal or other minerals;
       9. A device or implement, especially one held in the hand, used to carry out a particular function;
       10. A person responsible for controlling or administering an organization or group of staff.
2. ***Fill in the blanks with the proper words. Change the form if necessary.***

#### productivity/productive/product

* 1. He nursed the farm back to .
  2. There has been an increase in .
  3. Each has been coded.
  4. This may contain nuts.
  5. Most of us are more in the morning.
  6. The meeting was of several good ideas.

**efficient/efficiently/efficiency**

1. Our new air conditioner is more than our old one.
2. Open ditches drain very .
3. Because of her , we got all the work done in a few hours.
4. She looks and as cool as a cucumber.
5. The whole tax system is now operating more .
6. She did her job with emotionless .
7. Lighting is now more energy .

#### improvement/improve

1. Are you making some to your home?
2. The weather toward evening.
3. Many wines with age.
4. We're aiming for a big .
5. He fathered the plan.
6. This operation will greatly her chances of survival.
7. We read to our vocabularies.
8. ***Match the synonyms*.**

|  |  |
| --- | --- |
| appoint | volume, magnitude |
| guidelines | nominate |
| responsible for | effect, influence |
| critical | in control of |
| achieve | discuss terms |
| capacity | attain |
| negotiating | censorious |
| impact | instructions |

1. ***Put 7 – 10 questions to the text.***
2. ***Control points*.**
   1. What responsibilities of a mine manager do you know?
   2. Explain, please, what does a manager`s typical day consist of?
   3. Give short information about the tools or software a manager uses on a daily basis.
   4. Tell a few words about the compressional boundary.
3. ***Read the text from Additional reading.***
4. ***Speak on the:*** Position Summary

### ADDITIONAL READING

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### POSITION SUMMARY

We are searching for a Manager, Manufacturing and Projects to direct Mining Service Operations for *Orica* across North America. This will include overseeing field manufacturing facilities, operations teams, fixed and mobile equipment, policies and processes, safety and quality assurance.

* Work closely with technical resources to assure that all products produced by NA (North America) Mining Services conforms *Orica* standards/specifications.
* Assure that all NA Mining Services plants are properly maintained and fully compliant with regional & local regulatory requirements and meet all *Orica* standards.
* Work with corporate & regional audit teams and regional Mining Services staff to inspect/verify applicable standards compliance at all NA operations & closely follow remediation efforts, as and if required, to resolution with country based leadership.
* Work with country based manufacturing teams on upgrades & improvement projects involving field manufacturing facilities that improve safety, operating efficiency and product quality.
* Direct overall NA Mining Services asset and equipment acquisition, upgrade and maintenance processes.
* Work closely with *Orica* Engineering and Projects department to assure all quotes & plant projects are provided at the most effective cost and employing the most efficient construction methods and are delivered to meet the needs of the business.
* Collaborate with procurement to develop a network of outside engineering companies, fabricators and construction contractors to erect & maintain Mining Services plant facilities across NA.

**MINE MANAGER**

We need Mine Managers because they provide leadership to ensure the safety, quality, cost-effectiveness and overall success of a mine. They manage the various teams running mining operations and are responsible for preparing operational plans and budgets, among many other projects.

**What is it Like to Work as a Mine Manager in Mining?**

Note: conditions vary according to employer and region.

Mine Managers work in an office in the mine site, and spend some time in the mine. They chair internal meetings and participate in other management meetings, lead large teams of people, contribute to the business management and act as an ambassador for the industry by working with other executives and the community.

**Why are People Attracted to this Career?**

Mine Manager are highly motivated to take on a senior position with challenging work, covering many different aspects of management. They take on tasks of high responsibility, and are well compensated for their efforts.

**Job Description**

* Maintain and encourage a safe work environment at all times
* Lead the mine operations management team and manage all mining personnel and resources
* Prepare operational plans for the mine, and monitor and report progress
* Propose capital expenditure projects to expand capacity or improve operations
* Prepare production and operating budgets, and report performance and costs
* Recognize operational, technical and safety challenges, take action to prevent or overcome them, and continuously seek improvement
* Contribute to business strategy to improve company’s competitiveness, profitability and growth
* Engage with local communities and regulatory authorities to ensure company policies are met
* Oversee new projects, (ex. Installing new mining equipment or opening a new shaft)
* Oversee the recruitment and development of superintendents, supervisors, and operators, providing support and guidance to build an effective workforce
* Manage relations with trade unions

**Education Requirement: Mining Engineering Degree or equivalent**

**Number of Roles Available: 1**

**Stage: Operations**

**Department: Mine Management**

**Job Purpose**

This is a key managerial role with overall responsibility for all activities in the underground mine. The Mine Manager heads the mine management team which controls mining operations, and is responsible for safety, quality, costs and achieving targets in relation to the mine plan. The Mine Manager interacts with other departments to ensure that his team has all information, equipment, manpower to achieve to mine plan safely with all legislative and company requirements followed. The role requires a high level of underground mining experience, leadership, communication skill, management expertise and the ability to manage change.

**Duties and Responsibilities**

* Establish and encourage a responsible, safe, productive and environmentally friendly culture.
* Engage with regulatory authorities to ensure that operations are compliant with legislation.
* Lead the mine operations management team and manage all mining personnel.
* Prepare and implement operational plans for the mine with the Engineering team, in line with the life of mine business plan.
* Monitor and report progress on the relevant plans and budget.
* Propose capital expenditure projects to expand capacity and improve operations.
* Prepare production & operating budgets, monitor & report performance and costs. Review and revise budget mid-year based on non-planned changes in the mining sequence. Complete a revised budget at mid-year based on unplanned changes in the mining sequence.
* Recognize and anticipate operational, technical and safety challenges and take action to manage them.
* Identify and implement plans for continuous improvement.
* Contribute to business planning and company strategy, to improve competitiveness, profitability and growth. Be able to adapt plans to deliver the production rate.
* Work closely with maintenance department to ensure continuous, safe, efficient operations.
* Work closely with the HR and training department to ensure that the mining department has all qualified employees needed to achieve the production schedule in a safe manner.
* Oversee new and ongoing projects, such as installing new mining equipment, managing new mine development, etc.
* Oversee the recruitment and development of the mining team by providing support, encouragement, advice and guidance to build an effective workforce.
* Engage with local communities and regulatory authorities to promote company policies.
* Any other duties as required.

**Personal Requirements**

* Degree in Mining Engineering or equivalent.
* Minimum of 10 years experience in progressive roles in mining and/or technical services.
* Minimum of 5 years of supervisory and planning experience in a similar role.
* Experience in Risk Management.
* Good knowledge of technical services and related systems.

**Competencies**

* Ability to influence people at all levels.
* Ability to make and implement difficult decisions, and communicate the reasons for them.
* Strong communications, interpersonal and computer skills.
* Ability to coach a team.
* Dalradian Gold Ltd is an Equal Opportunities Employer and welcomes applications from all sections of the community.

**MINING PRODUCTION MANAGE**

**What they do**

Mine managers are responsible for planning, organising and supervising the activities of a mine. They are responsible for planning future mine production, overseeing the development and tunnelling of the mine, checking the quality of stone, rock and minerals and inspecting the mine for danger. Mine managers also carry out generic management duties, such as hiring staff, organising staff training, overseeing financial administration, and liaising and negotiating with suppliers, contractors and other stakeholders. They also ensure occupational health and safety guidelines are followed, which includes planning and overseeing maintenance of the mine and developing emergency response plans.

**Working conditions**

Mine managers work in mines and offices throughout Western Australia, from the mineral sands mines in Bunbury and the South West, coal mining in Collie, gold mining in Boddington and the Goldfields, to iron ore mining in the Pilbara and Gascoyne regions. They often work at mines in remote locations and may need work on a fly-in, fly-out basis. Depending on the type of mine, they may work outside in most weather conditions, or underground in cramped, enclosed spaces. Most mines operate 24-hours a day, so shift work may be required, which can include working nights, and on weekends and public holidays. The work can often be dangerous, so strict safety policies must be followed and enforced to minimise risks.

**Tools and technologies**

Mine managers use a combination of office and mining equipment. When in the office they use standard office equipment, including computers with specialised mining software. When on mine sites they need to be familiar with a range of explosives and heavy machinery, including drilling equipment, diggers, trucks and rock-cutting devices. They must also wear safety equipment including overalls, a hard hats, safety glasses, steel-capped boots, hearing protection and reflective clothing.

**How do i become one?**

**Education and training**

To become a mining production manager you must hold a First Class Mine Manager's Certificate of Competency, issued by the Department of Mines, Industry Regulation and Safety. In order to qualify for the mine manager's certificate you must have completed an engineering degree majoring in mining, have five years practical mining experience (including three years underground), have a current Apply First Aid Certificate and be at least 25 years old.

Mining engineering degrees are currently offered at two universities in Western Australia.

Curtin University offers a four year Bachelor of Engineering (Mining Engineering). The final two years of the course are delivered at the Western Australian School of Mines (WASM) in Kalgoorlie.

The University of Western Australia offers a two year Master of Professional Engineering with a specialisation in mining engineering available. Prior to enrolling in the masters program students must complete a three year undergraduate degree majoring in engineering science.

Contact the universities you are interested in for more information.

# UNIT IX. ENVIRONMENTAL GEOLOGY

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#### Science Vocabulary

|  |  |
| --- | --- |
| interaction | взаємодія |
| degradation | деградація, погіршення, руйнування |
| advantageous | сприятливий, корисний, вигідний |
| fossil fuel | викопне паливо |
| edaphology | ґрунтознавство |
| mitigation | запобігання наслідкам; пом’якшення наслідків |
| exposure | виставляння; піддавання (небезпеці тощо) |
| hazard | ризик; небезпека |
| domestic waste | побутові відходи, комунально- побутові стічні води |
| disposal | розташування, розміщення, усунення, видалення |
| eliminate | усувати, знищувати |
| pollution | забруднення |
| litigation | судова справа, процес |
| damage | збиток, шкода, завдавати збитків, шкоди |
| erosion | ерозія, роз’їдання, поступове руйнування |
| sinkhole | карстова воронка |
| biodiversity | біорізноманіття |
| protective measure | заходи безпеки |
| debris | уламки порід, наносні породи, що вкривають родовище |
| drainage | дренаж, осушення, стік |
| aqueous | водний, водяний, водянистий |
| devastate | спустошувати, розоряти |
| vegetation | рослинність, вегетація |
| bioleaching | біовилуговування |
| technique | метод, методика, технологія |
| diversion system | система відведення |
| treatment facilities | очисні споруди |
| tailings dam | хвостосховище |
| siltation | замулення |
| disturbance | порушення, пошкодження |
| grazing | пасовисько, випас |
| leakage | витік, теча, просочування |
| impact | вплив, дія |

***Read and translate the text***

### ENVIRONMENTAL GEOLOGY

Each of these fields involves the study of the interaction of humans with the geologic environment, including the biosphere, the lithosphere, the hydrosphere, and to some extent the atmosphere. In other words Environmental geology is the application of geological information to solve conflicts, minimizing possible environmental degradation or maximizing possible advantageous condition resulting from the use of natural and modified environment.

Environmental geology includes:

* managing geological and hydrogeological resources such as fossil fuels, minerals, water (surface and ground water), and land use.
* studying the earth’s surface through the disciplines of geomorphology, and edaphology;
* defining and mitigating exposure of natural hazards on humans;
* managing industrial and domestic waste disposal and minimizing or eliminating effects of pollution;
* performing associated activities, often involving litigation.

Multiple studies show that demand for strategic natural resources continues to increase. As global population grows and countries become more developed, there is no doubt that demand for strategic resources will continue to grow as well.

Modern mining is an industry that involves the exploration for and removal of minerals from the earth with minimum damage to the environment.

The **environmental impact of mining** includes erosion, formation of sinkholes, loss of biodiversity, and contamination of soil, groundwater, surface water by chemicals from mining processes. Mining can have bad effects on surrounding surface and ground water if protective measures are not taken. Large amounts of water produced from mine drainage, mine cooling, aqueous extraction and other mining processes increase the potential for ground and surface water contamination. The result can be unnaturally high concentrations of some chemicals (arsenic, sulfuric acid, mercury) and heavy metals (lead, cadmium). Runoff of soil or rock debris, even non-toxic, devastates the surrounding vegetation. In well-regulated mines, hydrologists and geologists take careful measurements of water and soil to exclude any type of water contamination that could be caused by the mine’s operations. The reducing or eliminating of environmental degradation is best done through the use of such non-toxic extraction processes as bioleaching. If the project site becomes nonetheless polluted, mitigation techniques such as acid mine drainage (AMD) need to be performed. The five principal technologies used to monitor and control water flow at mine sites are diversion systems, containment ponds, ground water pumping systems, subsurface drainage systems, and subsurface barriers. In the case of AMD, contaminated water is generally pumped to treatment facilities that neutralize the contaminants.

Erosion of exposed hillsides, mine dumps, tailings dams and resultant siltation of drainages, creeks and rivers can also significantly impact the surrounding areas. In areas of wilderness mining may cause destruction and disturbance of ecosystems and habitats, and in areas of farming it may disturb or destroy productive grazing and croplands. In urbanized environments mining may produce noise pollution, dust pollution and visual pollution.

Besides creating environmental damage, the contamination resulting from leakage of chemicals also affects the health of the local population. Mining companies in some countries are required to follow environmental and rehabilitation codes, ensuring the area mined is returned closely to its original state.

To minimize environmental and public health effects the new mining technologies should be used. The plan for improving efficiency and decreasing the environmental impact of mining can be broken up into the following categories:

* Shutting down illegal and unregulated mines;
* Choosing environmentally friendly general mining processes;
* Implementing recently discovered green mining technologies;
* Cleaning up the sites of shut-down mines;
* Research and Development of Green Mining Technology.

1. ***Use the dictionary and write down transcriptions and translations of the words given below.***

Effect, affect, leak, advantage, population, expose, efficiency, solve, rehabilitation

1. ***Give English equivalents to the following Ukrainian words and word combinations. Make up your own sentences*.**

Навколишнє середовище; хімічні речовини; оточувати; ресурси; гарантувати; зупинити (закрити); поліпшувати; розбивати (на частини); науково-дослідна робота

1. ***Match the definitions.***
   1. environment
   2. erosion
   3. visual pollution
   4. extraction
   5. AMD
   6. bioleaching
   7. noise pollution
   8. mineral
   9. Environmental Geology
      1. It refers to the outflow of acidic water from metal mines or coal mines;
      2. The extraction of metals from their ores through the use of living organisms;
      3. An aesthetic issue which refers to the impacts of pollution that impair one's ability to enjoy a vista or view;
      4. The disturbing or excessive noise that may harm the activity or balance of human or animal life;
      5. A naturally occurring, homogeneous inorganic solid substance having a definite chemical composition and characteristic crystalline structure, color, and hardness;
      6. A community of living organisms (plants, animals and microbes) in conjunction with the nonliving components of their environment (things like air, water and mineral soil), interacting as a system;
      7. The wearing away of rocks and other deposits on the earth's surface by the action of water, ice, wind, etc;
      8. An applied science concerned with the practical application of the principles of geology in the solving of environmental problems;

**K.** The process of removing a substance from the ground or from another substance.

1. ***Fill in the blanks with the proper words. Change the form if necessary.***

#### contaminate/contamination/contaminant

* 1. Radioactive is the deposition of, or presence of radioactive substances on surfaces or within solids, liquids or gases.
  2. The town's water-supply has been by chemicals from the factory.
  3. The researchers used a polymer with chemical groups that attract the strongly.
  4. What you eat affects the ability of your lungs to withstand smoke and many .

#### protect/protection/protective

1. The trees were a good against the wind.
2. He wore glasses.
3. Nature Conservancy freshwater sources around the world.

#### disturb/disturbance

1. of the river's sediment causes cloudy water.
2. He was arrested for of the peace.
3. A violent storm the surface of the lake.
4. ***Match the synonyms.***

|  |  |
| --- | --- |
| impact | degradation |
| reduce | technology |
| contamination | pollution |
| affect | apply |
| increase | grow |
| technique | decrease |
| use | cause |
| destruction | require |
| demand | effect |

1. ***Put 7 – 10 key questions to the text.***
2. ***Control points.***
   1. Name the sciences which are closely related to Environmental Geology. What does each of these sciences study?
   2. What ecological systems of biosphere do you know? What are the elements of these ecological systems?
   3. Speak about the aspects Environmental Geology concerns.
   4. What is the environmental impact of mining?
   5. What techniques to reduce or to eliminate environmental degradation do you know? Give more detailed analysis to one of the techniques.
3. ***Analyze the chart. Speak on the environmental hazards associated with mining.***

|  |  |  |
| --- | --- | --- |
| ***Risk*** | ***Affected compartments*** | ***Relevant toxic compounds*** |
| Overtopping of tailing  dam | ground water, surface  water, soil | **Water emissions**   * In most cases radionuclides, mainly thorium and uranium; * Heavy metals; * Acids; * Fluorides |
| Collapse of tailing dam  by poor construction | ground water, surface  water, soil |
| Collapse of tailing dam  by seismic event | ground water, surface  water, soil |
| Pipe leakage | ground water, surface  water, soil |
| Ground of tailing pond  not leak-proof | ground water |
| Waste rock stockpiles  exposed to rainwater | ground water, surface  water, soil |

|  |  |  |
| --- | --- | --- |
| Dusts from waste rock  and tailings | air, soil | **Air emissions:**   * In most cases radionuclides, mainly thorium and uranium; * Heavy metals * HF, HCI, SO2, etc. |
| No site-rehabilitation after cease of mining  operation | land-use, long-term contaminated land |
| Processing without flue  gas filters | air, soil |
| Processing without  waste water treatment | surface water |

1. ***Give Ukrainian equivalents to the following:***

arsenic, sulfuric acid, mercury, lead, cadmium

1. ***Read the texts from Additional reading. Describe briefly each of the forms of mining. Speak on the: Environmental Risks of mining; how they arise and how their effects can be mitigated*.**

### ADDITIONAL READING

Unregulated mining has the potential to release harmful substances into the soil, air, and water. Governments should enforce regulations on companies and control their use of cutting-edge technology to reduce the damage from mining-related sources.

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### ENVIRONMENTAL DAMAGES OF MINING

***Open pit mining***

Open pit mining is one of the most common forms of mining for strategic minerals. This type of mining is particularly damaging to the environment because strategic minerals are often available only in small concentrations, which increases the amount of ore needed to be mined.

Environmental hazards are present during every step of the open- pit mining process. Hardrock mining exposes rock that has lain unexposed for geological eras. When crushed, these rocks expose radioactive elements, asbestos-like minerals, and metallic dust. During separation, residual rock slurries, which are mixtures of pulverized rock and liquid, are produced as tailings. Toxic and radioactive elements from these liquids can leak into bedrock if not properly contained.

***Underground Mining***

Underground mining has the potential for tunnel collapses and land subsidence. It involves large-scale movements of waste rock and vegetation, similar to open pit mining. Additionally, like most traditional forms of mining, underground mining can release toxic compounds into the air and water. As water takes on harmful concentrations of minerals and heavy metals, it becomes a contaminant. This contaminated water can pollute the region surrounding the mine and beyond. Mercury is commonly used in as an amalgamating agent to facilitate the recovery of some precious ores. Mercury tailings then become a major source of concern, and improper disposal can lead to contamination of the atmosphere and neighboring bodies of water. Most underground mining operations increase sedimentation in nearby rivers through their use of hydraulic pumps and suction dredges; blasting with hydraulic pumps removes ecologically valuable topsoil containing seed banks, making it difficult for vegetation to recover. Deforestation due to mining leads to the disintegration of biomes and contributes to the effects of erosion.

***In situ leach (ISL) mining***

ISL mining has environmental and safety advantages over conventional mining in that the ore body is dissolved and then pumped out, leaving minimal surface disturbance and no tailings or waste rock (World Nuclear Association, 2012). There is no ore dust or direct ore exposure to the environment and a lower consumption of water is needed in the mining process (International Atomic Energy Agency [IAEA], 2005). However, the strong acids used to dissolve the ore body commonly dissolve metals in the host rock as well. The fluids remaining after the leaching process commonly contain elevated concentrations of metals and radioactive isotopes, posing a significant risk to nearby ground and surface water sources (IAEA, 2005). Additionally, the low pH of ISL mining wastewater can result in acidification of the surrounding environment.

***Heap Leaching***

Environmental issues with heap leaching are centered on the failure to keep process solutions within the heap leaching circuit. Release of toxic heap leaching fluids into the environment can affect the health of both the surrounding ecosystem and human population. Water balance is crucial in heap leaching projects because of the possibility of the overflow of solutions containing toxic concentrations of heavy metals after a heavy rainfall or rapid snowmelt. In some cases cyanide is used to extract metals from oxidized ores and the resulting leach ponds have caused significant wildlife mortality.

***Brine Mining***

Brine mining involves extracting and evaporating the brine solutions to remove harmful elements and compounds, potentially releasing them into the environment. The drilling and transport of brine solutions can disrupt existing ecosystems and well casings, pipelines, and storage tanks are subject to corrosion due to the high salinity content of the solutions that they are exposed to, which can lead to leaks and contamination of adjacent bodies of water. Currently, there is no economically plausible plan to clean up contamination of an aquifer by sodium chloride and harmful concentrations of chloride inhibit plant growth and can cause fish kills.

***Specific Contaminant Materials***

*Radionuclides*

All REE (rare-earth element)-bearing minerals contain low levels of the radioactive isotopes that can become concentrated in mine tailings. Radionuclides are released as dust during mining or from exposed waste rock stockpiles where they are least containable (and mostly airborne). Radiation can also leak into the ground and nearby water sources after they have been separated into tailings, if the tailings are not stored safely. Once radionuclides are in an ecosystem, they accumulate in plants, where the higher concentrations are ingested and ascend the levels of the food chain. Radioactive contamination has become such a problem that monazite mining has been banned by China and the United States has imposed strict regulations effectively accomplishing the same.

***Dust & Metal***

When companies break up materials during mining, the dust can release a variety of heavy metals commonly associated with health problems. As dust, these minerals (such as the asbestos-like mineral riebeckite) can be absorbed into lung tissue, causing problems like pneumoconiosis and silicosis, commonly known as “Black Lung”. Another example of harmful dust generated is flue dust, a byproduct of mining fluorine. According to the Chinese Society of Rare Earths, every ton of REE produced generates 8.5 kilograms of fluorine and 13 kilograms of flue dust, waste materials which contain the heavy metals discussed above.

**HEALTH AND ENVIRONMENTAL IMPACT OF THE COAL INDUSTRY**

The health and environmental impact of the coal industry includes issues such as land use, waste management, water and air pollution, caused by the coal mining, processing and the use of its products. In addition to atmospheric pollution, coal burning produces hundreds of millions of tons of solid waste products annually, including fly ash, bottom ash, and flue-gas desulfurization sludge, that contain mercury, uranium, thorium, arsenic, and other heavy metals. Coal is the largest contributor to the human-made increase of carbon dioxide in Earth's atmosphere.

There are severe health effects caused by burning coal. Worldwide 25 people die early for each terawatt hour of electricity generated by coal, around a thousand times more than nuclear or solar.

In addition, there have been many coal mining disasters, although work related coal deaths has declined substantially as safety measures have been enacted and underground mining has given up market share to surface mining.[citation needed] Underground mining hazards include suffocation, gas poisoning, roof collapse and gas explosions. Open cut hazards are principally mine wall failures and vehicle collisions. Hundreds of people died in coal mine accidents in 2022.

**Impact to land and surroundings**

Strip mining severely alters the landscape, which reduces the value of the natural environment in the surrounding land. The land surface is dedicated to mining activities until it can be reshaped and reclaimed. If mining is allowed, resident human populations must be resettled off the mine site; economic activities, such as agriculture or hunting and gathering food and medicinal plants are interrupted. What becomes of the land surface after mining is determined by the manner in which the mining is conducted. Usually reclamation of disturbed lands to a land use condition is not equal to the original use. Existing land uses (such as livestock grazing, crop and timber production) are temporarily eliminated in mining areas. High-value, intensive-land-use areas like urban and transportation systems are not usually affected by mining operations. If mineral values are sufficient, these improvements may be removed to an adjacent area.

Strip mining eliminates existing vegetation, destroys the genetic soil profile, displaces or destroys wildlife and habitat, alters current land uses, and to some extent permanently changes the general topography of the area mined. Adverse impacts on geological features of human interest may occur in a coal strip mine. Geomorphic and geophysical features and outstanding scenic resources may be sacrificed by indiscriminate mining. Paleontological, cultural, and other historic values may be endangered due to the disruptive activities of blasting, ripping, and excavating coal. Stripping of overburden eliminates and destroys archeological and historic features, unless they are removed beforehand.

The removal of vegetative cover and activities associated with the construction of haul roads, stockpiling of topsoil, displacement of overburden and hauling of soil and coal increase the quantity of dust around mining operations. Dust degrades air quality in the immediate area, has an adverse impact on vegetative life, and constitutes health and safety hazards for mine workers and nearby residents.

Surface mining disrupts virtually all aesthetic elements of the landscape. Alteration of land forms often imposes unfamiliar and discontinuous configurations. New linear patterns appear as material is extracted and waste piles are developed. Different colors and textures are exposed as vegetative cover is removed and overburden dumped to the side. Dust, vibration, and diesel exhaust odors are created (affecting sight, sound, and smell). Residents of local communities often find such impacts disturbing or unpleasant. In case of mountaintop removal, tops are removed from mountains or hills to expose thick coal seams underneath. The soil and rock removed is deposited in nearby valleys, hollows and depressions, resulting in blocked (and contaminated) waterways.

Removal of soil and rock overburden covering the coal resource may cause burial and loss of topsoil, exposes parent material, and creates large infertile wastelands. Soil disturbance and associated compaction result in conditions conducive to erosion. Soil removal from the area to be surface-mined alters or destroys many natural soil characteristics, and reduces its biodiversity and productivity for agriculture. Soil structure may be disturbed by pulverization or aggregate breakdown.

Mine collapses (or mine subsidences) have the potential to produce major effects above ground, which are especially devastating in developed areas. German underground coal-mining (especially in North Rhine-Westphalia) has damaged thousands of houses, and the coal-mining industries have set aside large sums in funding for future subsidence damages as part of their insurance and state-subsidy schemes. In a particularly spectacular case in the German Saar region (another historical coal-mining area), a suspected mine collapse in 2008 created an earthquake measuring 4.0 on the Richter magnitude scale, causing some damage to houses. Previously, smaller earthquakes had become increasingly common and coal mining was temporarily suspended in the area.

In response to negative land effects of coal mining and the abundance of abandoned mines in the US the federal government enacted the Surface Mining Control and Reclamation Act of 1977, which requires reclamation plans for future coal mining sites. These plans must be approved by federal or state authorities before mining begins.

**Water management**

Surface mining may impair groundwater in numerous ways: by drainage of usable water from shallow aquifers; lowering of water levels in adjacent areas and changes in flow direction within aquifers; contamination of usable aquifers below mining operations due to infiltration (percolation) of poor-quality mine water; and increased infiltration of precipitation on spoil piles. Where coal or carbonaceous shale is present, increased infiltration may result in: increased runoff of poor-quality water and erosion from spoil piles, recharge of poor-quality water to shallow groundwater aquifers and poor-quality water flow to nearby streams.

The contamination of both groundwater and nearby streams may be for long periods of time. Deterioration of stream quality results from acid mine drainage, toxic trace elements, high content of dissolved solids in mine drainage water, and increased sediment loads discharged to streams. When coal surfaces are exposed, pyrite comes in contact with water and air and forms sulfuric acid. As water drains from the mine, the acid moves into the waterways; as long as rain falls on the mine tailings the sulfuric-acid production continues, whether the mine is still operating or not. Also waste piles and coal storage piles can yield sediment to streams. Surface waters may be rendered unfit for agriculture, human consumption, bathing, or other household uses.

There are five principal technologies used to control water flow at mine sites: diversion systems, ash ponds (surface impoundments), groundwater pumping systems, subsurface drainage systems, and subsurface barriers.[citation needed]

In the United States, due to few federal and state regulations concerning ash ponds, most power plants do not use geomembranes, leachate collection systems, or other flow controls often found in municipal solid waste landfills. EPA promulgated more stringent requirements for ash ponds and landfills in its first national regulation in 2015. Subsequently, there has been litigation and several amendments or proposed revisions to the regulations. Final regulations are pending as of December 2020.

**Water pollution**

Coal-fired boilers, using either coal or lignite rich in limestone, produces fly ash containing calcium oxide (CaO). CaO readily dissolves in water to form slaked lime (Ca(OH)2) which is carried by rainwater to rivers/irrigation water from the ash dump areas. Lime softening process precipitates Ca and Mg ions / removes temporary hardness in the water and also converts sodium bicarbonates in river water into sodium carbonate.[20] Sodium carbonate (washing soda) further reacts with the remaining Ca and Mg in the water to remove / precipitate the total hardness. Also, water-soluble sodium salts present in the ash enhance the sodium content in water further. Thus river water is converted into soft water by eliminating Ca and Mg ions and enhancing Na ions by coal-fired boilers. Soft water application in irrigation (surface or ground water) converts the fertile soils into alkaline sodic soils. River water alkalinity and sodicity due to the accumulation of salts in the remaining water after meeting various transpiration and evaporation losses, become acute when many coal-fired boilers and power stations are installed in a river basin. River water sodicity affects downstream cultivated river basins located in China, India, Egypt, Pakistan, west Asia, Australia, western US, etc.

Pollutant discharges from ash ponds to surface waters typically include arsenic, lead, mercury, selenium, chromium, and cadmium.[23] In the US, discharges to surface waters are regulated by permits in the National Pollutant Discharge Elimination System (NPDES).

**Waste management**

See also: Health effects of coal ash

The burning of coal leaves substantial quantities of fly ash, which is usually stored in ash ponds (wet storage) or landfills (dry storage). Pollutants such as heavy metals leach into groundwater from unlined ponds or landfills, and can pollute aquifers for decades or centuries. The EPA classified 44 sites in the US as potential hazards to communities. Such a classification means that the waste sites could cause death and significant property damage if an event such as a storm, a terrorist attack or a structural failure caused a spill. EPA estimated that about 300 dry landfills and wet storage ponds are used around the country to store ash from coal-fired power plants. The storage facilities hold the noncombustible ingredients of coal, including the ash captured by equipment designed to reduce air pollution.

In the low-coal-content areas waste forms spoil tip.

**Wildlife**

Surface mining of coal causes direct and indirect damage to wildlife. The impact on wildlife stems primarily from disturbing, removing and redistributing the land surface. Some impacts are short-term and confined to the mine site however others have far-reaching, long-term effects.

The most direct effect on wildlife is destruction or displacement of species in areas of excavation and spoil piling. Pit and spoil areas are not capable of providing food and cover for most species of wildlife. Mobile wildlife species like game animals, birds, and predators leave these areas. More sedentary animals like invertebrates, reptiles, burrowing rodents, and small mammals may be destroyed. The community of microorganisms and nutrient-cycling processes are upset by movement, storage, and redistribution of soil.

Degradation of aquatic habitats is a major impact by surface mining and may be apparent many miles from a mining site. Sediment contamination of surface water is common with surface mining. Sediment yields may increase a thousand times their former level as a result of strip mining.

The effects of sediment on aquatic wildlife vary with the species and the amount of contamination. High sediment levels can kill fish directly, bury spawning beds, reduce light transmission, alter temperature gradients, fill in pools, spread streamflows over wider, shallower areas, and reduce the production of aquatic organisms used as food by other species. These changes destroy the habitat of valued species and may enhance habitat for less-desirable species. Existing conditions are already marginal for some freshwater fish in the United States, and the sedimentation of their habitat may result in their extinction. The heaviest sediment pollution of drainage normally comes within 5 to 25 years after mining. In some areas, unvegetated spoil piles continue to erode even 50 to 65 years after mining.

The presence of acid-forming materials exposed as a result of surface mining can affect wildlife by eliminating habitat and by causing direct destruction of some species. Lesser concentrations can suppress productivity, growth rate and reproduction of many aquatic species. Acids, dilute concentrations of heavy metals, and high alkalinity can cause severe damage to wildlife in some areas. The duration of acidic-waste pollution can be long; estimates of the time required to leach exposed acidic materials in the Eastern United States range from 800 to 3,000 years.

**Annual excess mortality and morbidity**

In 2008 the World Health Organization (WHO) and other organizations calculated that coal particulates pollution cause approximately one million deaths annually across the world, which is approximately one third of all premature deaths related to all air pollution sources, for example in Istanbul by lung diseases and cancer.

Pollutants emitted by burning coal include fine particulates (PM2.5) and ground level ozone. Every year, the burning of coal without the use of available pollution control technology causes thousands of preventable deaths in the United States. A study commissioned by the Maryland nurses association in 2006 found that emissions from just six of Maryland's coal-burning plants caused 700 deaths per year nationwide, including 100 in Maryland. Since installation of pollution abatement equipment on one of these six, the Brandon Shores plant, now "produces 90 percent less nitrogen oxide, an ingredient of smog; 95 percent less sulfur, which causes acid rain; and vastly lower fractions of other pollutants."In the United States, an average of 26 coal miners per year died in the decade 2005–2014.

**Dangers to miners**

Historically, coal mining has been a very dangerous activity, and the list of historical coal mining disasters is long. The principal hazards are mine wall failures and vehicle collisions; underground mining hazards include suffocation, gas poisoning, roof collapse and gas explosions. Chronic lung diseases, such as pneumoconiosis (black lung) were once common in miners, leading to reduced life expectancy. In some mining countries black lung is still common, with 4,000 new cases of black lung every year in the US (4 percent of workers annually) and 10,000 new cases every year in China (0.2 percent of workers). Rates may be higher than reported in some regions.

In the United States, an average of 23 coal miners per year died in the decade 2007–2016. Recent U.S. coal-mining disasters include the Sago Mine disaster of January 2006. In 2007, a mine accident in Utah's Crandall Canyon Mine killed nine miners, with six entombed. The Upper Big Branch Mine disaster in West Virginia killed 29 miners in April 2010.

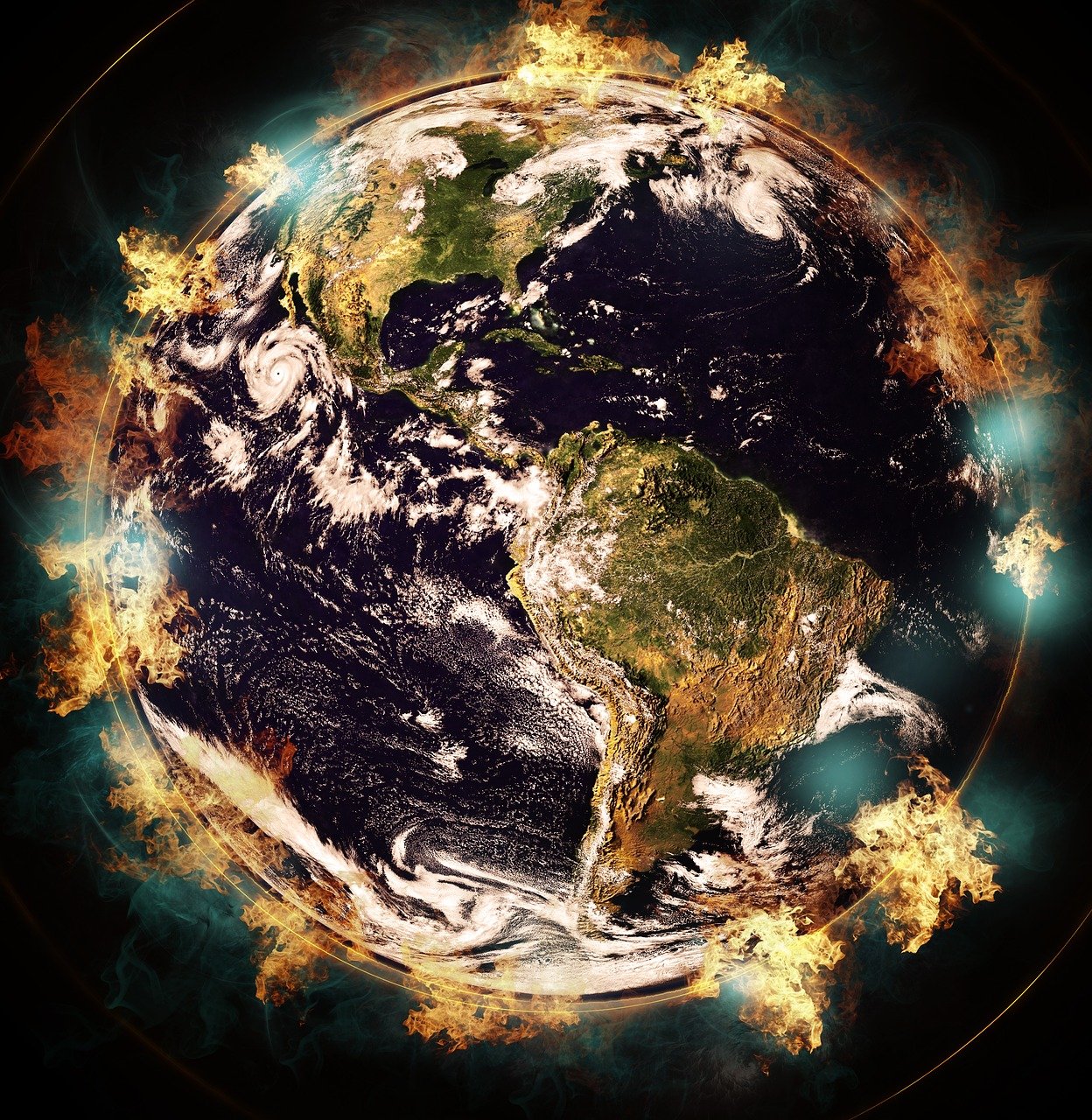
However, in lesser developed countries and some developing countries, many miners continue to die annually, either through direct accidents in coal mines or through adverse health consequences from working under poor conditions. China, in particular, has the highest number of coal mining related deaths in the world, with official statistics claiming that 6,027 deaths in 2004. To compare, 28 deaths were reported in the US in the same year. Coal production in China is twice that in the US, while the number of coal miners is around 50 times that of the US, making deaths in coal mines in China 4 times as common per worker (108 times as common per unit output) as in the US.

The Farmington coal mine disaster kills 78. West Virginia, US, 1968.

Build-ups of a hazardous gas are known as damps:

* Black damp: a mixture of carbon dioxide and nitrogen in a mine can cause suffocation. The anoxic condition results of depletion of oxygen in enclosed spaces, e.g. by corrosion.
* After damp: similar to black damp, after damp consists of carbon monoxide, carbon dioxide and nitrogen and forms after a mine explosion.
* Fire damp: consists of mostly methane, a highly flammable gas that explodes between 5% and 15% – at 25% it causes asphyxiation.
* Stink damp: so named for the rotten egg smell of the hydrogen sulphide gas, stink damp can explode and is also very toxic.
* White damp: air containing carbon monoxide which is toxic, even at low concentrations

Firedamp explosions can trigger the much more dangerous coal dust explosions, which can engulf an entire pit. Most of these risks can be greatly reduced in modern mines, and multiple fatality incidents are now rare in some parts of the developed world. Modern mining in the US results in approximately 30 deaths per year due to mine accidents.

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**UNIT X. MINING AND THE ENVIRONMENT**

It should be stressed that effects of mining on the environment are twofold: firstly, there are direct effects arising from mining as a physical activity, which include disturbances of the land surface and accumulation of waste. Secondly, there are indirect destructive effects resulting from treatment of mineral products, such as coal burning, ore processing, smelting and other metallurgical processes. These frequently result in contamination of soil and ground water, pollution of the atmosphere and an adverse effect on vegetation and wildlife. Mining, especially open-pit mining, deforms the surface of the land and creates a large amount of waste materials which contain hazardous substances that pollute water and soil. Water from mining and concentration operations may contaminate the subsoil and rivers into which it flows. Most serious of all are gases produced by smelting, which may not only contaminate the air in the region of the smelter, but affect lakes and vegetation hundreds of miles away through the creation of acid rain.

There is one more point which affects the environment. It concerns the transport of coal representing one component of the complete coal cycle — from exploration and extraction of the fuel, through refining, processing, storage and finally its conversion to an end-use product for consumers. Coal transportation is executed by train, truck (lorry), water (on rivers, canals, lakes, etc.) and slurry pipeline or conveyer belt. Environmental impacts of coal transport occur during loading or unloading. For example, rail transport and trucks cause damage to buildings, highways and other places.

Accidents are associated with all forms of transport. Besides, the transport of coal in all its forms involves dust, even though special measures are increasingly taken. Emission of coal particulate and other air pollutants occur during loading, unloading and during coal movement.

At the same time, research and development have provided greatly improved engineering and biological methods of land reclamation. It is necessary to say that land reclamation has emerged as a method of controlling the negative after-effects of extracting coal and other minerals. Land reclamation covers the problem of landscape redevelopment and the restoration of its productivity, ecological integrity, and economic and aesthetic value. The economic uses of reclaimed land depend on natural and socioeconomic factors of the locality. They may be orchards, meadows, parks, swimming pools, etc.

In recent years, many industrial countries have developed and adopted laws, national programs and specific policies for environmental protection. The basis of most laws applicable to the mining industry and its effect on land is to control land management for resources protection, regulate land reclamation and landscape retraction. The principal impact of pollution regulations on the mining industry arises from regulations on emissions of CO2 and other air pollutants from copper lead and zinc smelters.

1. **Match the synonyms:**

|  |  |
| --- | --- |
| result | negative |
| contamination | effect |
| adverse | affect |
| disturb | pollution |
| execute | reclamation |
| impact | cause |
| restoration | perform |

1. **Find the synonyms to the following words in the text:**

mine, take place, appear, contaminants, form, affect

1. **Translate into English. Make up sentences with these words:**

впливати, призводити до, використовувати, відходи, регулювати, гірнича промисловість, захищати, засоби.

1. **а) Find the topic sentence of each of the paragraphs. Entitle the paragraphs.**

**b) Briefly retell the text using the following phrases:**

*The «object of the text is ...; The text deals with ...; It is pointed out that...; It should be stressed that...*

1. **Put 10 questions to the text. Ask your classmates to answer these questions.**
2. **Generalize the information of the text.**
3. **Read the advertisement about the Conference.**

**Words for understanding:**

*Implication — залучення, причетність; appropriate — підходящий, відповідний; legislation — законодавстство; workshop — секція, семінар; issue — питання, проблема; agenda — порядок денний*

Leaders from the international mining, regulatory and environmental communities will meet in October to discuss the most crucial environmental issues facing the mining industry.

Sponsored by Mining Journal LTD and Mining World News, the First International Conference on Mining Environmental Manage­ment will focus on mining-oriented environmental legislation, the financial implications, the available technological solutions and management control systems.

The three-day meeting will be held at R's Conference Hall starting with a reception on Sunday evening. The event will comprise three parts: a central conference, plus parallel workshop sessions and an exhibition.

The main Conference will be broken into six halfday sessions which will contain only four or five papers in each session. These 20-minute papers will focus on subjects which are appropriate for executive debate. Each session will end with a 40-minute discussion on the topic.

The six session topics will be: The differing perspectives of the mining industry / environmentalists in developed / developing countries; Cont-international regulations and standards; Management practices and legal obligations; The role of government; Financial implications of a greener world.

The two-hour Workshops will occur on the morning of each day, being scheduled for completion by the start of the main conference proceedings. Papers will be 20 minutes each (to include time for questions after each presentation), with the workshops being divided into three sections; Air / Water Issues, Land Issues, and General Issues. The six papers in each workshop will be devoted to case studies and technical presentations. Consideration is also given to Poster Displays of relevant technical work.

The Exhibition will offer equipment manufacturers and consultants the opportunity to present their products to the international industry.

Details of papers, speakers and exhibitors will be advised as soon as possible.

For further details please contact:

Mining Journal Ltd,

60 Worship Street, London, U.K.

Telephone: \_\_\_\_\_\_\_\_

Fax: \_\_\_\_\_\_\_\_\_

1. **Speak about the problems to be discussed at the Conference. Who are the participants? What is the Exhibition organized for?**

### ADDITIONAL READING

### ENVIRONMENTAL IMPACTS OF COAL TRANSPORTATION

### Publisher Summary

The transport of coal represents one component of the complete coal cycle—from exploration and extraction of the fuel, through beneficiation, storage, and finally, its conversion to an end-use product for consumers. Like all components of the cycle, environmental impacts result from the transport of coal. Coal transportation is executed by rail, truck, water, and slurry pipeline or conveyer belt. Environmental impacts of coal transport occur during loading, en route, or during unloading. The impacts are likely to affect “natural” systems, including agriculture, forestry, horticulture, and aquaculture, buildings and installations, and involve death or injury to humans in an occupational capacity, or to the public. The environmental impacts of coal transportation on humans have received most attention in a series of studies conducted under contract to the United States Department of Energy. This chapter discusses the environmental impacts of coal transportation utilizing the reports of these studies. All forms of transport of coal exhibit certain common environmental impact features. The transport of coal in all its forms necessarily involves fugitive dusts, even though precautionary measures are increasingly taken. It is necessary to keep estimates of the environmental impacts of coal transport in perspective to other components of the coal fuel cycle, other means of electricity generation, and the hazards experienced by human beings in everyday life.

**LAND DISTURBANCE AND RECLAMATION AFTER MINING**

**Publisher Summary**

This chapter explains that the land reclamation has emerged as a method of countering the negative after-effects of extracting coal and other minerals. It also covers the problems of landscape redevelopment and the restoration of productivity, ecological integrity, and economic and aesthetic value. Land reclamation sequentially involves planning, followed by research and development. Reclamation work in the United States leaves surfaces incompletely leveled and this provides biological advantages in reclamation. Regulations for coal mine reclamation established minimum reclamation performance standards. The selection of objectives is made more rational and cost-effective by classification of disturbed land types by spoil type, relief, rock composition, and characteristic colonizing vegetation. The pyritic oxidation on coal tips produces surface layers of low pH and low pH values cause phosphate fixation and reduce nitrogen availability. The economics of the total coal production and utilization cycle needs to be analysed from the standpoint of energy consumption.

**EFFECT OF COAL MINING ON VEGETATION DISTURBANCE AND ASSOCIATED CARBON LOSS**

Vegetation is an important part of the environment but may be subjected to disturbance in areas close to coal mines. This results in a slowing of the rate of biomass growth, which is caused by fading of vegetation. Simultaneously, carbon stored in vegetation is constantly released, weakening vegetation ability to act as a carbon sink. Indirect release of carbon during coal mining processes is difficult to measure and is often neglected in carbon accounting. In this work, these measurements are performed for a real case study. Within the study area, factors that affect vegetation were divided into: natural factors; human surface activities; and coal mining, with each of these directly reflected in the spatial and temporal variation of the Normalized Difference Vegetation Index (NDVI).

To clarify the relationship between coal mining and local vegetation damage, high spatial–temporal resolution remote sensing images were created using the spatial and temporal adaptive reflectance fusion model. Data showing the mine coalface and the variation of vegetation at Xinzhouyao coal mine allowed identification of influential factors. Quantized synthetic effect values of NDVI from coal mining and changes in local climate were then evaluated. Using a theoretical analysis of carbon released from vegetation, the net primary productivity (NPP) and biomass loss of vegetation were calculated. Results showed that fluctuations in vegetation NDVI as a response to changes in local climate were positively correlated with the average NDVI value. Vegetation disturbance caused by coal mining leads to loss of biomass and decreases the ability of vegetation to absorb atmospheric CO2.

From 2001 to 2010, loss of vegetation biomass owing to coal mining was 2,608.48 t with annual rates of biomass loss of 33.48 gC/m2 year. Over the same period, the amount of atmospheric carbon absorbed by vegetation was reduced by 1,925.23 t with annual vegetation NPP loss of 24.71 gC/m2 year. Comparing these figures with the amount of coal produced, this calculates the carbon release from vegetation owing to coal mining at Xinzhouyao coal mine as 77.568 g/t. Because much of the carbon in lost biomass is recycled to the soil, the biggest impact on the carbon balance of vegetation near coal mines may be attributed to a reduced ability to absorb atmospheric CO2. These results may be useful for further analysis of the impact of mining on local environments and for the calculation of appropriate ecological compensation.

**IDENTIFICATION OF THE DISTURBED RANGE OF COAL MINING ACTIVITIES: A NEW LAND SURFACE PHENOLOGY PERSPECTIVE**

**Highlights**

* We propose a new index based on phenological responses to effectively identify the disturbance ranges of coal mining activities.
* The range of influence of PS on vegetation phenology -climate coupling relationship is 11–12 km.
* Underground mining may have a greater impact on vegetation phenology than surface mining.

**Abstract**

Coal mining activities not only damage the ecosystems located inside mining areas, but also affect the buffer areas located within a certain radius of the mining activities. Effectively identifying the range disturbed by mining activities is beneficial for guiding ecological restoration and ecological assessments in mining areas. However, methods for quantitatively identifying the range of disturbances associated with coal mining activities are still lacking. In this study, the phenological disturbance range index (PDRI) based on remote sensing observed vegetation phenology was proposed. Normalized difference vegetation index (NDVI) time series data were collected, and land surface phenology parameters were estimated in the Pinshuo mining area on the Loess Plateau. The proportion of the phenology-climate coupling relationship destroyed by human activities was then calculated. The range of mining activity disturbances was then determined by mutually validating the function-fitting and trajectory-segmentation algorithms.

The results show that the proposed PDRI can effectively identify the extent of disturbances resulting from mining activities. Clear differences among the PDRIs reflecting mining activity disturbances, urbanization disturbances and natural states were found. Taking the Pingshuo mine as an example, the range of disturbances was approximately 11 ∼ 12 km, and shaft mining was found to have a greater impact than open pit mining. The PDRI proposed herein solves the initial problem from a climate-response perspective and can be used as a standardized scheme to detect the extent of disturbances resulting from coal mining activities. This study can also provide a reference for policy formulation and ecological compensation range.

**IMPACT OF COAL MINING ON ENVIRONMENT AND NATURAL RESOURCES –**

**CAUSES AND POTENTIAL EFFECTS**

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**Abstract:** Coal mining and consumption play a significant role in the economic and social development of any country. Coal mining industry generates a large volume of gangue wastes, from which a considerable number of toxic heavy metals could be released during weathering of the waste under the joint effects of water, microorganisms, vegetation. Irrespective of the actual methods of coal mining being used, mining processes unavoidably bring about land-surface disturbances, and increased mining for expanded coal supplies will inevitably lead to extended land disturbances. With the continuous improvement of mechanized mining technology, many thousands of tons of large-scale mines have been put into production. Mining induced sharply increasing of coal mine water drainage and decreasing of groundwater table. these findings highlight the impacts of coal mining on soil properties and the findings can greatly contribute to understanding soil conditions and the environmental risks associated with coal mining.

**Keywords:** Coal Mining; soil pollution, land subsidence, land disturbance, water pollution

**1. INTRODUCTION**

The world production of coal is approximately 3.5 × 109t yr1, most of which is used to produce 38%

of the world's electricity, and coal is an important energy resource for steel, cement and thermal power plants. Coal production has important economic and social benefits; however, it generates large amounts of coal mine spoils, and waste rocks which oxidize under atmospheric conditions and release metal-rich effluents to the surrounding environment. This causes serious problems to surrounding water-soil bodies. Coal mining and consumption play a significant role in the economic and social development of any country. It is well known that various toxic elements exist in coal refuse and fly ash, and these toxic elements can be released and enter the soil through coal industry activities, including production and accumulation of a large amount of gangue, discharge of sewage, and emissions from coal-fired power plants and coal transportation. This article reviews the impact of coal mining on environment, soil heavy metal pollution and land subsidence by referring the earlier reports.

**2. EFFECT ON ENVIRONMENT**

Coal mining industry generates a large volume of gangue wastes, from which a considerable number

of toxic heavy metals could be released during weathering of the waste under the joint effects of water, microorganisms, vegetation, sunlight radiation and heat. These hazardous substances enter the ecosystem by a variety of pathways where they could be detrimental to crops and animals, and might be taken up by human through direct contact (ingestion, dermal absorption and inhalation) or food chains. Coal mining activities are unavoidably linked with the excavation of huge amounts of dump rocks, which are of great environmental concern due to the potential for production of acidic and metal-rich drainage. Burning coal gives rise to airborne compounds such as fly ash and bottom ash, which contain heavy metals that settle down or wash out from the atmosphere into the land and thus contaminate soil. This, in turn, degrades the chemical and microbiological quality of soil, and subsequently creates a threat to humans and the ecosystem through direct contact with contaminated soils and the food chain because trace elements can be transferred from soil to plants and impact on crop growth and food safety. Environmental studies of coal mining areas were conducted by many researchers from USA, Europe and China. Knowledge of the spatial distribution of toxic elements in soil in the entire mining area is necessary.

**3. SOIL HEAVY METAL POLLUTION**

Soil is important nonrenewable resources that act as origin and pool of various contaminants. Soil

contamination by heavy metals is an important issue, and various activities such as agricultural, urbanization, and industrialization are responsible for enhancing the heavy metal content in the soil. It was shown that numerous studies of soil heavy metal pollution caused by mining activities have been carried out over the past few years. For instance, Ge et al., (2016) analyzed and assessed the ecological risk from seven heavy metals, namely, Cd, Hg, As, Cu, Pb, Cr and Zn, that were present in soils surrounding a coal waste pile. Bhuiyan made a complete evaluation of the pollution level in the coal mine affected agricultural soils of Barapukuria coal mine region in Bangladesh. They have shown that the average concentrations of Ti, Mn, Zn, Pb, As, Fe, Rb, Sr, Nb and Zr exceeded the world normal averages and in some cases Mn, Zn, As and Pb exceeded the toxic limit and the entire area has high magnitude of contamination level. Yu et al. (2002) assessed spatio-temporal variation of heavy metal concentration in reclaimed soil of Fushun coal mine of China. In a study by Guo (2018), the soil quality index (SQI) values were calculated to quantify the influence of slope position because of coal mining subsidence on soil quality using principal component analysis. The SQI values irregularly varied with different slope positions. It was mainly because the slope changed the spatial distribution of soil properties, and preference of cropping activity by local farmers can also intensify the distribution.

**4. LAND SUBSIDENCE**

Land subsidence can directly affect the soil water and texture due to surface deformation, and cause an extensive decrease in the groundwater level. In this sense, land subsidence triggered by underground mining can have an immediate and long-lasting impact on the soil quality, and thus on the ecosystem services. Land subsidence causes substantial ecological and environmental problems, such as water and soil erosion, aggravation of land degradation, and declines in soil quality. The soil structure and soil properties are both disturbed by land subsidence, which increases the average internal fraction angle value and reduces the average values of water and organic matter in soil (Yang et al, 2016). In addition, land subsidence alters soil hydraulic properties, increases soil micropores, and decreases the field capacity. Mining subsidence increases the soil infiltration depth and evaporation, while reducing the water-holding capacity of the upper soil layers. The loss of soil water inevitably leads to severe ecological deterioration. Furthermore, the plant density, coverage, and biomass are affected by land subsidence after mining. Therefore, the ecosystem is disturbed by land subsidence and the soil quality further changes. Soil texture is measured using the percentages of clay, silt, and sand, and is critical for understanding the transportation and storage of soil water and nutrients, as well as the mineralization of organic matter content. Land subsidence causes dense surface cracks and this may result in the loss of silt and clay, an increased sand percentage, and a tendency for soil to undergo desertification. Additionally, the SWC in the subsidence areas was significantly lower than that in the control areas in the current study. This reduction in SWC could be attributed to the dense surface cracks caused by coal seam exploitation destroying the soil structure and increasing the total soil porosity; thus, land subsidence increases the evaporation and infiltration capacity of soil.

**5. LAND DISTURBANCE**

Irrespective of the actual methods of coal mining being used, mining processes unavoidably bring

about land-surface disturbances, and increased mining for expanded coal supplies will inevitably lead to extended land disturbances. Such disturbed land tends to create a negative effect on the surrounding environment and reduces its economic value. The character of the disturbance depends upon the disposition of the mined strata, and upon the methods used to mine them. Continued improvement of coal-mining methods is associated with the exploitation of deeper coal seams (below 1000 m in deep mining operations and a few hundred metres in surface or strip-mine operations). Generally speaking, progress in mining has led to greater use of open coal extraction methods which produce larger-scale disturbances on the earth's surface. At the same time, research and development has provided greatly improved engineering and biological methods of landscape reclamation.

**6. IMPACT OF COAL MINING ON WATER QUALITY**

Coal mining activities can directly affect the quality of the water or indirectly through processes which may show its consequences at a later stage in the life of the mine. The gravity of the impact of these activities depends on a number of factors like the geology of the area, the mineral constituents of the coal, the composition of the overburden, scale of operations, rainfall distribution, etc. Some of the major sources of water pollution in coal mining areas are; Mine water drainage/Acid mine drainage. Coal seams sometimes have high concentration of pyrites which in presence of water and oxygen undergo oxidation to give sulphuric acid thereby increasing the acidity and pH of the water used. This water contaminates the other water bodies and the ground water when discharged from the mine.

*Loose material runoffs.* The process of mining is usually associated with generation of large amount of dust and, the mineral and overburden excavated are converted to lose material. Winds pick up these dust particles along with loose material and deposit them on water bodies. Loose material is also carried by the streams running through the mines which eventually meet the main course or end into a water reservoir causing pollution in both cases.

*Oil and fuel spills.* Oils and fuels are used for the machinery and equipment used in the mining operations. These oils andfuel sometimes leak away or washed off during cleaning and maintenance. The water used for washing or during rains, these oils and fuels contaminate the nearby water bodies.

*Pollutant leaching from overburden dump.* Overburden dump is the waste material which has to be removed before the mineral resources can besalvaged. The waste materials can contain pollutants in the form of heavy metals of other chemicalswhich leach out during the rains and pollute the surrounding areas.

*Sewage discharges* A mine employs hundreds of people, who’s domestic and sanitary water needs have to be taken care of. The sewage from the domestic and sanitary use of water can cause pollution if they discharge untreated. With the continuous improvement of mechanized mining technology, many thousands of tons of large-scale mines (in the yield of thousands of tons) have been put into production. Mining induced sharply increasing of coal mine water drainage and decreasing of groundwater table, and moreover with each passing year, the substantial growth of drainage volume because of overlying aquifer was connected by a vertical fracture.

**7. FUGITIVE EMISSIONS**

The transport of coal in all its forms necessarily involves fugitive dusts, even though precautionary measures are increasingly taken. It is generally estimated that 0.02 % of the coal loaded is lost as fugitive dust and a similar percentage lost at unloading. Until recently, loss during transportation has not been estimated, but more work is enabling these losses now to be assessed. Fugitive emissions of coal particulates and other air pollutants occur during loading, unloading and en route. It is now estimated that about 50 % of the coal dust losses occur during journey time and 25 % at loading and 25 % at unloading. There is some loss also due to spillage. Some estimates suggest that 0.2 kg t" 1 is emitted during loading and a similar amount during unloading. Losses in transit may be from 0.05 to 1.0 % of the total coal involved. For this reason wind guards are used, moistened coal transported or latex polymer or asphalt sprays used. Some wagons incorporate flip-top lids.

**8. CONCLUSION**

In short, these findings highlight the impacts of coal mining on soil properties and the findings can greatly contribute to understanding soil conditions and the environmental risks associated with coal mining.

# INFLUENCE OF COAL MINING DISTURBANCE ON SOIL PHYSIOCHEMICAL PROPERTIES AND THE RESPONSE MECHANISM OF MICROBIAL COMMUNITY

# Abstract

The ecological problems caused by coal mining in Yellow River Basin are becoming more serious. In order to explore the influence characteristics of coal mining disturbance on soil factors and microbial community in Yellow River Basin, and to clarify the differences in soil microbial communities between the marginal coal mining subsidence area and the unmined area, equidistant sampling was performed from the marginal subsidence area, the start point (HD), to the unmined area in the study area of Shangwan Mine in Inner Mongolia. Specifically, sampling points at 150 (D1), 300 (D2), 450 (D3), 600 (D4) and 750 m (D5) from the marginal subsidence area were selected to measure the three soil factors (nutrient indicators, soil enzymes and soil C∶N∶P stoichiometric characteristics) and the microbial communities.

The results show that the difference of soil factors and microbial diversity between the marginal subsidence area and the unmined area is mainly concentrated in the unmined area closer to the marginal subsidence area (less than 300 m). The total nitrogen, organic matter, and bacterial abundance of soil decrease in varying extent in the region near the marginal subsidence area, while the available potassium, carbon to nitrogen ratio (C/N), and the activity of sucrase and phosphatase increase in varying extent. Regarding the composition of microbial community, the relative abundance of Acidobacteria in the unmined area increases at first and then decreases with the increasing of distance.

The relative abundance of Chloroflexi in the marginal subsidence area is higher than that in the unmined area. Further, the relative abundances of Phaeosphaeriaceae and Chaetomiaceae in the marginal subsidence area are significantly higher than that in the unmined area. It is found through the study that the influence of the marginal subsidence area on the unmined area is mainly concentrated within the area close to the marginal subsidence area (within 300 m). The diversities of bacteria and fungi are more sensitive to soil factors. Besides, the key taxa are correlated with the soil factors in varying degrees. In the future, more attention should be paid in the artificial restoration to the marginal subsidence areas and its influence on unmined areas, and the artificial means should be applied to the key affected areas, so as to achieve a better restoration effect.

**Keywords:** coal mining subsidence area, soil physiochemical properties, microbial community, high-throughput sequencing, ecological stoichiometry

**AN INVESTIGATION INTO THE DISTURBANCE EFFECTS OF COAL MINING ON GROUNDWATER AND SURFACE ECOSYSTEMS**

**Abstract**

Coal mining disturbs surface ecosystems in coal mining subsidence areas. Based on the groundwater-surface composite ecosystem analysis, we constructed an ecological disturbance evaluation index system (18 indices) in a coal mining subsidence area using the analytic hierarchy process (AHP). Taking the Nalinhe mining area in Wushen Banner, China, in 2018-2020 as an example, the weight, ecological disturbance grade and correlation of different indicators were determined by implementing fuzzy mathematics, weighting method, and correlation analysis method. The major conclusions of this review were: (i) After two years of mining, ecological disturbance was the highest in the study area (Grade III) and the lowest in the non-mining area (Grade I). (ii) Coal mining not only directly interfered with the environment, but also strengthened the connection of different ecological indicators, forming multiple ecological disturbance chains such as "mining intensity-mining thickness-buried depth/Mining thickness", "coal mining-surface subsidence-soil chemical factors", and "natural environment-soil physical factors". The disturbance chain that controls the ecological response factors in the region remains to be determined. However, the ecological response factors are the most important factor that hinders the restoration of the ecology in a coal mining subsidence area. (iii) The ecological disturbance in the coal mining subsidence area continued increasing over two years due to coal mining. The ecological disturbance by coal mining cannot be completely mitigated by relying on the self-repair capability of the environment. This study is of great significance for ecological restoration and governance of coal mining subsidence areas.

**Keywords:** Analytic hierarchy process; Coal mining subsidence area; Ecological disturbance assessment; Groundwater and surface ecosystem.

**UNIT XI. MY FUTURE PROFESSION**

#### Science Vocabulary

|  |  |
| --- | --- |
| a mine surveyor | маркшейдер |
| accurate | точний |
| to ensure | забезпечувати, гарантувати |
| to encroach | втручатися |
| elevation | підвищення |
| a legal permit | законний дозвіл |
| to trigger | спрацьовувати |
| assessment | вимірювання |

***Read and translate the text:***

******

### MY FUTURE PROFESSION

First of all it is necessary to mention that every successful person is devoted to his profession. Nowadays technical and mining professions are getting more and more popular. Let us try to find out the advantages and the peculiarities of a mine surveyer profession.

A mine surveyor is a professional engineer and architect who manages the design and future plans for a mining site. These professionals tend to come from various educational backgrounds, and they may work as independent consultants or with a mining operation. A mine surveyor has a tremendous responsibility to ensure the safety of a mine for workers through accurate assessment and careful management.

Becoming a mine surveyor usually requires an educational background that may include mathematics, engineering, or architecture. In addition to formal education, many surveyors receive extensive vocational and on-the-job training in their field. Some surveying jobs require university degrees, but others may substitute sufficient work experience in place of a traditional education.

One of the biggest jobs that a mine surveyor will usually take part in is the creation of maps and plans for the mine. In this task, the surveyor must be able to take accurate measurements of the landscape, including height, depth, and other considerations, and turn the information into a usable map. Surveyors must also be able to research the clear boundaries of the mine area, to ensure that the operation does not encroach on other properties.

Getting the topographical information requires knowledge of surveying instruments, such as theodolites and GPS systems. Surveyors may spend most of their working days out of doors, taking exact and careful measurements of every dip and rise in the landscape. With raw measurement data in hand, a surveyor will then need to convert the information into data that can be used to create a topographical map that includes relative positions, elevations, and other critical measurement information.

In addition to building maps for both the surface and underground operations of a mine, a mine surveyor may need to provide detailed drawings, written explanations, and plans for future expansion. These documents may be very important to obtaining legal permits and insurance certification for the mining operation. Technical drawing, writing ability, and good communication skills are often helpful in this process.

A mine surveyor may be needed to keep records of all mine activity, such as excavations. Mine surveys may need to be updated on a weekly or monthly basis to incorporate all changes to the mine. Any additions or changes to the surface landscape, such as new buildings added or permanent landscape alterations caused by an event such as an earthquake, may also trigger the need for updated surveys. With the busy aura of activity that usually surrounds a productive mine, the job of a mine surveyor may never fully be completed.

1. ***Use the dictionary and write down transcriptions and translations of the words given below:***

landscape alterations, updated surveys, excavations, to obtain permits, theodolite, a topographical map, a mining site.

***Give English equivalents to the following Ukrainian words and word combinations. Make up your own sentences:***

гірнича професія, перевага, особливість, маркшейдер, зміни (коливання), страхування, перемикати (спрацьовувати), землетрус, впроваджувати, поширення.

1. ***Match the synonyms:***

|  |  |
| --- | --- |
| alteration | to give rise |
| to trigger | change |
| to ensure | to intrude |
| to update | to affect |
| to complete | to provide |
| to convert | to finish |
| to encroach | to transform |
| to cause | to interfere |

1. ***Fill in the blanks with the proper words. Change the form if necessary:***

*requirement, train, development, survey, alter*

1. A mine may be needed to keep records of all mine activity.
2. Getting the topographical information knowledge of surveying instruments.
3. Many surveyors receive extensive vocational and on-the-job in their field.
4. A mine surveyor is a professional engineer and architect who the design and future plans for a mining site.
5. Landscape may be caused by earthquakes.
6. ***Put 7-10 key questions to the text.***
7. ***Control points:***
   1. Discuss the advantages of mining professions.
   2. Make up 8-10 sentences about mine surveyors' jobs in Ukraine and in your region in particular.
   3. Make up a dialogue about the challenges of your future profession.

**ADDITIONAL READING**



**Mine Surveyor Job Description**

Mine Surveyors create designs and plan to accurately represent underground mining and surface activities. They generally use scientific tools to map out mineral deposits and determine the commercial viability of mines.

**Responsibilities**

* Create 3D models of mining sites using design software and digital imaging
* Identify potential risks and environmental effects on a mine planning sheet
* Use GIS to create site maps such as mining structures and deposit layers
* Certify the accuracy of surface mining plans and underground surveys
* Negotiate contracts to purchase, lease, or access mining construction sites
* Update construction site maps and plans for mine development
* Chart surface areas using GPS
* Review ownership rights or naive titles
* Advise operators and other mining professionals in restoring the landscape

**Requirements**

* An accredited degree in surveying, spatial science, geospatial science, or geographical information systems
* Strong understanding of safety regulations and practices in mining environments
* Have knowledge and experience using surveying tools, equipment, and surveying technology such as GIS
* Strong organisational skills, is observant, and analytical skills
* Registration as a Surveyor – all states have different eligibility requirements

**Working Conditions**

* Can be physically exhausting working in mines – long walking distances, long-standing hours in all types of weather
* Carry all surveying instruments/equipment to locations
* Travel is essential
* Safety clothing and equipment must be on at all times in hazardous mining environments

**Average Salary**

$140k – $160k per year in Australia

Salary is based on © SEEK and © Indeed statistics and research.

This Mine Surveyor job description is a guideline only and will vary depending on the company, project and location within the Australian/New Zealand market

**Job Opportunities for Mine Surveyors**

If you are a Mine Surveyor and would like to be part of the infrastructure boom in Australia or New Zealand, register your CV here or search for our jobs.

Consult ANZ Recruitment – We consult our Clients on their hiring needs and our Candidates on their career prospects.

Keep up to date with industry news and job opportunities through the ConsultANZ Recruitment LinkedIn page or subscribe to our LinkedIn Newsletter here.

**MINE SURVEYING**

Mine surveyors are responsible for maintaining an accurate plan of the mine as a whole and will update maps of the surface layout to account for new buildings and other structures, as well as surveying the underground mine workings in order to keep a record of the mining operation.

More importantly, the surveyor is involved in the measuring process to calculate ore production, in volume or mass units, from the mining operation. In addition to this, the volume of the dumps of waste accumulating on the surface of the mining property will also be surveyed. This aspect of the work has turned the mine surveyor into a manager of the ‘resources’ of the mine.

Since valuable minerals occur in a variety of concentrations in the ore, the resource manager, in cooperation with the geologist, is responsible for dividing up the ore body into blocks where the average grades of the ore are known. This allows the mining engineer to decide which blocks are economical to extract and which are not. As a result of this information a plan for the extraction of a blended mixture of low and high grade ores can be made. This planning ensures that the mining process is prolonged, the removal of ore is optimised and the metallurgical processing plant, which will not work well if there are large grade variations, is able to operate at consistently high levels of efficiency.

The Mine Surveyor is therefore one of the key contributors to the welfare of the mining industry.surveyors are responsible for maintaining an accurate plan of the mine as a whole and will update maps of the surface layout to account for new buildings and other structures, as well as surveying the underground mine workings in order to keep a record of the mining operation.

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**University Qualified**

Mine Surveyors are involved in mining operations from inception to completion. They assist with the processes of determining the economic viability of potential mine sites, managing and developing sites, and mapping and recording the extent of mineral extraction. Once a mine has been exhausted, they work with other professionals to restore the land and provide advice as to how waste material should be disposed of.

Throughout the course of their work, Mine Surveyors make a significant contribution to the safety of a mine, and those who work on it, through accurate assessments and careful management of data collection.

Mine Surveyors are good at maths and have an interest in geography and the sciences. They also have good organisational and problem-solving skills and enjoy working outdoors as well as indoors.

**“Surveying is a great variety of indoor and outdoor work, and the mines offer a unique lifestyle that I enjoy” -Adam, Grange Resources**

**Tasks for this role**

* Undertakes research and development of surveying and photogrammetric measurement systems, cadastral systems and land information systems.
* Plans and designs land subdivision projects and negotiates details with local governments and other authorities.
* Advises architects, engineering professionals, environmental and other scientists or other relevant professionals on the technical requirements of surveying, mapping and spatial information systems.
* Compiles and evaluates data, interprets codes of practice, and writes reports concerning survey measurement, land use and tenure.
* Prepares site plans and survey reports required for conveyance and land ownership matters.

**THE WORK OF THE MINE SURVEYING TEAM: PITS, BOUNDARIES AND GEODATA**

The members of the mine surveying team play a vital role in the comprehensive monitoring of stability in the Morsleben repository. Their main task is the regular measurement and documentation of movements in a mine in order to record changes in the mine cavities. The technical term for this is geomechanical monitoring.

**A traditional practice with modern applications**

The age-old practice of mine surveying continues to play a vital role in modern mining. Traditional mine surveying was the origin of modern geodetic surveying.

The occupation of the mine surveyor existed as far back as the Middle Ages. Like their modern counterparts, the mine surveyors of the time were also tasked with surveying open-cast and underground mines, defining boundaries and assigning mining districts to different mining operators. They also drew up the first mine plans.

Then, as now, the mine surveyor always played an objective role. To ensure their objectivity, section 64(2) of the Federal Mining Act (BBergG) states that: “Mine surveyors may conduct their professional work independently. The mine surveyor is authorized to certify documents with the presumption of legal force within his geographical area of responsibility.” In other words, a client must not influence a mine surveyor in the carrying out of their profession. The mine surveyor is always answerable to the relevant mining inspectorate.

From site exploration, planning and operation to renovation and the post-mining phase, mine surveying is involved in all stages of mining – and is in greater demand than ever. Mine surveyors record and process a large volume of geodata and use this data to create digital 3D models, for example. These models also reflect the future of mining, because they allow rock to be dealt with in a particularly targeted manner. They also serve as a planning aid when it comes to the environmentally friendly and resource-efficient decommissioning of the Morsleben repository.

One specific example is the measure for the “prevention of mining hazards in the central part” of the Morsleben repository. Geomechanical monitoring in MorslebenInternal Link is to thank for the fact that a damage process in the central part of the Bartensleben pit was detected at an early stage and halted. This process was caused by the large total volume of open drifts and chambers in the mine workings and the long service life of the large mining chambers. High-quality rock salt was mined in the Bartensleben pit until 1969, leaving behind mining chambers with cavity volumes of up to 140,000 cubic metres.

As part of the project for the “prevention of mining hazards in the central part Internal Link, extensive stabilisation work was carried out from 2003 to 2011. Miners backfilled 27 mining chambers in the central part with salt concrete, and the entire process – from the planning to the subsequent long-term monitoring – was accompanied by the mine surveyors.

In summary, mine surveying is involved in every aspect of mining and allows deposits to be exploited in a safe and sustainable manner. The work produces an extensive volume of geodata relating to the planning, management and documentation of mining operations. The data is also used by the mine surveyors to derive a modern mine plan of the Morsleben repository. This plan is provided to the relevant mining office, in its capacity as the supervisory authority, twice a year.

**ABOUT THE DEPARTMENT OF MINING ENGINEERING AND MINE SURVEYING**

**“de terra pro bono humanitatis”**

Latin, translates to: “from the earth for the good of humanity”

“Our vision is to be the leader in the 4th industrial revolution through applied research and development of realistic mining related applications that guides our teaching and learning focused on safe, sustainable exploitation of our continent’s mineral wealth.”

All the resources used by humankind can be categorized into two very basic formats. If a commodity cannot be grown, it must be mined. Therefore, all the modern technology used in the Industrial revolution 4.0, in its most fundamental form has its origin in a mine. Mining is crucial to the development of our economy and our society. The programmes in Mining Engineering and Mine Surveying are the backbone of the mining industry both on the continent but also world-wide.

We are very proud of our history and our contribution to the development of the mining industry in South Africa. The Department of Mining Engineering and Mine Surveying can trace its origins back over 125 years to the School of Mines that was established in Kimberly in 1896. The current School of Mines at the University of Johannesburg will turn 100 in 2026. If you start working on any mine in South Africa, the chances are good that some of your supervisors will be alumni from UJ. UJ has a hard-earned international reputation for developing practical, “hands-on” Mining Engineers and Mine Surveyors that are immediately employable and productive after graduation. It is exciting to know that the graduates from these new programmes will continue this legacy in times to come. We have a very proud history with a number of well-known figures within the mining industry that have graduated from this institution.

Our Mining Engineering and Mine Surveying graduates are designing and operating mines that are up to 4 000metres underground and the ore they need to mine is only one metre high. To put that in perspective, imagine a book that is 4 000 pages thick. Our graduates are trained to develop a safely mine down to that one specific page. Graduates will work as a team of Surveyors, Mining Engineers, Rock engineers, Geologists and other experts to ensure the optimal extraction of a mineral resource to the benefit of both the shareholders and the local community.

Our department use GPS, drones, laser scanning technology and 3D printing to visualize these complex 3D structures at all stages of the mining process in our undergraduate teaching. The Minerals industry is adapting to the IR4.0 and our students are now introduced to VR training, the safe operation of Drones (RPAS) and Laser scanning amongst others. Our lecturers are involved in research in the fields as diverse as underground navigation systems that will ultimately guide autonomous mining machines, holo-lens applications and the impact of Women in Mining on the productivity of the industry.

The UJ was identified as a Flagship university the UNESCO international competence centre for mining engineering education in St Petersburg, Russia. Prof. Grobler attended the Governing Board and Supervisory Council of the International Competence Centre for Mining-Engineering Education under the auspices of the United Nations Educational, Scientific and Cultural Organization (UNESCO) hosted at the Saint Petersburg Mining University, Russia on the 19th and 20th of February 2020 in the role of Professional Expert Community member.

Mining Engineering technologists are involved in the daily production activities that includes the design of excavations, developing drilling patterns for the explosives, the cleaning of the broken rock and the support of excavations. Mine Engineers are appointed as Mine Managers and are responsible for all the operations on a mine from the financial management, mechanical and electrical engineering, mineral beneficiation and mining operations. It is a job with extremely high responsibilities.

Mine Surveyors plan and design excavations based on a valuation of the ore deposit and providing the production personnel with controls to ensure that the excavations are made in the correct 3D position of the design. Mine Surveyors are legally appointed in terms of the Mine Health and Safety Act to take responsibility for the accurate spatial control of mining operations and the updating of mine plans (maps) of all the workings of the mine. UJ offers the only accredited and recognized degree in Mine Surveying in South Africa.

Head of Department: Prof Hendrik Grobler

**ADDITIONAL READING**

**THE ROCK CYCLE**

The rock cycle best explained as the relationship between earth's internal and external processes. Weathering (breaking down rock) and erosion (transporting rock material) at or near the earth's surface breaks down rocks into small and smaller pieces. These smaller pieces of rock (such as sand, silt, or mud) can be deposited as sediments that, after hardening, or lithifying, become sedimentary rocks. Extreme pressure from burial, increasing temperature at depth, and a lot of time, can alter any rock type to form a metamorphic rock. If the newly formed metamorphic rock continues to heat, it can eventually melt and become molten (magma). When the molten rock cools it forms an igneous rock. Metamorphic rocks can form from either sedimentary or igneous rocks. The sedimentary particles from which a sedimentary rock is formed can be derived from a metamorphic, an igneous, or another sedimentary rock. All three rock types can be melted to form a magma. Thus, the cycle has continued over the ages, constantly forming new rocks, breaking those down in various ways, and forming still younger rocks. Rocks at the surface of the earth range in age from over three billion years old to a few hundred years old.

Igneous rock can change into sedimentary rock or into metamorphic rock. Sedimentary rock can change into metamorphic rock or into igneous rock. Metamorphic rock can change into igneous or sedimentary rock.

Igneous rock forms when magma cools and makes crystals. Magma is a hot liquid made of melted minerals. The minerals can form crystals when they cool. Igneous rock can form underground, where the magma cools slowly. Or, igneous rock can form above ground, where the magma cools quickly.

When it pours out on Earth's surface, magma is called lava. Yes, the same liquid rock matter that you see coming out of volcanoes. Igneous rock that pours out onto the Earth's surface is called igneous extrusive, whereas igneous rock that cools beneath the surface is called igneous intrusive.

On Earth's surface, wind and water can break rock into pieces (weathering!). They can also carry rock pieces to another place (erosion)!. Usually, the rock pieces, called sediments, drop from the wind or water to make a layer. The layer can be buried under other layers of sediments. After a long time the sediments can be cemented together to make sedimentary rock. In this way, igneous rock can become sedimentary rock.

All rock can be heated. But where does the heat come from? Inside Earth there is heat from pressure (push your hands together very hard and feel the heat). There is heat from friction (rub your hands together and feel the heat). There is also heat from radioactive decay (the process that gives us nuclear power plants that make electricity). So, what does the heat do to the rock? It bakes the rock.

Remember, all rocks are made up of mineral crystals, or pieces of other rocks made up of crystals. Baked rock does not melt, but it does change. It forms crystals. If it has crystals already, it forms larger crystals. Because this rock changes, it is called metamorphic. Remember that a caterpillar changes to become a butterfly. That change is called metamorphosis. Metamorphosis can occur in rock when they are heated to 300 to 700 degrees Celsius.

When Earth's tectonic plates move around, they produce heat. When they collide, they build mountains and metamorphose the rock.

The rock cycle continues. Mountains made of metamorphic rocks can be broken up and washed away by streams. New sediments from these mountains can make new sedimentary rock. The rock cycle never stops.

**Igneous Rocks.** Igneous rocks are a type of rock formed from extremely hot (2,200 degrees F) molten masses known as magma. Magma is present everywhere below the surface of the earth's crust. Generally, magma lies about 90 miles below the surface. In certain places, such as Yellowstone National Park, the magma is as close as 40 miles below the surface. On average, every 100 feet you dig down into the earth, the temperature will increase about 1.4 degrees F (this is a bit scary - keep this in mind the next time you visit a coal mine in Pennsylvania or the next time you descend into a lava tube near Flagstaff!.

Sometimes magma forces its way up to the surface through a vent (such as a volcano) and spills onto the surface. This happened near Flagstaff, Arizona at Sunset Crater less than 1,000 years ago. Once magma comes out onto the surface of the earth it is called lava, and it cools rapidly at the surface. The resulting rock is called extrusive igneous rock (it is extrusive because the rock extruded out of the ground onto the surface). Extrusive igneous rocks can be distinguished by their small crystal sizes. In all extrusive igneous rock, it is nearly impossible to detect crystals without the aid of a microscope. The faster the rock cools, the smaller the crystals. Some extrusive igneous rocks cool so quickly that they have a glassy texture. Common extrusive igneous rocks are: andesite, basalt, dacite, pumice, rhyolite, and obsidian. The crystals are so fine in obsidian, that paleo-people and modern surgeons alike use/used the rock to manufacture razor-sharp tools.

However, a much greater volume of this fluid magma never reaches the earth's surface; it only intrudes into the upper part of the earth's crust and solidifies. The rocks that form by this process are known as intrusive igneous rocks (it is intrusive because the rock did not extrude out of the ground onto the surface). Intrusive igneous rocks solidify over a period of thousands of years. This slow cooling rate allows better development of mineral crystals. Intrusive igneous rocks will have eye visible crystals and will appear coarse-grained. Igneous intrusive rocks eventually will become exposed at the surface of the earth by erosion of the overlying material. Common intrusive igneous rocks are granite, diorite, gabbro, and peridotite.

The La Sal Mountains were formed by widespread igneous activity that began about 40 million years ago. Caldera explosions erupted thousands of cubic miles of volcanic rocks from several locations. Volcanoes spewed ash and lava. For 20 million years these extrusive volcanic rocks smoothed the landscape, filling depressions with accumulations of ash, flows, and debris literally miles thick. These mostly pastel-colored extrusive rocks still blanket much of the high areas of central and southwestern Utah. Not all of the molten rising igneous material erupted as volcanic rocks; some material, along with its mineral-bearing fluids, congealed in the earth's crust. Several of these intruded masses having been exposed by erosion or encountered out by exploration drilling became great mining districts, such as at Alta, Brighton, Bingham, Park City, and Cedar City. In the Colorado Plateau, bodies of intrusive rocks domed the overlying sedimentary rocks to form the Abajo and Henry Mountains (as well as the La Sal Mountains).

**Metamorphic Rocks**. Morphos is the Greek word for “form” or “shape”, and metamorphism means ``change of form''.

Inside the Earth, the temperature and pressure are much higher than on the surface, and these effects, along with fluids percolating through rock, can change the chemistry, mineralogy, and/or structure of the rocks, without melting them. Rocks which have undergone these sorts of changes are called metamorphic rocks.

**Agents of Matamorphosis.** The three primary agents which metamorphose rock are temperature, pressure, and fluids:

**1) *Temperature***

High temperatures can change rock by changing the structure of the minerals which make up the rocks; changing the structure of the minerals changes them into new minerals (remember the definition of a mineral). Two primary sources for high temperatures inside the Earth are:

*Geotherm*

As you dig deeper into the Earth, the temperature increases; it typically increases at a rate between 20° and 60°C per kilometer into the Earth. This increase in temperature with increase in depth is called the geotherm.

*Intrusions*

Another source of high temperatures inside the Earth is magma intruding cooler rock. These temperature increases are localized near the intrusion, but also metamorphose rock (this is called contact metamorphism).

**2) *Pressure* (aka Stress)**

Pressure (or more properly, stress) can also change rock. There are two main kinds I want you to know about:

*Confining Pressure*

Pressure due to the weight of overlying rock. This kind of pressure is roughly the same in all directions (this is like water pressure when scuba diving), and is the kind which compacts rock during diagenesis. Confining pressure changes rock by compaction and by changing the crystal structure of minerals from relatively open forms to more densely-packed forms. One mineral which does this is olivine, which changes from olivine (isolated silica tetrahedra) to spinel (a much more tightly-bonded structure) to perovskite (a still more highly compressed structure).

*Directed Pressure*

Pressure which is “aimed”, in the sense that it is higher in certain directions than in others. Imagine squeezing a ball of Play-Doh between your fingers - you direct pressure along the line between your fingers and thus squish the Play-Doh. This kind of pressure is usually due to tectonic forces. It changes rocks by changing the structure of minerals and by changing the orientation of mineral grains, particularly platy minerals like mica or clay.

**3) Fluids**

Fluids which metamorphose rock are not pore fluids remaining from when sedimentary rocks were deposited. Instead, they come from two main sources: hydrothermal fluids from magmatic intrusions and dehydration of minerals, like clay, which contain water in their structures (hydrous minerals).

Whatever the source, fluids contain ions dissolved from other rock or from their original source. As fluids percolate through rocks, they can exchange ions with the existing minerals and thus change the chemical makeup of those minerals. The other way fluids change minerals is by hydrating minerals which previously did not contain water.

Either way, fluids change the chemical makeup of minerals, turning them into new minerals, which changes the rocks which were made of the previous minerals. This process of change by fluids is called metasomatism.

**Vocabulary:**

**silica tetrahedra -** кремнеземні тетраедри

**andesite** - андезит

**basalt** - базальт

**dacite** - дацит

**pumice** - пемза

**rhyolite** - ріоліт

**obsidian** – обсидіан

**Play-Doh -** пластилін

**olivine –** олівін

***I. Match the terms with their correct definitions.***

1. **Heat and Pressure**
2. **Erosion**
3. **Deposition**
4. **Compaction**
5. **Cementation**
6. **Melting**
7. **Cooling**
8. **Weathering**

***Definitions***:

* 1. The process by which sediments are pressed together under their own weight.
  2. The breaking down of rocks into smaller pieces by wind, water, or biological activity.
  3. The process by which sediments settle out of a transporting medium.
  4. The movement of rock fragments by wind, water, ice, or gravity.
  5. The process that binds sediments into solid rock.
  6. The process of turning solid rock into magma.
  7. The solidification of magma or lava to form igneous rock.
  8. Forces that cause metamorphic rocks to form from existing rocks.

***II. Complete the sentences using the appropriate vocabulary words.***

1. The process of \_\_\_\_\_\_\_\_\_\_ breaks down rocks into smaller pieces.
2. \_\_\_\_\_\_\_\_\_\_ transports these rock fragments to new locations.
3. When these particles settle, the process of \_\_\_\_\_\_\_\_\_\_ occurs.
4. Over time, sediments are pressed together through \_\_\_\_\_\_\_\_\_\_.
5. \_\_\_\_\_\_\_\_\_\_ then binds these particles into a solid rock.
6. Under extreme conditions, rocks can undergo \_\_\_\_\_\_\_\_\_\_ to form magma.
7. When magma cools, it solidifies into \_\_\_\_\_\_\_\_\_\_ rock.
8. Existing rocks can become metamorphic through \_\_\_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_.

***III. Choose the correct answer for each question.***

1. Which process describes the breakdown of rocks into smaller pieces?

a. Erosion

b. Weathering

c. Deposition

1. What happens during the process of deposition?

a. Rocks are transported to new locations.

b. Particles settle and accumulate.

c. Rocks are broken down by natural forces.

1. What is the term for the process that binds sediments into solid rock?

a. Compaction

b. Cementation

c. Cooling

1. How are metamorphic rocks formed?

a. By the cooling of magma.

b. By weathering and erosion.

c. By heat and pressure on existing rocks.

1. Which process is necessary to transform rock into magma?

a. Cooling

b. Melting

c. Deposition

***IV. Determine if the statements are true or false.***

1. Erosion is the process of rocks being broken down by wind, water, or biological activity. (True/False)
2. Deposition occurs when particles are transported to a new location. (True/False)
3. Metamorphic rocks are formed by the cooling of magma. (True/False)
4. Cementation is the process that binds sediments into solid rock. (True/False)
5. Compaction is the melting of rocks to form magma. (True/False)

***V. Answer the following questions in one or two sentences.***

1. What is the process of weathering, and what causes it?
2. How does erosion differ from weathering?
3. Explain the process of deposition.
4. Describe how compaction and cementation contribute to the formation of sedimentary rock.
5. What conditions are necessary for the formation of metamorphic rock?
6. How is magma formed from existing rock?
7. What happens when magma cools?

**TYPES OF ROCK METAMORPHISM**

**Some kinds of metamorphism:**

*Burial*

Bury rocks deeply enough and they will warm up and change. This form of metamorphism is found anywhere where sediments and rocks are buried deeply, and should strike you as being pretty similar to diagenesis, which we discussed last time. The line between diagenesis and burial metamorphism is fuzzy.

*Regional*

Caused by widespread moderate-to-high temperatures and pressures, as opposed to localized changes along faults or near magmatic intrusions. You find this type of metamorphism in mountain building regions and near subduction zone volcanism.

*Contact*

Caused by high temperatures near magmatic intrusions. Found in volcanic regions (subduction zones, hot spots) and mountain building zones.

*Cataclastic*

Caused by grinding along fault zones. Found along major faults (like the San Andreas Fault in California), in mountain building zones, and in deformation regions associated with subduction zones.

*Hydrothermal*

Caused by hot fluids percolating through rocks. Found anywhere where hot fluids can percolate through rocks, notably along mid-ocean ridges.

**Metamorphic Rocks and Rock Textures.** Three major texture and rock types for metamorphic rocks that you need to know:

*Foliated Rocks*

Characterized by parallel planes formed through directed pressure and preferred growth orientations of certain platy minerals. Two common kinds are schist and gneiss, which have been used in a great many really bad geological puns.

*Non-foliated Rocks*

Don't have those planes, usually because they are made of mineral grains which are cubic or spherical, and therefore have no preferred orientation. Two common examples are marble and amphibolites.

*Deformational*

Caused by cataclastic metamorphism. The most common rock of this kind is called a mylonite; there is a big mylonite belt in the mountains south of Palm Springs, CA.

*Metamorphic Grade*

Geologists who study metamorphic rocks have come up with the concept of metamorphic grade to describe how 'metamorphosed' a rock is. It runs from low grade, where the rocks are hardly changed from their original form due to low pressures and temperatures, to high grade, where the rocks are heavily altered due to high pressures and/or temperatures.

More specific distinctions can be made through lab experiments in which various kinds of rocks are squeezed and heated up and the changes observed. Through this kind of work, geologists have found a set of index minerals, which are common minerals which form under particular combinations of pressure and temperature. Armed with knowledge from these experiments, field geologists can go out and make maps of mineral location to determine how metamorphism is distributed over large regions of rocks.

*Metamorphic Facies*

Two fundamental points about metamorphism are:

If you start with two different rocks (say a basalt and a sandstone) and heat them up and squeeze them identically, so that they have gone through the same pressure/temperature conditions, you will get new minerals. Those minerals will be different for the different rocks, even under identical pressure/temperature conditions.

If you start with two identical rocks (say two chunks of the same sandstone) and heat them and squeeze them differently, so that they have gone through different sets of pressure/temperature conditions, you will get new minerals. Those minerals will be different for the same rocks under different pressure/temperature conditions.

Keep that in mind: you get different minerals from different rocks under the same conditions and you get different minerals from the same rocks under different conditions.

Geologists have formalized these statements into a system of classifications for rocks by pressure and temperature conditions, so that a given combination of pressure and temperature will give a specific class of rocks. These classifications are called metamorphic facies.

The most important thing about metamorphic facies is that if you know the kind of metamorphic rock you have, you can work backward to find out the pressure/temperature conditions under which it formed. This is vital information for figuring out past tectonic conditions in the region, since certain facies form in certain plate tectonic environments.

For example, blueschists form under low temperatures and moderate-to-high pressures, which indicates that the material which metamorphosed was shoved down into the Earth so quickly it didn't have much time to warm up. What kind of plate tectonic environment displays these features? Subduction zones!

**Sedimentary Rocks:**

Once material is weathered from rocks, it is transported away and later deposited somewhere else, and eventually is turned into new rocks. Such rocks are called sedimentary rocks. What are sediments? What is a sedimentary rock?

Sediments are loose particles of former rocks. They can either be bits of rock (ranging from mineral grains all the way to boulders) or material which was dissolved and then later precipitated from water to form solid crystals.

After these sediments are deposited, they may be buried and undergo a set of physical and chemical changes which turn them into solid rock. Rocks formed from sediments are called sedimentary rocks.

**Types of Sedimentary Rocks.** There are three main types of sedimentary rocks I want you to know about:

*Clastic*

Made from solid particles which were weathered from previous rocks.

*Chemical/Biochemical*

Made from sediments which precipitate from water (usually seawater) through chemical or biochemical processes

**Sedimentary Cycle**

All sedimentary rocks go through a cycle similar to this one:

* Weathering from previous rocks
* Erosion of weathering products
* Transport of particles from weathering region to someplace else
* Deposition of sediments
* Burial of sediments
* Diagenesis

We will illustrate these processes with clastic rocks, then discuss chemical and biochemical rocks.

**Clastic Rocks: Transport**

There are a number of different ``transportation agents'', or ways in which sediments are moved from one place to another; practically all of them move things downhill or downstream. Here's a brief list of some:

* Rivers
* Glaciers
* Wind
* Ocean Waves/Tides/Currents

All these modes can transport clastic particles of various sizes, and the size each can transport depends on the force with which it flows. For example, a river can transport clastic particles of all sizes when it is flowing rapidly, high in the mountains or during a flash flood. As the current slows, the river drops big particles first, then the next size, then the next, and so on. When the current is very gentle, only the smallest particles are carried. This phenomenon is called sorting.

Another phenomenon resulting from transport of clastic particles is called rounding. Basically, as particles are moved downstream, they bounce around and chips are taken off, especially around the corners. In this way, the sharp edges are worn away and a smoother, rounder particle is left. The farther a particle travels, the rounder and smoother it will be.

**Clastic Rocks: Deposition**

Rivers (and all other modes) transport clastic material downstream and then drop it someplace; this process is called deposition or sedimentation. Places where this occurs are called sedimentary environments.

**Clastic Rocks: Burial/Diagenesis**

As sediments are deposited, they build layers of material. These layers are buried by later sediments, which are buried by later sediments, and so on and so on.

As more and more sediments are deposited, the sediments near the bottom get heated up and squeezed more and more. The sediments begin to undergo diagenesis, which is an umbrella term for physical and chemical changes which turn sediment into sedimentary rocks.

Physically, the primary change is compacting sediments and squeezing out fluid in the pores between sediment grains; imagine squeezing water out of a sponge. One of the major chemical changes is that new minerals can form between the clastic grains and cement the grains together; calcite is a common cement. On the other hand, some of the more soluble clastic grains may dissolve over time or be replaced by other materials.

**Classification of Clastic Rocks**

There are two major kinds of clastic sedimentary rocks to discuss: sandstones and fine-grained rocks.

When sand lithifies, it turns into a sandstone. Sandstones can be classified by a number of different criteria, but the most common are grain size and shape and mineralogy. There are three major kinds of fine-grained clastic sedimentary rocks:

*Siltstone.*

Made of lithified silt.

*Shale*

Made of silt and clay, and tend to break on thin planes. Some kinds of shale contain lots of oily stuff and may be important sources of oil in the future. Purely as a sidelight, you can light these rocks on fire with a blowtorch (of course, it's really the oily stuff burning, not the rock, but it's still impressive to see a rock “burning”).

*Mudstone*

Made of lithified mud, usually blocky and smell musty when you breathe on them.

**Chemical/Biochemical Rocks: A Brief Overview**

Having dealt with clastic rocks, we now look at chemical and biochemical rocks. The raw materials to make these rocks are chemical solutions of water containing various ions dissolved from pre-existing rocks. These ions are dissolved in the water and flow with it downstream into lakes and the ocean. Once the material arrives in the ocean, it can be precipitated out of the water through either biochemical or inorganic chemical means.

Chemical and biochemical materials, once precipitated as solids, go through diagenesis just as clastic rocks do, though chemical changes are more important for these rocks than are physical changes. One common chemical change is changing aragonite, which is fine-grained calcium carbonate, to less fine-grained calcite.

Chemical and biochemical rocks can be classified by chemistry, and here are three major kinds:

*Carbonates*

Rocks which are made from lithified carbonate materials. They are formed mostly in ocean waters, and mostly are biochemical. In fact, many of the carbonate rocks found are actually formed from the shells of marine critters like foraminifera, gastropods (snails), and such. Coral reefs are also made from carbonate materials. The most important carbonate rock is limestone.

*Evaporites*

Start with a shallow brackish lagoon in an arid region and evaporate water from it; evaporite minerals will precipitate and lithify on the floor of the lagoon. Common rocks formed are carbonates, rock salt, and gypsum. These materials are also formed in saline inland lakes, such as the Great Salt Lake in Utah and Mono Lake in California.

*Cherts*

Cherts are formed in the deep, deep ocean in some places. They are made from lithifying silica-rich gunk called “siliceous ooze”. This siliceous ooze is actually made from the shells of dead diatoms!

**Vocabulary**:

**diagenesis** - діагенез

**schist** - сланець

**gneiss** – гнейс

**chunk** – шматок

**mudstone** – аргіліт

**brackish lagoon** - солонувата лагуна

**siliceous ooze -** крем'янистий осад

**chert -** крем'янистий вапняк

1. ***Match the rock types with their definitions.***
2. **Igneous Rock**
3. **Sedimentary Rock**
4. **Metamorphic Rock**
5. **Granite**
6. **Limestone**
7. **Marble**
8. **Sandstone**
9. **Basalt**

***Definitions***:

1. A rock formed from the cooling and solidification of magma or lava.
2. A rock that forms from the compression and cementation of particles and sediments.
3. A rock that has been changed by heat, pressure, or chemical processes.
4. A coarse-grained igneous rock composed mainly of quartz, feldspar, and mica.
5. A sedimentary rock consisting mainly of calcium carbonate, often composed of marine fossils.
6. A metamorphic rock formed from limestone under high pressure and temperature.
7. A sedimentary rock composed of sand-sized particles.
8. A fine-grained, dark-colored igneous rock commonly found in volcanic regions.

1. ***Complete the sentences using the appropriate vocabulary words.***
2. \_\_\_\_\_\_\_\_\_ rock is formed from the cooling of magma or lava.
3. Layers of sediment compress over time to form \_\_\_\_\_\_\_\_\_\_ rock.
4. Under extreme heat and pressure, limestone can become \_\_\_\_\_\_\_\_\_\_.
5. \_\_\_\_\_\_\_\_\_\_ is an example of a sedimentary rock that often contains fossils.
6. \_\_\_\_\_\_\_\_\_\_ is a common igneous rock that is light in color and coarse-grained.
7. \_\_\_\_\_\_\_\_\_\_ rock is created when existing rock is subjected to high heat and pressure.
8. \_\_\_\_\_\_\_\_\_\_ is a dark, fine-grained igneous rock often found in oceanic crust.
9. \_\_\_\_\_\_\_\_\_\_ is a sedimentary rock that forms from sand particles cemented together.
10. ***Choose the correct answer for each question.***

1. Which type of rock is formed from molten material?

a. Sedimentary

b. Metamorphic

c. Igneous

2. What type of rock is sandstone?

a. Igneous

b. Sedimentary

c. Metamorphic

3. Which rock is formed from limestone under heat and pressure?

a. Basalt

b. Marble

c. Granite

4. Which type of rock often contains fossils?

a. Igneous

b. Metamorphic

c. Sedimentary

5. Granite is an example of which type of rock?

a. Igneous

b. Sedimentary

c. Metamorphic

1. ***Determine if the statements are true or false.***

1. Basalt is a coarse-grained igneous rock. (True/False)

2. Metamorphic rocks are formed by the cooling and solidification of magma. (True/False)

3. Limestone can become marble through metamorphic processes. (True/False)

4. Sandstone is a type of igneous rock. (True/False)

5. Igneous rocks are formed from sediments compressed and cemented over time. (True/False)

1. ***Answer the following questions in one or two sentences.***

1. How are igneous rocks formed?

2. What is the primary process that forms sedimentary rocks?

3. Describe how metamorphic rocks are created.

4. Give an example of a rock that is commonly found in oceanic crust.

5. What type of rock is marble, and how is it formed?

**PROPERTIES OF MINERALS**

The Physical properties of minerals are used by Mineralogists to help determine the identity of a specimen. Some of the tests can be performed easily in the field, while others require laboratory equipment. For the beginning student of geology, there are a number of simple tests that can be used with a good degree of accuracy. The list of tests is in a suggested order, progressing from simple experimentation and observation to more complicated either in procedure or concept.

Most books about minerals list these characteristic for each mineral.

***Properties of Minerals***

The following physical properties of minerals can be easily used to identify a mineral:

* Color
* Streak
* Hardness
* Cleavage or Fracture
* Crystalline Structure
* Diaphaneity or Amount of Transparency
* Tenacity
* Magnetism
* Luster
* Odor
* Taste
* Specific Gravity
* Properties of Minerals A Detailed Description

***Color***

Most minerals have a distinctive color that can be used for identification. In opaque minerals, the color tends to be more consistent, so learning the colors associated with these minerals can be very helpful in identification. Translucent to transparent minerals have a much more varied degree of color due to the presence of trace minerals. Therefore, color alone is not reliable as a single identifying characteristic.

***Streak***

Streak is the color of the mineral in powdered form. Streak shows the true color of the mineral. In large solid form, trace minerals can change the color appearance of a mineral by reflecting the light in a certain way. Trace minerals have little influence on the reflection of the small powdery particles of the streak.

The streak of metallic minerals tends to appear dark because the small particles of the streak absorb the light hitting them. Non-metallic particles tend to reflect most of the light so they appear lighter in color or almost white.

Because streak is a more accurate illustration of the mineral’s color, streak is a more reliable property of minerals than color for identification.

***Streak Test***

To test the streak color of a mineral you need a streak plate. A streak plate is just a ceramic, unglazed tile. To test a mineral rub the specimen across the tile as if trying to make a scratch. Observe the color the residue left on the tile.

***Hardness***

Hardness is one of the better properties of minerals to use for identifying a mineral. Hardness is a measure of the mineral’s resistance to scratching. The Mohs scale is a set of 10 minerals whose hardness is known. The softest mineral, talc, has a Mohs scale rating of one. Diamond is the hardest mineral and has a rating of ten. Softer minerals can be scratched by harder minerals because the forces that hold the crystals together are weaker and can be broken by the harder mineral.

The following is a listing of the minerals of the Mohs scale and their rating:

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

If you do not have the set of minerals listed above there are some common household items that can be used to get a good approximation.

* fingernail- 2 to 2.5 on the Mosh scale
* Copper penny or house wire-3 on the Mosh scale
* Glass-5.5 on the Mosh scale
* knife-5.5 to 6 on the Mosh scale
* Steel file-6.5 on the Mosh scale
* Streak plate (unglazed ceramic tile)- 6.5 to 7 on the Mosh scale

To preform the hardness test try to scratch one item with the other.

***Cleavage & Fracture***

Minerals tend to break along lines or smooth surfaces when hit sharply. Different minerals break in different ways showing different types of cleavage.

Cleavage is defined using two sets of criteria. The first set of criteria describes how easily the cleavage is obtained. Cleavage is considered perfect if it is easily obtained and the cleavage planes are easily distinguished. It is considered good if the cleavage is produced with some difficulty but has obvious cleavage planes. Finally it is considered imperfect if cleavage is obtained with difficulty and some of the planes are difficult to distinguish.

The second set of criteria is the direction of the cleavage surfaces. The names correspond to the shape formed by the cleavage surfaces: Cubic, rhombohedral, octahedral, dodecahedral, basal or prismatic. These criteria are defined specifically by the angles of the cleavage lines as indicated in the chart below:

Fracture describes the quality of the cleavage surface. Most minerals display either uneven or grainy fracture, conchoidal (curved, shell-like lines) fracture, or hackly (rough, jagged) fracture.

***Crystalline Structure***

Mineral crystals occur in various shapes and sizes. The particular shape is determined by the arrangement of the atoms, molecules or ions that make up the crystal and how they are joined. This is called the crystal lattice. There are degrees of crystalline structure, in which the fibers of the crystal become increasingly difficult or impossible to see with the naked eye or the use of a hand lens. Microcrystalline and cryptocrystalline structures can only be viewed using high magnification. If there is no crystalline structure, it is called amorphous. However, there are very few amorphous crystals and these are only observed under extremely high magnification.

***Transparency or Diaphaneity***

Diaphaneity is a mineral’s degree of transparency or ability to allow light to pass through it. The degree of transparency may also depend on the thickness of the mineral.

To test for transparency hold the specimen up to the light. If you can see through it it is called transparent. If you put your finger behind the mineral and can see the shadow of your finger it is called translucent. If no light comes through it is called opaque.

***Tenacity***

Tenacity is the characteristic that describes how the particles of a mineral hold together or resist separation. Follow the link below to view the list of terms used to describe tenacity and a description of each term. Tenacity refers to the resistance of a mineral to breaking, bending, cutting, or other forms of deformation. It describes how a mineral behaves when it is subjected to stress. Tenacity can be described using terms such as brittle, malleable, ductile, sectile, and flexible.

**Tenacity Terms**

***Magnetism***

Magnetism is the characteristic that allows a mineral to attract or repel other magnetic materials. It can be difficult to determine the differences between the various types of magnetism, but it is worth knowing that there are distinctions made. This property is most commonly associated with minerals that contain iron, such as magnetite. Magnetic minerals can be identified using a magnet.

***Luster***

Luster is the property of minerals that indicates how much the surface of a mineral reflects light. The luster of a mineral is affected by the brilliance of the light used to observe the mineral surface. Luster of a mineral is described in the following terms:

*Metallic.* The mineral is opaque and reflects light as a metal would.Submettalic The mineral is opaque and dull. The mineral is dark colored.Nonmettalic The mineral does not reflect light like a metal.

*Nonmetallic*. Мinerals are described using modifiers that refer to commonly known qualities.

*Waxy.* The mineral looks like paraffin or wax.

*Vitreous.* The mineral looks like broken glass. Vitreous luster refers to a glassy appearance of a mineral surface. Minerals with vitreous luster reflect light in a way similar to glass. Quartz is a common example of a mineral with a vitreous luster.

*Pearly.* The mineral appears iridescent, like a pearl.

*Silky.* The mineral looks fibrous, like silk.

*Greasy*. The mineral looks like oil on water.

*Resinous*. The mineral looks like hardened tree sap (resin).

*Adamantine*. The mineral looks brilliant, like a diamond.

***Odor***

Most minerals have no odor unless they are acted upon in one of the following ways: moistened, heated, breathed upon, or rubbed.

***Taste***

Only soluble minerals have a taste, but it is very important that minerals not be placed in the mouth or on the tongue. You should not test for this property in the classroom.

***Specific Gravity***

Specific Gravity of a mineral is a comparison or ratio of the weight of the mineral to the weight of an equal amount of water. The weight of the equal amount of water is found by finding the difference between the weight of the mineral in air and the weight of the mineral in water.

Knowing the properties of minerals will help you to identify minerals in the field.

**Vocabulary:**

**tenacity**

the determination to continue what you are doing

**magnetism**

the power of being able to attract iron and steel objects

**luster**

the brightness that a shiny surface has

**vitreous**

made of or similar to glass

**cubic**

used in units of volume to show when the length of something has been multiplied by its width and height (cubic is a term used to describe the crystal system or habit of a mineral that forms in the shape of a cube or exhibits a symmetry that conforms to a cube. Minerals like halite and pyrite often crystallize in the cubic system).

**rhombohedral**

describes a crystal system or habit where the crystals are shaped like a rhombohedron, a three-dimensional figure where all faces are rhombus-shaped. Calcite commonly exhibits rhombohedral cleavage.

**octahedral**

octahedral describes a crystal system or habit where the mineral forms in the shape of an octahedron, which has eight faces. Fluorite and diamonds are examples of minerals that can exhibit octahedral shapes.

**dodecahedral**

dodecahedral refers to a crystal system or habit where the mineral forms in the shape of a dodecahedron, a polyhedron with twelve flat faces. Garnet is a common example of a mineral that can exhibit dodecahedral crystal form.

**basal**

basal cleavage refers to the ability of a mineral to split along a flat plane parallel to its base. Minerals with basal cleavage can be split into thin sheets. An example is mica.

**prismatic**

prismatic refers to a crystal habit or cleavage where the mineral forms elongated, prism-like shapes. Prismatic cleavage occurs along planes parallel to the length of the prism. Minerals like tourmaline and beryl can show prismatic forms.

**MINING SURVEYING**

Mining surveying is one of the essential processes for exploration activities and efficient resource management. Providing accurate data on an area’s geology allows companies to make informed decisions about where best to locate their operations, how much mineral they have available, and what potential hazards are present in the vicinity.

With the proper techniques and experienced professionals, making the most of available resources and maximizing profits is possible. And with the advancement of technology, mining companies have already upgraded their technique in making this work operation.

**Getting to Know Mineral Exploration**

Mineral exploration is identifying and assessing potential areas for mineral extraction. It involves researching, mapping, and surveying an area of land to determine if it contains exploitable deposits of minerals or resources.

Exploration typically begins with geological studies identifying features such as ore bodies, faults, or other structures that may contain valuable minerals. Surveying techniques such as aerial mapping and drone surveys help to map out the target area in more detail.

Exploration is an integral part of the mineral extraction process. It helps identify potential mining sites for maximum development and returns on investment. Mineral exploration typically comes with considerable risks, so companies must carefully assess potential areas before committing resources.

**What is Mining Surveying?**

Mining surveying is an essential technique in mineral exploration and aerial mapping. It involves using remote sensing and ground-based measurements to determine mineral deposits’ location, size, shape, and orientation.

Detailed surveys make it possible to accurately measure ore bodies that are difficult or impossible to access. Mining companies can utilize the gathered information for efficient resource management, economic evaluation, and legal filings. Mining surveying also provides valuable data on the subsurface geology, which can help identify areas suitable for further exploration.

This work procedure is irreplaceable for exploration activities and efficient resource management. Providing accurate data on an area’s geology allows companies to make informed decisions about where best to locate their operations, how much mineral they have available, and what potential hazards are present in the vicinity.

**Traditional Surveying Technique**

Before the technology upgrade, surveying has become a crucial part of mining. The traditional surveying procedure is there to help miners mine successfully.

Traditional mining survey involves the use of ground-based instruments and manual measurements. It is a slow process but can be very accurate as it allows for direct contact with the ore body. Getting an accurate picture of the subsurface geology is possible by taking detailed measurements such as depths, widths, and angles.

This method was used extensively during the 19th century when most mineral exploration occurred on foot or by horseback. Although traditional techniques are still in use in some places, this method has been replaced or accompanied by modern solutions such as aerial mapping and remote sensing.

Despite this, the traditional method is still essential for some mining companies and resource management. It gives a detailed, up-close view of the subsurface geology. With careful application, achieving accurate results with minimal effort and cost is possible.

**Advanced Mining Surveying Technique**

Technological advances have enabled the use of more sophisticated methods for mining surveying. These include satellite imagery, aerial LiDAR (Light Detection and Ranging), gravimetry, and magnetometry.

*Satellite imagery* allows for large-scale mapping of an area with high-resolution images. It is ideal for mineral exploration as it can detect subtle changes in surface topography that may indicate potential ore bodies or other features of interest.

*Aerial LiDAR* uses laser pulses to map out an area quickly and accurately. It provides detailed data on the shape and orientation of ore bodies that are difficult or impossible to access by other methods.

*Gravimetry* and *magnetometry* are other advanced methods for mining surveying. These techniques measure changes in gravity and magnetic fields, which can detect subsurface structures such as faults or veins that may contain valuable minerals.

*Drone Surveying for Mining Exploration*

Another commendable advanced technique for mining surveying is the utilization of drone technology. It is a new and exciting technology rapidly becoming popular in the mining industry. Using drones makes it possible to quickly and cheaply map large land areas and accurately identify ore bodies, faults, and other features of interest.

It also has the advantage of being less intrusive than other methods, such as aerial LiDAR or satellite imagery. It is ideal for mineral exploration activities in remote or sensitive locations. Here are some of the uses of drone solutions that give significant advantages to mining companies.

*Use 1: It supports site mapping.*

Drone technology can capture high-resolution images and video of a mine site to create detailed maps for exploration activities and resource management projects. With the right drone technology, surveyors can also take more footages as much as they can. That way, they can produce a better mapping of the area.

*Use 2: It can monitor environmental changes.*

Monitoring the environment before, during, and after the mining activities is essential. Drone surveys can make environmental monitoring accessible and cost-effective. It allows mining companies to take their jobs responsibly by identifying situations like land reclamation and land degradation. And with drone solutions, regular monitoring can be more manageable than ever.

*Use 3: It is suitable for ore body mapping.*

Drones technology can take aerial mapping for ore bodies with precision. It can provide data for resource estimation and mine planning activities in the most time-efficient and safer way. The multispectral sensors and the ability for remote surveying can help miners do the job faster yet still more efficiently.

*Use 4: It aids mining inspections.*

Drones can easily access hard-to-reach mine site areas, making it easier to inspect infrastructure, equipment, and other structures for safety. It is an efficient solution to keep surveyors safe as possible.

*Use 5: It tightens area security*.

Drones are also commendable for perimeter monitoring of the mine site. The sensors and high-quality cameras can help detect any unauthorized intrusions or breaches in security. Hence, it improves the existing security.

*Takeaway.*

Mining surveying is a crucial task that makes exploration and extracting successful. The different surveying technique allows mining companies to make their operations accurate and less risky. And from traditional and high-technology surveying approaches, a drone solution can aid this job in the most cost and time-efficient way.

**Vocabulary**:

**hazard**

something that is dangerous and likely to cause damage

**vicinity**

the area immediately surrounding something

**gravimetry**

the measurement of weight, a gravitational field, or density

**magnetometry**

the measurement of magnetic fields (strength and direction etc.)

**footage**

the size of an area or building in feet

**takeaway**

something that you get or learn from an experience, activity, etc.

**MINING**



*Surface coal mining*

**Mining** is the extraction of valuable minerals or other geological materials from the earth from an orebody, lode, vein, seam, or reef, which forms the mineralized package of economic interest to the miner.

Ores recovered by mining include metals, coal, oil shale, gemstones, limestone, dimension stone, rock salt, potash, gravel, and clay. Mining is required to obtain any material that cannot be grown through agricultural processes, or created artificially in a laboratory or factory. Mining in a wider sense includes extraction of any non-renewable resource such as petroleum, natural gas, or even water.

Mining of stone and metal has been done since pre-historic times. Modern mining processes involve prospecting for ore bodies, analysis of the profit potential of a proposed mine, extraction of the desired materials, and final reclamation of the land after the mine is closed.

The nature of mining processes creates a potential negative impact on the environment both during the mining operations and for years after the mine is closed. This impact has led most of the world’s nations to adopt regulations designed to moderate the negative effects of mining operations. Safety has long been a concern as well, and modern practices have improved safety in mines significantly.

**Mine Development and Lifecycle**

The process of mining from discovery of an ore body through extraction of minerals and finally to returning the land to its natural state consists of several distinct steps. The first is discovery of the ore body, which is carried out through prospecting or exploration to find and then define the extent, location and value of the ore body. This leads to a mathematical resource estimation to estimate the size and grade of the deposit.

This estimation is used to conduct a pre-feasibility study to determine the theoretical economics of the ore deposit. This identifies, early on, whether further investment in estimation and engineering studies is warranted and identifies key risks and areas for further work. The next step is to conduct a feasibility study to evaluate the financial viability, the technical and financial risks, and the robustness of the project.

This is when the mining company makes the decision whether to develop the mine or to walk away from the project. This includes mine planning to evaluate the economically recoverable portion of the deposit, the metallurgy and ore recoverability, marketability and payability of the ore concentrates, engineering concerns, milling and infrastructure costs, finance and equity requirements, and an analysis of the proposed mine from the initial excavation all the way through to reclamation. The proportion of a deposit that is economically recoverable is dependent on the enrichment factor of the ore in the area.

To gain access to the mineral deposit within an area it is often necessary to mine through or remove waste material which is not of immediate interest to the miner. The total movement of ore and waste constitutes the mining process. Often more waste than ore is mined during the life of a mine, depending on the nature and location of the ore body. Waste removal and placement is a major cost to the mining operator, so a detailed characterization of the waste material forms an essential part of the geological exploration program for a mining operation.

Once the analysis determines a given ore body is worth recovering, development begins to create access to the ore body. The mine buildings and processing plants are built, and any necessary equipment is obtained. The operation of the mine to recover the ore begins and continues as long as the company operating the mine finds it economical to do so. Once all the ore that the mine can produce profitably is recovered, reclamation begins to make the land used by the mine suitable for future use.

**Mining Techniques**

Mining techniques can be divided into two common excavation types: surface mining and sub-surface (underground) mining. Today, surface mining is much more common, and produces, for example, 85% of minerals (excluding petroleum and natural gas) in the United States, including 98% of metallic ores.

Targets are divided into two general categories of materials: *placer deposits*, consisting of valuable minerals contained within river gravels, beach sands, and other unconsolidated materials; and *lode deposits*, where valuable minerals are found in veins, in layers, or in mineral grains generally distributed throughout a mass of actual rock. Both types of ore deposit, placer or lode, are mined by both surface and underground methods.

Some mining, including much of the rare earth elements and uranium mining, is done by less-common methods, such as in-situ leaching: this technique involves digging neither at the surface nor underground. The extraction of target minerals by this technique requires that they be soluble, e.g., potash, potassium chloride, sodium chloride, sodium sulfate, which dissolve in water. Some minerals, such as copper minerals and uranium oxide, require acid or carbonate solutions to dissolve.

**Surface Mining**

Surface mining is done by removing (stripping) surface vegetation, dirt, and, if necessary, layers of bedrock in order to reach buried ore deposits. Techniques of surface mining include: open-pit mining, which is the recovery of materials from an open pit in the ground, quarrying or gathering building materials from an open-pit mine; strip mining, which consists of stripping surface layers off to reveal ore/seams underneath; and mountaintop removal, commonly associated with coal mining, which involves taking the top of a mountain off to reach ore deposits at depth. Most (but not all) placer deposits, because of their shallowly buried nature, are mined by surface methods. Finally, landfill mining involves sites where landfills are excavated and processed.



*Garzweiler surface mine, Germany*

**Open-Pit Mining**

**Open-pit mining**, or **open-cast mining** is a surface mining technique of extracting rock or minerals from the earth by their removal from an open pit or borrow.

This form of mining differs from extractive methods that require tunneling into the earth, such as long wall mining. Open-pit mines are used when deposits of commercially useful minerals or rocks are found near the surface; that is, where the overburden (surface material covering the valuable deposit) is relatively thin or the material of interest is structurally unsuitable for tunneling (as would be the case for sand, cinder, and gravel). For minerals that occur deep below the surface—where the overburden is thick or the mineral occurs as veins in hard rock—underground mining methods extract the valued material.

Open-pit mines that produce building materials and dimension stone are commonly referred to as “quarries.”

Open-pit mines are typically enlarged until either the mineral resource is exhausted, or an increasing ratio of overburden to ore makes further mining uneconomic. When this occurs, the exhausted mines are sometimes converted to landfills for disposal of solid wastes. However, some form of water control is usually required to keep the mine pit from becoming a lake, if the mine is situated in a climate of considerable precipitation or if any layers of the pit forming the mine border productive aquifers.



*Note the angled and stepped sides of the Sunrise Dam Gold Mine, Australia.*

Open-cast mines are dug on benches, which describe vertical levels of the hole. These benches are usually on four to sixty meter intervals, depending on the size of the machinery that is being used. Many quarries do not use benches, as they are usually shallow.

Most walls of the pit are generally dug on an angle less than vertical, to prevent and minimize damage and danger from rock falls. This depends on how weathered the rocks are, and the type of rock, and also how many structural weaknesses occur within the rocks, such as a faults, shears, joints or foliations.

The walls are stepped. The inclined section of the wall is known as the batter, and the flat part of the step is known as the bench or berm. The steps in the walls help prevent rock falls continuing down the entire face of the wall. In some instances additional ground support is required and rock bolts, cable bolts and shotcrete are used. De-watering bores may be used to relieve water pressure by drilling horizontally into the wall, which is often enough to cause failures in the wall by itself.

A haul road is usually situated at the side of the pit, forming a ramp up which trucks can drive, carrying ore and waste rock.

Waste rock is piled up at the surface, near the edge of the open pit. This is known as the waste dump. The waste dump is also tiered and stepped, to minimize degradation.

Ore which has been processed is known as tailings, and is generally a slurry. This is pumped to a tailings dam or settling pond, where the water evaporates. Tailings dams can often be toxic due to the presence of unextracted sulfide minerals, some forms of toxic minerals in the gangue, and often cyanide which is used to treat gold ore via the cyanide leach process. This toxicity can harm the surrounding environment.

**Typical Open Cut Grades**

Gold is generally extracted in open-pit mines at 1 to 2 ppm (parts per million) but in certain cases, 0.75 ppm gold is economical. This was achieved by bulk heap leaching at the Peak Hill mine in western New South Wales, near Dubbo, Australia.

Nickel, generally as laterite, is extracted via open-pit down to 0.2%. Copper is extracted at grades as low as 0.15% to 0.2%, generally in massive open-pit mines in Chile, where the size of the resources and favorable metallurgy allows economies of scale.

Materials typically extracted from open-pit mines include:

* Bitumen
* Clay
* Coal
* Copper
* Coquina
* Diamonds
* Gravel and stone (stone refers to bedrock, while gravel is unconsolidated material)
* Granite
* Gritstone
* Gypsum
* Limestone
* Marble
* Metal ores, such as Copper, Iron, Gold, Silver and Molybdenum
* Uranium
* Phosphate

**Underground Mining**



*Mantrip used for transporting miners within an underground mine*

Sub-surface mining consists of digging tunnels or shafts into the earth to reach buried ore deposits. Ore, for processing, and waste rock, for disposal, are brought to the surface through the tunnels and shafts. Sub-surface mining can be classified by the type of access shafts used, the extraction method or the technique used to reach the mineral deposit. Drift mining utilizes horizontal access tunnels, slope mining uses diagonally sloping access shafts, and shaft mining utilizes vertical access shafts. Mining in hard and soft rock formations require different techniques.

Other methods include shrinkage stope mining, which is mining upward, creating a sloping underground room, long wall mining, which is grinding a long ore surface underground, and room and pillar mining, which is removing ore from rooms while leaving pillars in place to support the roof of the room. Room and pillar mining often leads to retreat mining, in which supporting pillars are removed as miners retreat, allowing the room to cave in, thereby loosening more ore. Additional sub-surface mining methods include hard rock mining, which is mining of hard rock (igneous, metamorphic or sedimentary) materials, bore hole mining, drift and fill mining, long hole slope mining, sub level caving, and block caving.

**Machines**

Heavy machinery is used in mining to explore and develop sites, to remove and stockpile overburden, to break and remove rocks of various hardness and toughness, to process the ore, and to carry out reclamation projects after the mine is closed. Bulldozers, drills, explosives and trucks are all necessary for excavating the land. In the case of placer mining, unconsolidated gravel, or alluvium, is fed into machinery consisting of a hopper and a shaking screen or trommel which frees the desired minerals from the waste gravel. The minerals are then concentrated using sluices or jigs.

Large drills are used to sink shafts, excavate stopes, and obtain samples for analysis. Trams are used to transport miners, minerals and waste. Lifts carry miners into and out of mines, and move rock and ore out, and machinery in and out, of underground mines. Huge trucks, shovels and cranes are employed in surface mining to move large quantities of overburden and ore. Processing plants utilize large crushers, mills, reactors, roasters and other equipment to consolidate the mineral-rich material and extract the desired compounds and metals from the ore.



*The Bagger 288 is a bucket-wheel excavator used in strip mining. It is also the largest land vehicle of all time.*

**Processing**

Once the mineral is extracted, it is often then processed. The science of extractive metallurgy is a specialized area in the science of metallurgy that studies the extraction of valuable metals from their ores, especially through chemical or mechanical means.

Mineral processing (or mineral dressing) is a specialized area in the science of metallurgy that studies the mechanical means of crushing, grinding, and washing that enable the separation (extractive metallurgy) of valuable metals or minerals from their gangue (waste material). Processing of placer ore material consists of gravity-dependent methods of separation, such as sluice boxes. Only minor shaking or washing may be necessary to disaggregate (unclump) the sands or gravels before processing. Processing of ore from a lode mine, whether it is a surface or subsurface mine, requires that the rock ore be crushed and pulverized before extraction of the valuable minerals begins. After lode ore is crushed, recovery of the valuable minerals is done by one, or a combination of several, mechanical and chemical techniques.

Since most metals are present in ores as oxides or sulfides, the metal needs to be reduced to its metallic form. This can be accomplished through chemical means such as smelting or through electrolytic reduction, as in the case of aluminium. Geometallurgy combines the geologic sciences with extractive metallurgy and mining.

**Mining Industry**

Mining exists in many countries. London is known as the capital of global “mining houses” such as Rio Tinto Group, BHP Billiton, and Anglo American PLC. The US mining industry is also large, but it is dominated by the coal and other nonmetal minerals (e.g., rock and sand), and various regulations have worked to reduce the significance of mining in the United States. In 2007 the totalmarket capitalization of mining companies was reported at US$962 billion, which compares to a total global market cap of publicly traded companies of about US$50 trillion in 2007. In 2002, Chile and Peru were reportedly the major mining countries of South America. The mineral industry of Africa includes the mining of various minerals; it produces relatively little of the industrial metals copper, lead, and zinc, but according to one estimate has as a percent of world reserves 40% of gold, 60% of cobalt, and 90% of the world’s platinum group metals. Mining in India is a significant part of that country’s economy. In the developed world, mining in Australia, with BHP Billiton founded and headquartered in the country, and mining in Canada are particularly significant. For rare earth minerals mining, China reportedly controlled 95% of production in 2013.

Mining operations can be grouped into five major categories in terms of their respective resources. These are oil and gas extraction, coal mining, metal ore mining, nonmetallic mineral mining and quarrying, and mining support activities. Of all of these categories, oil and gas extraction remains one of the largest in terms of its global economic importance. Prospecting potential mining sites, a vital area of concern for the mining industry, is now done using sophisticated new technologies such as seismic prospecting and remote-sensing satellites. Mining is heavily affected by the prices of the commodity minerals, which are often volatile. The 2000s commodities boom (“commodities supercycle”) increased the prices of commodities, driving aggressive mining. In addition, the price of gold increased dramatically in the 2000s, which increased gold mining; for example, one study found that conversion of forest in the Amazon increased six-fold from the period 2003–2006 (292 ha/yr) to the period 2006–2009 (1,915 ha/yr), largely due to artisanal mining.

**Safety**

Safety has long been a concern in the mining business especially in sub-surface mining. The Courrières mine disaster, Europe’s worst mining accident, involved the death of 1,099 miners in Northern France on March 10, 1906. This disaster was surpassed only by the Benxihu Colliery accident in China on April 26, 1942, which killed 1,549 miners. While mining today is substantially safer than it was in previous decades, mining accidents still occur. Government figures indicate that 5,000 Chinese miners die in accidents each year, while other reports have suggested a figure as high as 20,000. Mining accidents continue worldwide, including accidents causing dozens of fatalities at a time such as the 2007 Ulyanovskaya Mine disaster in Russia, the 2009 Heilongjiang mine explosion in China, and the 2010 Upper Big Branch Mine disaster in the United States.

Mining ventilation is a significant safety concern for many miners. Poor ventilation inside sub-surface mines causes exposure to harmful gases, heat, and dust, which can cause illness, injury, and death. The concentration of methane and other airborne contaminants underground can generally be controlled by dilution (ventilation), capture before entering the host air stream (methane drainage), or isolation (seals and stoppings). Rock dusts, including coal dust and silicon dust, can cause long-term lung problems including silicosis, asbestosis, and pneumoconiosis (also known as miners lung or black lungdisease). A ventilation system is set up to force a stream of air through the working areas of the mine. The air circulation necessary for effective ventilation of a mine is generated by one or more large mine fans, usually located above ground. Air flows in one direction only, making circuits through the mine such that each main work area constantly receives a supply of fresh air. Watering down in coal mines also helps to keep dust levels down: by spraying the machine with water and filtering the dust-laden water with a scrubber fan, miners can successfully trap the dust.

Gases in mines can poison the workers or displace the oxygen in the mine, causing asphyxiation. For this reason, the U.S. Mine Safety and Health Administration requires that groups of miners in the United States carry gas detection equipment that can detect common gases, such as CO, O2, H2S, CH4, as well as calculate % Lower Explosive Limit. Regulation requires that all production stop if there is a concentration of 1.4% of flammable gas present. Additionally, further regulation is being requested for more gas detection as newer technology such as nanotechnology is introduced.

Ignited methane gas is a common source of explosions in coal mines, which in turn can initiate more extensive coal dust explosions. For this reason, rock dusts such as limestone dust are spread throughout coal mines to diminish the chances of coal dust explosions as well as to limit the extent of potential explosions, in a process known as rock dusting. Coal dust explosions can also begin independently of methane gas explosions. Frictional heat and sparks generated by mining equipment can ignite both methane gas and coal dust. For this reason, water is often used to cool rock-cutting sites.

Miners utilize equipment strong enough to break through extremely hard layers of the Earth’s crust. This equipment, combined with the closed work space in which underground miners work, can cause hearing loss. For example, a roof bolter (commonly used by mine roof bolter operators) can reach sound power levels of up to 115 dB. Combined with the reverberant effects of underground mines, a miner without proper hearing protection is at a high risk forhearing loss. By age 50, nearly 90% of U.S. coal miners have some hearing loss, compared to only 10% among workers not exposed to loud noises. Roof bolters are among the loudest machines, but auger miners, bulldozers, continuous mining machines, front end loaders, and shuttle cars and trucks are also among those machines most responsible for excessive noise in mine work.

Since mining entails removing dirt and rock from its natural location, thereby creating large empty pits, rooms, and tunnels, cave-ins as well as ground and rock falls are a major concern within mines. Modern techniques for timbering and bracing walls and ceilings within sub-surface mines have reduced the number of fatalities due to cave-ins, but ground falls continue to represent up to 50% of mining fatalities. Even in cases where mine collapses are not instantly fatal, they can trap mine workers deep underground. Cases such as these often lead to high-profile rescue efforts, such as when 33 Chilean miners were trapped deep underground for 69 days in 2010.

High temperatures and humidity may result in heat-related illnesses, including heat stroke, which can be fatal. The presence of heavy equipment in confined spaces also poses a risk to miners. To improve the safety of mine workers, modern mines use automation and remote operation including, for example, such equipment as automated loaders and remotely operated rockbreakers. However, despite modern improvements to safety practices, mining remains a dangerous occupation throughout the world.

**EFFECTS OF MINING**

**Environmental Effects**

Environmental issues can include erosion, formation of sinkholes, loss of biodiversity, and contamination of soil, groundwater and surface water by chemicals from mining processes. In some cases, additional forest logging is done in the vicinity of mines to create space for the storage of the created debris and soil. Contamination resulting from leakage of chemicals can also affect the health of the local population if not properly controlled. Extreme examples of pollution from mining activities include coal fires, which can last for years or even decades, producing massive amounts of environmental damage.

Mining companies in most countries are required to follow stringent environmental and rehabilitation codes in order to minimize environmental impact and avoid impacting human health. These codes and regulations all require the common steps of environmental impact assessment, development of environmental management plans, mine closure planning (which must be done before the start of mining operations), and environmental monitoring during operation and after closure. However, in some areas, particularly in the developing world, government regulations may not be well enforced.

**Waste**

Ore mills generate large amounts of waste, called tailings. For example, 99 tons of waste are generated per ton of copper, with even higher ratios in gold mining. These tailings can be toxic. Tailings, which are usually produced as a slurry, are most commonly dumped into ponds made from naturally existing valleys. These ponds are secured by impoundments (dams or embankment dams). In 2000 it was estimated that 3,500 tailings impoundments existed, and that every year, 2 to 5 major failures and 35 minor failures occurred; for example, in the Marcopper mining disaster at least 2 million tons of tailings were released into a local river. Subaqueous tailings disposal is another option. The mining industry has argued that submarine tailings disposal (STD), which disposes of tailings in the sea, is ideal because it avoids the risks of tailings ponds; although the practice is illegal in the United States and Canada, it is used in the developing world.

The waste is classified as either sterile or mineralised, with acid generating potential, and the movement and storage of this material forms a major part of the mine planning process. When the mineralised package is determined by an economic cut-off, the near-grade mineralised waste is usually dumped separately with view to later treatment should market conditions change and it becomes economically viable. Civil engineering design parameters are used in the design of the waste dumps, and special conditions apply to high-rainfall areas and to seismically active areas. Waste dump designs must meet all regulatory requirements of the country in whose jurisdiction the mine is located. It is also common practice to rehabilitate dumps to an internationally acceptable standard, which in some cases means that higher standards than the local regulatory standard are applied.

**Open-Pit Mining**



*Opencut coal mine loadout station and reclaimed land at the North Antelope Rochelle coal mine in Wyoming, United States.*

After mining finishes, the mine area must undergo rehabilitation. Waste dumps are contoured to flatten them out, to further stabilise them. If the ore contains sulfides it is usually covered with a layer of clay to prevent access of rain and oxygen from the air, which can oxidise the sulfides to produce sulfuric acid, a phenomenon known as acid mine drainage. This is then generally covered with soil, and vegetation is planted to help consolidate the material. Eventually this layer will erode, but it is generally hoped that the rate of leaching or acid will be slowed by the cover such that the environment can handle the load of acid and associated heavy metals. There are no long term studies on the success of these covers due to the relatively short time in which large scale open pit mining has existed. It may take hundreds to thousands of years for some waste dumps to become “acid neutral” and stop leaching to the environment. The dumps are usually fenced off to prevent livestock denuding them of vegetation. The open pit is then surrounded with afence, to prevent access, and it generally eventually fills up with ground water. In arid areas it may not fill due to deep groundwater levels.



*An open-pit sulfur mine at Tarnobrzeg, Poland undergoing land rehabilitation*

**Metal Reserves and Recycling**

During the twentieth century, the variety of metals used in society grew rapidly. Today, the development of major nations such as China and India and advances in technologies are fueling an ever greater demand. The result is that metal mining activities are expanding and more and more of the world’s metal stocks are above ground in use rather than below ground as unused reserves. An example is the in-use stock of copper. Between 1932 and 1999, copper in use in the USA rose from 73 kilograms (161 lb) to 238 kilograms (525 lb) per person.

95% of the energy used to make aluminum from bauxite ore is saved by using recycled material. However, levels of metals recycling are generally low. In 2010, the International Resource Panel, hosted by the United Nations Environment Programme (UNEP), published reports on metal stocks that exist within society and their recycling rates.

The report’s authors observed that the metal stocks in society can serve as huge mines above ground. However, they warned that the recycling rates of some rare metals used in applications such as mobile phones, battery packs for hybrid cars, and fuel cells are so low that unless future end-of-life recycling rates are dramatically stepped up these critical metals will become unavailable for use in modern technology.

**TECTONIC PLATES**

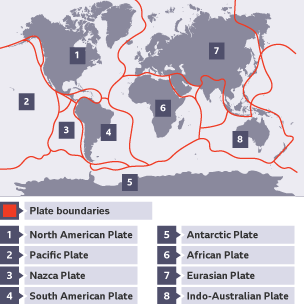
The crust of the Earth is not made up of one solid piece – it is split into plates which float on the upper portion of the mantle. There are two types of plate:

* dense oceanic crust
* less dense thick continental crust

These plates move slowly and either move apart, towards or past each other.

The point at which these plates meet is known as a ‘plate margin’. It is at the plate margins where the most tectonic activity and tectonic hazards, such as volcanoes and earthquakes, occur.

### Tectonic plates map



There are two theories as to why these plates move. The first, and most common, theory is that the plates move due to convection currents in the Earth’s mantle. This is where the heat from the Earth’s core causes magma to rise. As it nears the Earth’s surface, it then cools and sinks. This circular motion causes the plates in the crust to move.

The second theory is known as ‘slab pull’ where it is thought that the movement is caused by the weight of heavier denser plates sinking into the mantle and dragging other sections of the plate with it.



*Image caption*,

Lava eruption from the volcano, Mount Fagradalsfjall, Iceland. This volcano was formed when two tectonic plates moved apart causing magma to rise to the surface.

## Question

**Is the Earth’s crust made up of one solid piece?**

Plate tectonics is a scientific theory that explains how major landforms are created as a result of Earth’s subterranean movements. The theory, which solidified in the 1960s, transformed the earth sciences by explaining many phenomena, including mountain building events, volcanoes, and earthquakes.

In plate tectonics, Earth’s outermost layer, or lithosphere—made up of the crust and upper mantle—is broken into large rocky plates. These plates lie on top of a partially molten layer of rock called the asthenosphere. Due to the convection of the asthenosphere and lithosphere, the plates move relative to each other at different rates, from two to 15 centimeters (one to six inches) per year. This interaction of tectonic plates is responsible for many different geological formations such as the Himalaya mountain range in Asia, the East African Rift, and the San Andreas Fault in California, United States.

The idea that continents moved over time had been proposed before the 20th century. However, a German scientist named Alfred Wegener changed the scientific debate. Wegener published two articles about a concept called continental drift in 1912. He suggested that 200 million years ago, a supercontinent he called Pangaea began to break into pieces, its parts moving away from one another. The continents we see today are fragments of that supercontinent. To support his theory, Wegener pointed to matching rock formations and similar fossils in Brazil and West Africa. In addition, South America and Africa looked like they could fit together like puzzle pieces.

Despite being dismissed at first, the theory gained steam in the 1950s and 1960s as new data began to support the idea of continental drift. Maps of the ocean floor showed a massive undersea mountain range that almost circled the entire Earth. An American geologist named Harry Hess proposed that these ridges were the result of molten rock rising from the asthenosphere. As it came to the surface, the rock cooled, making new crust and spreading the seafloor away from the ridge in a conveyer-belt motion. Millions of years later, the crust would disappear into ocean trenches at places called subduction zones and cycle back into Earth. Magnetic data from the ocean floor and the relatively young age of oceanic crust supported Hess’s hypothesis of seafloor spreading.

There was one nagging question with the plate tectonics theory: Most volcanoes are found above subduction zones, but some form far away from these plate boundaries. How could this be explained? This question was finally answered in 1963 by a Canadian geologist, John Tuzo Wilson. He proposed that volcanic island chains, like the Hawaiian Islands, are created by fixed “hot spots” in the mantle. At those places, magma forces its way upward through the moving plate of the sea floor. As the plate moves over the hot spot, one volcanic island after another is formed. Wilson’s explanation gave further support to plate tectonics. Today, the theory is almost universally accepted.

**Vocabulary:**

**asthenosphere**

layer in Earth's mantle between the lithosphere (above) and the upper mantle (below).

**continental drift**

the movement of continents resulting from the motion of tectonic plates.

**convection**

transfer of heat by the movement of the heated parts of a liquid or gas.

**earthquake**

the sudden shaking of Earth's crust caused by the release of energy along fault lines or from volcanic activity.

**geologist**

person who studies the physical formations of the Earth.

**interaction**

relationship between two or more forces, objects, or organisms.

**lithosphere**

outer, solid portion of the Earth. Also called the geosphere.

**molten**

solid material turned to liquid by heat.

**plate tectonics**

movement and interaction of the Earth's plates.

**seafloor spreading**

rift in underwater mountain range where new oceanic crust is formed.

**subduction**

process of one tectonic plate melting, sliding, or falling beneath another.

**supercontinent**

ancient, giant landmass that split apart to form all the continents we know today.

**tectonic plate**

massive slab of solid rock made up of Earth's lithosphere (crust and upper mantle). Also called lithospheric plate.

**theory**

explanation that has not been proven as fact.

**volcano**

an opening in the Earth's crust, through which lava, ash, and gases erupt, and also the cone built by eruptions.

# CONTINENTAL DRIFT VERSUS PLATE TECTONICS

A scientific idea that was initially ridiculed paved the way for the theory of plate tectonics, which explains how Earth’s continents move.

##### **Alfred Wegener in Greenland**

Plate tectonics is the theory that Earth's land masses are in constant motion. The realization that Earth's land masses move was first proposed by Alfred Wegener, which he called continental drift. He is shown here in Greenland.



We don’t perceive that the continents we live on are moving. After all, it’s not as if an airplane flight between Europe and Africa takes five hours one year but only three hours the next. But the continents actually are shifting, very slowly, relative to one another. In the early 20th century, a scientific theory called continental drift was proposed about this migration of the continents. That theory was initially ridiculed, but it paved the way for another theory called plate tectonics that scientists have now accepted to explain how Earth’s continents move.

The story begins with Alfred Wegener (1880–1930), a German meteorologist and geophysicist who noticed something curious when he looked at a map of the world. Wegener observed that the continents of South America and Africa looked like they would fit together remarkably well—take away the Atlantic Ocean and these two massive landforms would lock neatly together. He also noted that similar fossils were found on continents separated by oceans, additional evidence that perhaps the landforms had once been joined. He hypothesized that all of the modern-day continents had previously been clumped together in a supercontinent he called Pangaea (from ancient Greek, meaning “all lands” or “all the Earth”). Over millions of years, Wegener suggested, the continents had drifted apart. He did not know what drove this movement, however. Wegener first presented his idea of continental drift in 1912, but it was widely ridiculed and soon, mostly, forgotten. Wegener never lived to see his theory accepted—he died at the age of 50 while on an expedition in Greenland.

Only decades later, in the 1960s, did the idea of continental drift resurface. That’s when technologies adapted from warfare made it possible to more thoroughly study Earth. Those advances included seismometers used to monitor ground shaking caused by nuclear testing and magnetometers to detect submarines. With seismometers, researchers discovered that earthquakes tended to occur in specific places rather than equally all over Earth. And scientists studying the seafloor with magnetometers found evidence of surprising magnetic variations near undersea ridges: alternating stripes of rock recorded a flip-flopping of Earth’s magnetic field.

Together, these observations were consistent with a new theory proposed by researchers who built on Wegener’s original idea of continental drift—the theory of plate tectonics. According to this theory, Earth’s crust is broken into roughly 20 sections called tectonic plates on which the continents ride. When these plates press together and then move suddenly, energy is released in the form of earthquakes. That is why earthquakes do not occur everywhere on Earth—they’re clustered around the boundaries of tectonic plates. Plate tectonics also explains the stripes of rock on the seafloor with alternating magnetic properties: As buoyant, molten rock rises up from deep within Earth, it emerges from the space between spreading tectonic plates and hardens, creating a ridge. Because some minerals within rocks record the orientation of Earth’s magnetic poles and this orientation flips every 100,000 years or so, rocks near ocean ridges exhibit alternating magnetic stripes.

Plate tectonics explains why Earth’s continents are moving; the theory of continental drift did not provide an explanation. Therefore, the theory of plate tectonics is more complete. It has gained widespread acceptance among scientists. This shift from one theory to another is an example of the scientific process: As more observations are made and measurements are collected, scientists revise their theories to be more accurate and consistent with the natural world.

By running computer simulations of how Earth’s tectonic plates are moving, researchers can estimate where the planet's continents will likely be in the future. Because tectonic plates move very slowly—only a few centimeters per year, on average—it takes a long time to observe changes. Scientists have found that the planet’s continents will likely again be joined together in about 250 million years. Researchers have dubbed this future continental configuration “Pangaea Proxima.”

One intriguing aspect of Pangaea Proxima is that it will likely contain a new mountain range with some of the world’s highest mountains. That is because as Africa continues to migrate north it will collide with Europe, a collision that will probably create a Himalaya-scale mountain range. However, Christopher Scotese, one of the scientists who developed these simulations, cautions that it is difficult to predict exactly how the continents will be arranged in millions of years. “We don’t really know the future, obviously,” Scotese told NASA. “All we can do is make predictions of how plate motions will continue, what new things might happen, and where it will all end up.”

**Vocabulary:**

**continent**

one of the seven main land masses on Earth.

**continental drift**

the movement of continents resulting from the motion of tectonic plates.**fossil**

**magnetic field**

area around and affected by a magnet or charged particle.

**magnetometer**

scientific instrument used to measure the presence, strength, and direction of Earth's magnetic field.

**meteorologist**

person who studies patterns and changes in Earth's atmosphere.

**Pangaea**

supercontinent of all the Earth's landmass that existed about 250 million years ago.

**seismometer**

device that measures movements of the ground.

**simulation**

copy or reenactment.

**COAL**

# What are the types of coal?

There are four major types (or “ranks”) of coal. Rank refers to steps in a slow, natural process called “coalification,” during which buried plant matter changes into an ever denser, drier, more carbon-rich, and harder material. The four ranks are:

* **Anthracite**: The highest rank of coal. It is a hard, brittle, and black lustrous coal, often referred to as hard coal, containing a high percentage of fixed carbon and a low percentage of volatile matter.
* **Bituminous**: Bituminous coal is a middle rank coal between subbituminous and anthracite. Bituminous coal usually has a high heating (Btu) value and is used in electricity generation and steel making in the United States. Bituminous coal is blocky and appears shiny and smooth when you first see it, but look closer and you might see it has thin, alternating, shiny and dull layers.
* **Subbituminous**: Subbituminous coal is black in color and is mainly dull (not shiny). Subbituminous coal has low-to-moderate heating values and is mainly used in electricity generation.
* **Lignite**: Lignite coal, aka brown coal, is the lowest grade coal with the least concentration of carbon. Lignite has a low heating value and a high moisture content and is mainly used in electricity generation.

The precursor to coal is peat. Peat is a soft, organic material consisting of partly decayed plant and mineral matter. When peat is placed under high pressure and heat, it undergoes physical and chemical changes (coalification) to become coal.

#### [What is coal used for?](https://www.usgs.gov/faqs/what-coal-used)

Coal is primarily used as fuel to generate electric power in the United States. In coal-fired power plants, bituminous coal, subbituminous coal, or lignite is burned. The heat produced by the combustion of the coal is used to convert water into high-pressure steam, which drives a turbine, which produces electricity. In 2019, about 23 percent of all electricity in the United States was generated by...

#### [What is coal?](https://www.usgs.gov/faqs/what-coal)

Coal is a sedimentary deposit composed predominantly of carbon that is readily combustible. Coal is black or brownish-black, and has a composition that (including inherent moisture) consists of more than 50 percent by weight and more than 70 percent by volume of carbonaceous material. It is formed from plant remains that have been compacted, hardened, chemically altered, and metamorphosed by heat.

[**What is the biggest coal deposit in the United States?**](https://www.usgs.gov/faqs/what-biggest-coal-deposit-united-states)

The biggest coal deposit by volume is the Powder River Basin in Wyoming and Montana, which the USGS estimated to have 1.07 trillion short tons of in-place coal resources, 162 billion short tons of recoverable coal resources, and 25 billion short tons of economic coal resources (also called reserves) in 2013. The coal in the Powder River Basin is subbituminous in rank. Large coal deposits can also...

[**Which country has the most coal?**](https://www.usgs.gov/faqs/which-country-has-most-coal)

As of January 2020, the United States has the largest recoverable coal reserves with an estimated 252 billion short tons of coal remaining, according to the U.S. Energy Information Administration . Learn more: U.S. Coal Resources and Assessment World Coal Quality Inventory

**ASSESSMENTS EVOLVED: USGS COAL RESEARCH IN THE 21ST CENTURY**

Although often associated with helping fuel the Nation’s growth during the Industrial Revolution, coal is very much part of our space-age present. In 2016, coal-fired power plants provided 30.4 percent of the country’s electricity, and it is an important source of employment in many states.

This is anthracite, the highest rank of coal. It is a hard, brittle, and black lustrous coal, often referred to as hard coal, containing a high percentage of fixed carbon and a low percentage of volatile matter. Anthracite is not as commonly mined as other ranks of coal. It played a significant role in Pennsylvania coal during the Industrial Revolution in the United States.

Here at the USGS, we have studied coal for more than 100 years, and worked with others, predominantly state geological surveys, to provide the basic geological research and  information to [assess the Nation’s coal resources](http://energy.usgs.gov/Coal/AssessmentsandData/CoalAssessments.aspx). We also coordinate with other federal agencies, including the [Bureau of Land Management](https://www.blm.gov/programs/energy-and-minerals/coal) and the [Energy Information Administration (EIA)](https://www.eia.gov/coal/), who also have responsibilities for managing coal resources or reporting coal information. The largest and most well-known areas of coal the USGS has assessed are the [Appalachian Basin](https://energy.usgs.gov/Coal/AssessmentsandData/CoalAssessments/AppalachianBasinCoalAssessment.aspx) and [Illinois Basin](http://energy.usgs.gov/Coal/AssessmentsandData/CoalAssessments/IllinoisBasinCoalAssessment.aspx) in the eastern U.S. and the [Williston Basin](http://energy.usgs.gov/Coal/AssessmentsandData/CoalAssessments/RockyMountainGreatPlainsCoalAssessment.aspx), [Colorado Plateau](https://energy.usgs.gov/Coal/AssessmentsandData/CoalAssessments/ColoradoPlateauCoalAssessment.aspx),  and the [Powder River Basin](http://energy.usgs.gov/RegionalStudies/PowderRiverBasin.aspx) in the western United States.

But just as the role for coal has evolved over the years years, so have our scientific methodologies and procedures used in assessing this important resource.

**It’s Not How Much There Is, But How Much You Can Get**

Traditionally, USGS coal assessments have focused on the remaining coal resources in a basin or region, based on minimum thickness and maximum depth of cover parameters.

However, beginning with our [2015 assessment of the Powder River Basin](https://pubs.usgs.gov/pp/1809/) in Wyoming and Montana, we began to calculate recoverable coal resources and coal reserves from the remaining coal resources.  Recoverable coal resources are calculated by subtracting coal resources that are lost due to environmental, societal, or legal restrictions, as well as those that are lost due to geological constraints and mining technology limitations.  Coal reserves, meanwhile, are the portion of recoverable coal resources that can be extracted profitably.

The amount of recoverable coal resources is usually much smaller than the amount of remaining coal resources.   Likewise, coal reserves are usually just a small fraction of the recoverable coal resources.

For instance, in 2015, we estimated that the Powder River Basin contained a mean of about 1.07 trillion short tons of remaining coal resources. That’s how much coal we believe to be in the entire Powder River Basin. Of that 1.07 trillion short tons, we estimated that about 162 billion short tons were recoverable coal resources, after environmental, societal, and legal restrictions, geological constraints, and technological limitations were determined. Finally, out of that 162 billion short tons of recoverable coal resources, we estimated that only 25 billion short tons could be classified as coal reserves, based on the average price of Powder River Basin coal when we conducted the assessment.

So, as a result, the 1.07 trillion short tons of remaining coal resources in the Powder River Basin yields an estimated 25 billion short tons of coal reserves, or 2.3 percent of the remaining coal resources, based on the price of coal in 2013. This is important because it gives resource managers and companies a more complete picture of the amount of coal in the Powder River Basin.

The USGS is taking this approach forward in our [current and future assessments](https://energy.usgs.gov/Coal/AssessmentsandData/CoalAssessments.aspx) of coal resources. Currently, we are assessing coal resources and reserves in the Green River Basin of Colorado and Wyoming. The Green River Basin contains large amounts of coal resources that have not been assessed in detail in previous assessment studies and much of the coal resources in this area lie under Federal lands, which we are mandated by Congress to assess.  Additionally, we have acquired a large amount of previously proprietary and unavailable geological data for this area.

**Mapping the Cost Curves**

One of the difficulties in determining coal reserves is that they fluctuate with the price of coal.  What may be profitable to mine one day may not be the next, as prices for commodities like coal can vary significantly. An assessment of coal reserves needs to be able to account for those changes.

In fact, current coal reserve estimates are not static: reserves grow and shrink as coal prices change. If reserve volumes shrink, it does not always mean that the amount of coal in the ground has changed-it can reflect  that less of the coal resources can be mined profitably.  If the price of coal increases, then the amount of recoverable coal resources classified as coal reserves may increase.

In our [2015 Powder River Basin assessment](https://pubs.usgs.gov/pp/1809/), we met the challenges of changing prices by including a cost curve that would allow readers to estimate what portions of the recoverable coal resources could be considered reserves at various price points.

The current and upcoming assessments in the Green River Basin will include similar cost curves.  We are working to make them even more sophisticated and accurate through price analysis and economic modeling based on analogs of mining operations in the region.

A sample of lignite, the lowest rank of coal. It is primarily mined for burning in steam-generation power plants.

**Refining the Models**

As technology and modeling have advanced in recent years, what they can tell us about what lies beneath the Earth’s surface has also greatly expanded. Because some of these formations are extremely large and located hundreds, even thousands of feet below ground, models are essential to allowing us to accurately estimate coal resources and reserves.

To make sure our models are providing us the best information, we have started including stochastic geostatistical analysis modeling to determine the optimum spacing for test drill holes. The current standard, as prescribed in USGS Circular 891, is to drill test holes at an arbitrary spacing (every quarter mile) to collect geologic data.  The geologic data is modeled using mathematical algorithms to extrapolate out from the test drill holes to the entire formation. By utilizing geostatistical modeling, we can define the optimum spacing for drill holes needed to best define the geology.

In addition, we are looking at the other end of our assessments-how resource managers can use the assessments to help make the best decisions on how to address the resource potential. One of the ways we are doing this is by utilizing the assessments to determine which areas possess the optimum combination of mineable coal thickness, cover or overburden, and favorable geologic conditions to warrant further exploration and possible economic development.

**Start with Science**

The United States is richly endowed with coal resources.  Coal has been and will remain, into the foreseeable future, an integral part of the fuel mix for the Nation’s electrical supply.  It is also critical to the revitalization of the Nation’s infrastructure, as some coal, known as [metallurgical coal](https://www.eia.gov/coal/production/quarterly/), provides the carbon used in the making of steel.  Even though the Powder River Basin is the largest deposit of low-sulfur, sub-bituminous coal in the world, it is just one of many large coal basins in the United States capable of providing sufficient coal resources for both electrical generation and steel making processes.  The USGS will continue to provide critical information for the Government, as well as for private industry, to define the location, extent, thickness, and quality of the Nation’s coal resources and reserves.

## WE USE MINERALS EVERY DAY!

Every person uses products made from minerals every day. The salt that we add to our food is the mineral [**halite**](https://geology.com/minerals/halite.shtml). Antacid tablets are made from the mineral [**calcite**](https://geology.com/minerals/calcite.shtml). [**Rubies and sapphires**](https://geology.com/gemstones/ruby-and-sapphire/) are colored varieties of a mineral named [**corundum**](https://geology.com/minerals/corundum.shtml).

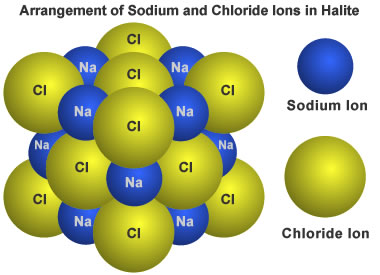
It takes many [**minerals**](https://geology.com/minerals/) to make something as simple as a wooden pencil. The "lead" is made from [**graphite**](https://geology.com/minerals/graphite.shtml) and clay minerals, the brass band is made of [**copper**](https://geology.com/usgs/uses-of-copper/) and [**zinc**](https://geology.com/usgs/uses-of-zinc/), and the paint that colors it contains pigments and fillers made from a variety of minerals. A cell phone is made using dozens of different minerals that are sourced from mines throughout the world.

The cars that we drive, the roads that we travel, the buildings that we live in, and the fertilizers used to produce our food are all made using minerals.

In the United States, about three billion tons of mineral commodities are consumed each year to support the standard of living of 300 million citizens. That is about ten tons of mineral materials consumed for every person, every year.



**Common items made from minerals:** Most of the things that we use in our daily life are either made from minerals or produced using mineral products. Antacid tablets are made from calcite, table salt is crushed halite, several minerals are used to make a wood pencil, and dozens of minerals from many different countries are used to make a cell phone.



**Structure of the mineral halite:** The mineral "halite" has a chemical composition of NaCl. That means it contains equal numbers of sodium and chloride atoms. In this case they are electrically charged atoms, known as ions. Those ions are arranged in a cubic pattern that repeats in all directions. The small sodium ions are positioned between the larger chloride ions.

## What are Minerals?

To meet the definition of "mineral" used by most geologists, a substance must meet five requirements:

|  |
| --- |
| * naturally occurring * inorganic * solid * definite chemical composition * ordered internal structure |

"**Naturally occurring**" means that people did not make it. Steel is not a mineral because it is an alloy produced by people.

"**Inorganic**" means that the substance is not made by an organism. Wood and pearls are made by organisms and thus are not minerals.

"**Solid**" means that it is not a liquid or a gas at standard temperature and pressure. Water is not a mineral because it is a liquid.

"**Definite chemical composition**" means that all occurrences of that mineral have a chemical composition that varies within a specific limited range. For example: the mineral halite (known as "[**rock salt**](https://geology.com/rocks/rock-salt.shtml)" when it is mined) has a chemical composition of NaCl. It is made up of an equal number of atoms of sodium and chlorine.

"**Ordered internal structure**" means that the atoms in a mineral are arranged in a systematic and repeating pattern. The structure of the mineral halite is shown in the illustration on this page. Halite is composed of an equal ratio of sodium and chlorine atoms arranged in a cubic pattern.

|  |  |
| --- | --- |
| ice is a mineral | **Did You Know?** Although liquid water is not a mineral, it is a mineral when it freezes. Ice is a naturally occurring, inorganic solid with a definite chemical composition and an ordered internal structure. |

## The Word "Mineral"

The word "mineral" is used in many different ways. Here are some examples:

### Geologist's Definition

A formal definition of a mineral, as used by geologists would be: A naturally occurring inorganic solid that has a definite chemical composition, and an ordered internal structure. Geologists are able to identify minerals because they have characteristic physical properties.

### Nutritionist's Definition

The word "mineral" also has a nutritional meaning, which is different from the meaning used by geologists.

A nutritionist uses the word mineral when referring to the many inorganic substances that organisms need to grow, repair tissue, metabolize, and carry out other body processes. Mineral nutrients for the human body include: iron, calcium, [**copper**](https://geology.com/minerals/copper.shtml), [**sulfur**](https://geology.com/minerals/sulfur.shtml), phosphorus, magnesium and many others.



**Rhodochrosite:** Specimen of [**rhodochrosite**](https://geology.com/minerals/rhodochrosite.shtml) from the Sunnyside Mine, San Juan County, Colorado. Rhodochrosite is a [**manganese**](https://geology.com/usgs/manganese/) carbonate mineral (MnCO3) that is used as an ore of manganese and is also cut as a gemstone. USGS image.

### Archaic Use of "Mineral"

An archaic use of the word "mineral" comes from the Linnaean taxonomy in which all things can be assigned to the animal, vegetable, and mineral kingdoms.



**Minerals in rocks:** Most rocks are aggregates of minerals. This rock, a granite pegmatite, is a mixture of mineral grains. It contains pink orthoclase, milky quartz, black hornblende and black biotite.

### Inconsistent Use of "Mineral"

The word "mineral" is also used inconsistently. In mining, anything obtained from the ground and used by man is considered to be a "mineral commodity" or a "mineral material." These include: [**crushed stone**](https://geology.com/articles/crushed-stone/), which is a manufactured product made from crushed rocks; lime, which is a manufactured product made from [**limestone**](https://geology.com/rocks/limestone.shtml) or [**marble**](https://geology.com/rocks/marble.shtml) (both composed of the mineral calcite); [**coal**](https://geology.com/rocks/coal.shtml) which is organic; [**oil and gas**](https://geology.com/oil-and-gas/) which are organic fluids; rocks such as [**granite**](https://geology.com/rocks/granite.shtml) that are mixtures of minerals; and, rocks such as [**obsidian**](https://geology.com/rocks/obsidian.shtml) which are [**mineraloids**](https://geology.com/minerals/mineraloids/) and do not have a definite composition and ordered internal structure.

**Rock-forming Minerals.**

Rocks are composed of minerals. A mineral is a naturally occurring substance which is usually solid, crystalline, stable at room temperature and inorganic.

There are almost 5000 known mineral species, yet the vast majority of rocks are formed from combinations of a few common minerals, referred to as “rock-forming minerals”. The rock-forming minerals are: feldspars, quartz, amphiboles, micas, olivine, garnet, calcite, pyroxenes.

Minerals occurring within a rock in small quantities are referred to as “accessory minerals”. Although accessory minerals are present in only small amounts, they may provide valuable insight into the geological history of a rock, and are often used to ascertain the age of a rock. Common accessory minerals are: zircon, monazite, apatite, titanite, tourmaline, pyrite and other opaques.

The abundance and diversity of minerals depend on the abundance in the Earth’s crust of the elements of which they are composed. Eight elements make up 98% of the Earth’s crust: oxygen, silicon, aluminium, iron, magnesium, calcium, sodium and potassium. The composition of minerals formed by igneous processes is directly controlled by the chemistry of the parent body. For example, a magma rich in iron and magnesium will form minerals such as olivine and pyroxene (as found in basalt). Magma richer in silicon will form more silica-rich minerals such as feldspar and quartz (as found in granite). It is unlikely that a mineral will be found in a rock with dissimilar bulk chemistry unlike its own; thus it is unlikely that andalusite (Al2SiO5) would be found in an aluminium-poor rock such as a quartzite.

**Physical properties of minerals**

Some minerals are easily identifiable; others can only be recognized only by the use of a petrographic microscope or by complex analytical techniques. The following criteria are used to differentiate minerals in hand sample. Most minerals cannot be identified from one particular property, and so it is advisable to use several of the diagnostic criteria outlined below. A hand lens will assist you greatly.

**Colour**

Colour is one of the most obvious characteristic of a mineral, but generally not the most useful diagnostic feature. Depending on impurities, individual mineral types may come in a vast variety of colours. For example, ruby and sapphire are differently coloured types of the mineral corundum (Al2O3). The red colour of ruby is due to the presence of the element chromium. Sapphires may come is a vast variety of colours; blue is the most familiar colour, but yellow, orange, green, pink, orange and brown varieties are also known. Garnets may also come in a large range of colours, depending on their composition. They can be found with virtually any colour, although blue garnets are exceptionally rare. It is therefore advisable not to rely on colour alone to identify a mineral.

**Crystal habit**

Crystal habit refers to the characteristic shape of a mineral unit (either an individual crystal or an aggregate of crystals). Crystals with well-developed faces are referred to as “euhedral”; for example garnet crystals are often euhedral. Minerals may also occur as aggregates of crystals; for example, asbestos is usually found as an aggregate of very fine fibres. The following list gives examples of different crystal habits and examples of common minerals that may exhibit each habit.

* Acicular – needle-like, e.g. natrolite, rutile
* Bladed – blade-like, slender and flattened, e.g. kyanite
* Botryoidal – grape-like masses, e.g. hematite, malachite
* Columnar – long, slender prisms, e.g. calcite, gypsum
* Cubic – cube-shaped, e.g. pyrite, galena, halite
* Dendritic – tree-like, branching in multiple directions, e.g. pyrolusite, native copper, native silver
* Fibrous – very slender prisms, e.g. asbestos, tremolite
* Foliated or lamellar – layered structure, parts easily into very thin sheets, e.g. muscovite, biotite
* Granular – aggregates of crystals, e.g. bornite, scheelite
* Hexagonal – six-sided, e.g. quartz, hanksite
* Massive – no distinct shape, e.g. turquoise, realgar
* Octahedral– eight-sided, e.g. diamond, magnetite
* Platy – flat, tablet shape, e.g. wulfenite
* Prismatic – elongate, prism like, e.g. tourmaline, beryl
* Radial or stellate – radiating outwards from a central point, star-like, e.g. wavellite, pyrophyllite

**Hardness**

Hardness is a measure of how resistant a mineral is to scratching. This physical property is controlled by the chemical composition and structure of the mineral. Hardness is commonly measured on the Mohs scale. This is defined by ten minerals, where each mineral can scratch those with a lower scale number. Diamond (hardness 10) can scratch everything below it on the Mohs scale, but cannot itself be scratched, whereas quartz (hardness 7) can scratch calcite (hardness 3) but not corundum (hardness 9).

|  |  |  |
| --- | --- | --- |
| **Scale Number** | **Indicator Mineral** | **Common Objects** |
| 1 | Talc |  |
| 2 | Gypsum | Fingernail |
| 3 | Calcite | Copper coin |
| 4 | Fluorite |  |
| 5 | Apatite | Knife blade |
| 6 | Orthoclase | Window glass |
| 7 | Quartz | Steel file |
| 8 | Topaz |  |
| 9 | Corundum |  |
| 10 | Diamond |  |

**Streak**

The streak of a mineral refers to the colour of the mark it leaves behind after being rubbed against a piece of unglazed porcelain. Hematite provides a good example of how streak works. While this mineral is usually black, silver or brown-red in hand sample, its streak is always a dark blood-red. Chalcopyrite is usually golden-brown in hand sample, but has a green-black streak. Streak can be used only for minerals with a Mohs hardness of 7 or less, as minerals with a hardness greater than 7 will themselves scratch the streak plate.

**Lustre**

Lustre refers to the way in which the surface of a mineral reflects light, and is controlled by the kinds of atoms present and their bonding. It is described by the following terms

Adamantine – diamond-like lustre; such minerals are usually transparent and have a high refractive index; e.g. diamond, cerussite, cubic zirconia

* Dull or earthy – no reflections; e.g. kaolinite
* Greasy – the appearance of being coated with an oily substance; may also be greasy to the touch; e.g. opal
* Pearly – the whitish iridescence of materials such as pearls; e.g. stilbite
* Vitreous – like glass; e.g. calcite, quartz, beryl
* Silky – like silk fabric; e.g. satin spar (a variety of gypsum)
* Resinous – like a resin; e.g. fire opal
* Metallic – metal-like in appearance; e.g. pyrite

**Cleavage**

Minerals are composed of atoms, which, for each mineral, have a characteristic arrangement. Weaknesses in the chemical bonds between these atoms cause planes of weakness in the crystal structure. Cleavage is an indication of how well a mineral breaks along these planes of weakness, and may be a good diagnostic characteristic. Cleavage may be described as “perfect”, ”good”, “distinct” or ”poor”. In transparent minerals or in thin sections viewed though a microscope, cleavage may be seen as a series of parallel lines.

The number of cleavage planes in a mineral may also aid its identification. Cleavage typically occurs in either one, two, three, four or six directions. Micas easily split along their one plane of cleavage to form thin sheets. Amphiboles exhibit two cleavage planes. Iceland spar, a variety of calcite, cleaves readily along three planes of weakness into distinctive rhombs. Galena breaks along three cleavage planes producing cubic fractions. Fluorite and diamond show cleavage in four directions. Sphalerite exhibits cleavage in six directions. Not every mineral displays cleavage. For example, quartz does not have a weakness in its crystal structure, and therefore does not exhibit cleavage. When a quartz specimen is broken with a hammer, it displays conchoidal (shell-like) fracture.

**HOW TO WRITE A RESUME**

Your resume is your chance to make a good first impression on an employer and increase your chances of being invited for an interview. If you have never written an English resume before, you might want some ideas on how to present the most important information in the most effective way. In this article, we give some samples and templates to help you write a clear resume which includes everything a recruiter expects.

**What is an English resume?**

An English resume should contain relevant information about your education, qualifications and employment history to show a recruiter your suitability for a role. If you are applying for jobs where you will be required to speak English, then your resume will need to be in English. This is a great opportunity to demonstrate your language skills. In order to impress a hiring manager, you will need to ensure that your resume uses correct English and is written in a professional style.

**How to write an English resume**

Follow these steps to write a resume that will help get you noticed:

Include your contact details

Only include relevant personal information

Write a clear objective statement or summary

Have separate sections for "Education" and "Skills and qualifications"

Use facts or figures to demonstrate your achievements

Tailor your resume to the job

Avoid references

**1. Include your contact details**

At the top of your resume, include your name, address, phone number, email address and professional networking platform or website link. You can include your full address or just the city and state depending on your preferences. You should also include your personal phone number and email address. Use a professional-looking email address, preferably with your name included.

If you have a professional networking website profile with examples of your work or additional information, you can include the link after your email address. It's also helpful to include a link to your professional website if you work in a field, like graphic design, where it's common to have one.

**2. Only include relevant personal information**

You do not need to disclose your social security number, age, marital status, dependents or anything else about your personal life on your resume. You will usually only need a photograph if your appearance is relevant to the job such as acting, modeling or similar. Employers gather your personal information to keep on file after you're hired.

**3. Write a clear objective statement or summary**

A summary or objective can show your experience or goals as they relate to the role and company. A resume objective usually includes a goal you want to achieve with the company while a summary focuses on the experience you have that makes you a good candidate. You can usually use an objective if you're an entry-level candidate or you just moved to a new geographical area. Summaries are useful if you have a lot of relevant experience you want to demonstrate.

For either a summary or objective, you should tailor it to each job you apply for. Include the specific role and company in the statement so you immediately get the attention of the hiring manager. Statements should usually be two to three sentences, and you can add it right after your contact details.

Read more: Resume Objective Writing Guide (With Examples and Tips)

**4. Have separate sections for "Education" and "Skills and Qualifications"**

Your education section should include the degree or diploma you earned, the school, dates attended and any academic achievements you received. Your skills and qualifications may be more closely aligned to the specific role you are applying for, so link them to the requirements listed in the job description if you can.

**5. Use facts or figures to demonstrate your achievements**

If you can show how you increased sales or improved customer satisfaction with results, a recruiter will be able to assess the impact of your effort more effectively. For example, "Increased customer retention rates by 17% by improving response time by three minutes" is more informative than "Increased customer retention rates by improving response time."

**6. Tailor your resume to the job**

You can use the job description to identify the most important elements of the role, then include keywords in your resume. Some recruiters use applicant tracking systems to scan applications and resumes to find relevant keywords, so including them can help the chances of your resume being selected for review by a hiring manager.

**7. Avoid references**

At this stage of the process, an employer will assume that you have references that they can contact if they want to move forward with you. You don't need to include your references, but you should have a separate document ready to present if they ask for them. You can also add "References available upon request" or a similar statement at the bottom of your resume to show you can provide them anytime.

**Tips for writing a resume in English**

Here are some tips you can follow when writing your English resume:

* Use action words to describe your experience rather than just listing your responsibilities.
* You don't need to include details of your hobbies or interests unless they are relevant.
* Include details of any relevant unpaid work you do, such as volunteering or internships.
* Try to keep your resume to one page, with two pages being the maximum.
* Use a spellchecker and grammar checker to catch any mistakes and typos.
* If possible, get someone who speaks English fluently to proofread your resume before you send it to employers.

**English resume template**

This template is an example of a standard English resume format. You can use it to help you organize your professional details when applying for a job:

[Name]

[Address]

[Phone number]

[Email address]

[Professional networking platform or website link]

**Objective**

[You can use a summary instead. Add two to three sentences that demonstrate your goals, experience and skills.]

Experience

[Title]

[Company name]

[Dates of employment]

[Bullet list of responsibilities]

**Qualifications**

[List any relevant training and qualifications with details of when and where they were completed.]

Education

[Degree or diploma]

[School]

[Dates attended]

[Academic achievements]

**Skills**

[Include a bullet list of skills that are relevant to the position.]

**Hobbies and interests**

[Include your hobbies, interests or volunteering experience if they are relevant.]

******

***English resume example***

*Here's an example of a standard English resume:*

Bonita Carlisle

Nashville, Tennessee

465-454-7982

bonita.carlisle@email.com

bonitacarlisle.com

**Objective**

Enthusiastic and innovative office administrator with experience of working with a number of different departments. Seeking office administrator role with Textiles, Ltd. to improve efficiency and leverage industry experience.

**Work Experience**

Office administrator

Juno Industries

October 2015 to Present

Manage calendars for several team leaders, schedule meetings to ensure that all attendees can attend and book travel and accommodation when required

Oversee correspondence by logging incoming letters and requests, allocating them to the appropriate member of staff and ensuring that they are filed correctly

Liaise with administrators from other teams to balance workloads at busy times, identifying team members with the capacity to complete urgent work while ensuring that all tasks are completed on time

Redesign the meeting room request process to reduce the risk of double booking and increase efficiency, reducing complaints by 68%.

|  |
| --- |
| **TEST I** |

|  |  |  |
| --- | --- | --- |
| № | Choose the correct option | |
| 1. | surveying | 1. геодезія 2. картографія 3. кривизна 4. розмір 5. горизонтальна зйомка |
| 2. | plane surveying | 1. геодезія 2. картографія 3. кривизна 4. розмір 5. горизонтальна зйомка |
| 3. | mapping | 1. геодезія 2. картографія 3. кривизна 4. розмір 5. горизонтальна зйомка |
| 4. | The process of polluting the place. | 1. recreation 2. reclamation 3. cleaning 4. contamination 5. deterioration |
| 5. | The act or process of destroying something. | 1. dissemination 2. abuse 3. influence 4. destruction 5. all above |
| 6. | curvature | 1. геодезія 2. картографія 3. кривизна 4. розмір 5. горизонтальна зйомка |
| 7. | A place where unwanted waste is taken and left. | 1. market 2. store 3. barn 4. garage 5. dump |
| 8. | equipment | 1. устаткування 2. карта 3. придбання 4. кривизна 5. розмір |
| 9. | chart | 1. устаткування 2. карта 3. придбання, здобуття 4. кривизна 5. розмір |
| 10. | large-scale | 1. устаткування 2. карта 3. придбання, здобуття 4. великомасштабний 5. розмір |
| 11. | acquisition | 1. устаткування 2. карта 3. придбання, здобуття 4. кривизна 5. розмір |
| 12. | to stakeout | 1. розмежувати 2. застовпити 3. намалювати 4. описати 5. закреслити |
| 13. | to delineate | 1. розмежувати 2. застовпити 3. намалювати 4. описати 5. закреслити |
| 14. | sewage system | 1. система охорони 2. система каналізації 3. трубопровід 4. застосування 5. вимірювання |
| 15. | application | 1. система охорони 2. система каналізації 3. трубопровід 4. застосування 5. вимірювання |
| 16. | measurement | 1. система охорони 2. система каналізації 3. трубопровід 4. застосування 5. вимірювання |
| 17. | pipeline | 1. система охорони 2. система каналізації 3. трубопровід 4. застосування 5. вимірювання |
| 18. | handheld tablet | 1. портативний планшет 2. рукоятка 3. посадкова площадка 4. матеріальні цінності 5. медичний препарат |
| 19. | inventory | 1. портативний планшет 2. рукоятка 3. посадкова площадка 4. матеріальні цінності 5. медичний препарат |
| 20. | landing site | 1. портативний планшет 2. рукоятка 3. посадкова площадка 4. матеріальні цінності 5. медичний препарат |
| 21. | Landsat | 1. земля 2. земельний наділ 3. землевпорядкування 4. штучний супутник 5. приймач сигналу системи глобального позиціонування |
| 22. | GPS receiver | 1. земля 2. земельний наділ 3. землевпорядкування 4. штучний супутник 5. приймач сигналу системи глобального позиціонування |
| 23. | surveying | 1. branch of applied mathematics that is concerned with determining the area of any portion of the earth's surface, the lengths and directions of the bounding lines, and the contour of the surface and with accurately delineating the whole on paper; 2. The surveying of the earth's surface, making allowance for its curvature and giving an accurate framework for smaller-scale surveys; 3. The surveying of areas of limited size, making no corrections for the earth’s curvature; 4. A radio system that uses signals from satellites to tell you where you are and to give you directions to other places; 5. An area of land that has been measured and is considered as a unit. |
| 24. | plane surveying | 1. branch of applied mathematics that is concerned with determining the area of any portion of the earth's surface, the lengths and directions of the bounding lines, and the contour of the surface and with accurately delineating the whole on paper; 2. The surveying of the earth's surface, making allowance for its curvature and giving an accurate framework for smaller-scale surveys; 3. The surveying of areas of limited size, making no corrections for the earth’s curvature; 4. A radio system that uses signals from satellites to tell you where you are and to give you directions to other places; 5. An area of land that has been measured and is considered as a unit. |
| 25. | geodetic surveying | 1. branch of applied mathematics that is concerned with determining the area of any portion of the earth's surface, the lengths and directions of the bounding lines, and the contour of the surface and with accurately delineating the whole on paper; 2. The surveying of the earth's surface, making allowance for its curvature and giving an accurate framework for smaller-scale surveys; 3. The surveying of areas of limited size, making no corrections for the earth’s curvature; 4. A radio system that uses signals from satellites to tell you where you are and to give you directions to other places; 5. An area of land that has been measured and is considered as a unit. |
| 26. | plot | 1. branch of applied mathematics that is concerned with determining the area of any portion of the earth's surface, the lengths and directions of the bounding lines, and the contour of the surface and with accurately delineating the whole on paper; 2. The surveying of the earth's surface, making allowance for its curvature and giving an accurate framework for smaller-scale surveys; 3. The surveying of areas of limited size, making no corrections for the earth’s curvature; 4. A radio system that uses signals from satellites to tell you where you are and to give you directions to other places; 5. An area of land that has been measured and is considered as a unit. |
| 27. | GPS | 1. branch of applied mathematics that is concerned with determining the area of any portion of the earth's surface, the lengths and directions of the bounding lines, and the contour of the surface and with accurately delineating the whole on paper; 2. The surveying of the earth's surface, making allowance for its curvature and giving an accurate framework for smaller-scale surveys; 3. The surveying of areas of limited size, making no corrections for the earth’s curvature; 4. A radio system that uses signals from satellites to tell you where you are and to give you directions to other places; 5. An area of land that has been measured and is considered as a unit. |
| 28. | mapping | 1. To mark the location or limits of with stake; 2. Can be used to place objects or points in three dimensions in relation to the unit; 3. The act or operation of making maps; 4. An area of land that has been measured and is considered as a unit; 5. Limitation. |
| 29. | stakeout | 1. To mark the location or limits of with stake; 2. Can be used to place objects or points in three dimensions in relation to the unit; 3. The act or operation of making maps; 4. An area of land that has been measured and is considered as a unit; 5. Limitation. |
| 30. | EDM | 1. To mark the location or limits of with stake; 2. Can be used to place objects or points in three dimensions in relation to the unit; 3. The act or operation of making maps; 4. An area of land that has been measured and is considered as a unit; 5. Limitation. |
| 31. | accurate  *Find the synonym* | 1. position 2. plotting 3. precise 4. processing 5. analysis |
| 32. | computing  *Find the synonym* | 1. position 2. plotting 3. precise 4. processing 5. analysis |
| 33. | survey  *Find the synonym* | 1. position 2. plotting 3. precise 4. processing 5. analysis |
| 34. | location  *Find the synonym* | 1. position 2. plotting 3. precise 4. processing 5. analysis |
| 35. | mapping  *Find the synonym* | 1. position 2. plotting 3. precise 4. processing 5. analysis |
| 36. | construct  *Find the synonym* | 1. position 2. build 3. determine 4. processing 5. analysis |
| 37. | define  *Find the synonym* | 1. position 2. build 3. determine 4. processing 5. analysis |
| 38. | The importance of this task \_\_\_\_\_ by scientists. | 1. was done 2. is given 3. is pointed out 4. is taken out 5. was broken |
| 39. | Geological Survey is a document reporting the results of a \_\_\_\_\_\_. | 1. surveyor 2. biologist 3. miner 4. teacher 5. bookkeeper |
| 40. | elimination | 1. родовище 2. величина, ступінь 3. кар’єр 4. розшарування, розщеплення 5. усунення, відсів |
| 41. | deposit | 1. родовище 2. величина, ступінь 3. кар’єр 4. розшарування, розщеплення 5. усунення, відсів |
| 42. | dimension | 1. родовище 2. величина, ступінь 3. кар’єр 4. розшарування, розщеплення 5. усунення, відсів |
| 43. | quarry | 1. родовище 2. величина, ступінь 3. кар’єр 4. розшарування, розщеплення 5. усунення, відсів |
| 44. | foliation | 1. родовище 2. величина, ступінь 3. кар’єр 4. розшарування, розщеплення 5. усунення, відсів |
| 45. | open-pit mining | 1. прокладання тунелів 2. зневоднення, осушування 3. запобігати (небезпеці, тощо 4. зріз, зсув 5. гірнича розробка відкритим способом |
| 46. | tunneling | 1. прокладання тунелів 2. зневоднення, осушування 3. запобігати (небезпеці, тощо 4. зріз, зсув 5. гірнича розробка відкритим способом |
| 47. | de-watering | 1. прокладання тунелів 2. зневоднення, осушування 3. запобігати (небезпеці, тощо 4. зріз, зсув 5. гірнича розробка відкритим способом |
| 48. | avert | 1. прокладання тунелів 2. зневоднення, осушування 3. запобігати (небезпеці, тощо) 4. зріз, зсув 5. гірнича розробка відкритим способом |
| 49. | shear | 1. прокладання тунелів 2. зневоднення, осушування 3. запобігати (небезпеці, тощо 4. зріз, зсув 5. гірнича розробка відкритим способом |
| 50. | haul road | 1. звалище 2. основна дорога 3. шлях буксирування 4. сульфідні мінерали 5. викопні мінерали |
| 51. | waste dump | 1. звалище 2. основна дорога 3. шлях буксирування 4. сульфідні мінерали 5. викопні мінерали |
| 52. | sulfide-minerals | 1. звалище 2. основна дорога 3. шлях буксирування 4. сульфідні мінерали 5. викопні мінерали |
| 53. | Open-pit mining is ….  *Match the definitions* | 1. … borrows, placers, quarries and strip mines; 2. … quarries; 3. … of solid wastes; 4. … normally slurry; 5. ... a process of digging out rock or minerals from the earth by their elimination from an open pit or borrow. |
| 54. | Open-pit mines are usually ….  *Match the definitions* | 1. … borrows, placers, quarries and strip mines; 2. … quarries; 3. … of solid wastes; 4. … normally slurry; 5. ... a process of digging out rock or minerals from the earth by their elimination from an open pit or borrow. |
| 55. | Open-cast mining may include …  *Match the definitions* | 1. … borrows, placers, quarries and strip mines; 2. … quarries; 3. … of solid wastes; 4. … normally slurry; 5. ... a process of digging out rock or minerals from the earth by their elimination from an open pit or borrow. |
| 56. | The exhausted mines are containers …  *Match the definitions* | 1. … borrows, placers, quarries and strip mines; 2. … quarries; 3. … of solid wastes; 4. … normally slurry; 5. ... a process of digging out rock or minerals from the earth by their elimination from an open pit or borrow. |
| 57. | Ore which has been processed is …  *Match the definitions* | 1. … borrows, placers, quarries and strip mines; 2. … quarries; 3. … of solid wastes; 4. … normally slurry; 5. ... a process of digging out rock or minerals from the earth by their elimination from an open pit or borrow. |
| 58. | \_\_\_\_\_\_\_ is a layer of soil that is distinguishable from other horizons because of differences in appearance and in physical and chemical properties | 1. water surface 2. land surface 3. soil horizon 4. Earth surface 5. deposit |
| 59. | \_\_\_\_\_\_ - all elastic waves that travel through rock, produced by an earthquake or explosion | 1. seismic method 2. deposit 3. soil horizon 4. seismic wave 5. shear stress |
| 60. | \_\_\_\_\_\_ is a method based on investigation of velocity of seismic waves propagation in the Earth’s interior in the result of earthquakes and explosions | 1. seismic method 2. deposit 3. soil horizon 4. seismic wave 5. shear stress |

**TEST II**

1. The word “fossil” originally referred to anything that is taken from ….. .
2. water b) ground c) air d) space
3. Fuels can not be …. .
4. Solid b) liquid c) gaseous c) inorganic
5. The chief sources of energy available to man are … .
6. Oil b) natural gas c) atomic energy d) all suggested
7. There are four general kinds of coal: …
8. hard coal, bituminous coal, brown coal, lignite; b) bituminous coal, brown coal, hard coal, soft coal; c) brown coal, bituminous coal, hard coal, anthracite; d) hard coal, bituminous coal, brown coal, solid coal
9. The theory and practice of mining and smelting were systematized by the great scientist . ..
10. M.Lomonosov b) O.Karpinsky c) V.Oruchev d) A.Fersman
11. The term … defines the amount of the mineral in a deposit by weight or volume.
12. Quarry b) fossil fuels c) reserves d) surveying
13. The main supplier of coal in Ukraine is …
14. The Kuzbas b) Karaganda c) The Donbas d) Ekibastuz
15. The Donbas is the old mining region rich in …
16. Gold b) copper ores c) coal d) iron ores
17. Fossils can be found in …
18. Sedimentary rocks b) igneous rocks c) metamorphic rocks d) all suggested
19. Liquid fuels are derived almost from …
20. Methane b) petroleum c) charcoal d) limestone
21. … is the thinnest layer of the Earth.
22. the inner core b) the outer core c) the mantle d) the crust
23. … is usually made of bedrock , subsoil in various layers and soil.
24. the inner core b) the outer core c) the mantle d) the crust
25. … is a solution of melted minerals.
26. Soil b) sand c) magma d) clay
27. … is the scientific assumption about the processes which take place on the Earth.
28. Classicism b) uniformitarianism c) reformism d) standardization
29. A major conceptual model of how Earth changes is the theory of …
30. Plate Tectonics b) Big Bang c) the Origin of Life d) Evolution
31. …. consist of fragments or particles of pre-existing rocks.
32. Igneous rocks b) metamorphic rocks c) sedimentary rocks d) volcanic rocks
33. … solidified from magma.
34. igneous rocks b) metamorphic rocks c) sedimentary rocks d) volcanic rocks
35. … have been changed from either igneous or sedimentary rocks by extreme [heat](https://simple.wikipedia.org/wiki/Heat) and [pressure](https://simple.wikipedia.org/wiki/Pressure).
36. igneous rocks b) metamorphic rocks c) sedimentary rocks d) volcanic rocks
37. Conglomerate, sandstone, siltstone, limestone and dolomite are the most principle kinds of …
38. igneous rocks b) metamorphic rocks c) sedimentary rocks d) volcanic rocks
39. There are two types of metamorphic rocks: …
40. Foliated and unfoliated b) soft and solid c) wet and dry d) gaseous and liquid
41. Minerals can be found in …
42. Rocks b) soil b) water d) all suggested
43. There are more than … kinds of minerals.
44. 100 b) 500 c) 1000 d) 5000
45. Minerals are … that form naturally.
46. Liquids b) solids c) gases d) all suggested
47. …is a naturally occurring substance, representable by a chemical formula, which is usually solid and inorganic, and has a crystal structure.
48. a mineral b) sand c) animal decay d) all suggested
49. The Earth crust is about … miles thick.
50. 30 b)50 c) 100 d) 200
51. …. may be defined as the process of wearing away.
52. corrosion b) erosion c) alteration c) fission
53. … is formed by the accumulation of vegetables remains.
54. valleys b) loam c) hills d) gorges
55. … is a bend in the rock.
56. fold b) erosion c) weathering d) all suggested
57. Two kinds of .… are called synclines and anticlines.
58. corrosion b) erosion c) fold d) weathering
59. … is a break in the rock.
60. corrosion b) erosion c) fault d) weathering
61. The inclination of a bed, vein, dike, etc., is called ….
62. fault b) fold c) dip d) break
63. … is the direction of a horizontal line which lies within the plane of the bed, vein, dike or fault.
64. fold b) strike c) dip d) bending
65. The … is the upper side of a vein, dike or fault.
66. Foot wall b) hanging wall c) bed d) strike
67. The … is the lower side of a vein, dike or fault.
68. foot wall b) hanging wall c) bed d) strike
69. If the reversed movement has taken place, the fault is called a reversed or …
70. thrust fault b) fold c) break d) crack
71. The term … is generally applied to cracks in rocks, large enough to be distinctly visible to the naked eye.
72. fold b) bending c) fracture d) yield
73. Fractures are the result of the straining and cracking of rocks under …
74. action of wind b) pressure c) action of acids d) action of water
75. The process of superficial disintegration of rocks is called …
76. weathering b) fold c) fault d) fracture
77. There are several kinds of weathering:
78. physical weathering b) chemical weathering c) mechanical weathering d) all suggested
79. … weathering is when it involves the reaction of some chemicals on rocks*.*

a) physical weathering b) chemical weathering c) mechanical weathering

d) all suggested

1. … weathering is caused by the effects of changing temperature on rocks, causing the rock to break apart.

a) physical weathering b) chemical weathering c) mechanical weathering

1. all suggested
2. The search for economically useful mineral deposits is called …
3. development b) prospecting c) opening d) panning
4. To establish the quality and quantity of a mineral deposits, the type of country rock, etc. means to prove it and this process is called …
5. proving b) prospecting c) opening d) panning
6. Prospecting work includes several stages:
7. finding signs of the mineral b) finding the deposits c)exploring the deposits d) all suggested
8. … is an applied science concerned with the practical application of the principles of geology in the solving of environmental problems.
9. ecology b) geology c) hydrology d) environmental geology
10. Modern …is an industry that involves the exploration for and removal of minerals from the earth with minimum damage to the environment.
11. surveying b) mining c) prospecting d) geology
12. … has been traditionally defined as the science of making relatively large-scale, accurate measurements of the Earth’s surface; mapping.
13. mining b) surveying c) geology d) prospecting
14. Most traditional surveying is …, which does not take into account the curvature of the earth.
15. geodetic surveying b) plane surveying c) mapping d) missle alignment
16. … is the survey in which the curvature of the earth is taken into account
17. geodetic surveying b) plane surveying c) mapping d) missle alignment
18. … is the act of operation of making maps.
19. mapping b) missle alignment c) stakeout d) EDM

# PART II GRAMMAR REVISION TENSES

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Простий час  Приклад | [**Past Simple**](http://easy-english.com.ua/past-simple/)  *I wrote a letter an hour ago.*  *Годину тому я написав листа.* | [**Present**](http://easy-english.com.ua/present-simple/)[**Simple**](http://easy-english.com.ua/present-simple/)  *I often write letters.*  *Я часто пишу листи.* | [**Future Simple**](http://easy-english.com.ua/future-simple/)  *I will write you a letter.*  *Я напишу тобі листа.* | [**Future in the**](http://easy-english.com.ua/future-simple-in-the-past/)[**Past Simple**](http://easy-english.com.ua/future-simple-in-the-past/)  *He said he would write a letter.*  *Biн сказав, що напише листа.* |
| Тривалий час  Приклад | [**Past**](http://easy-english.com.ua/past-continuous/)[**Continuous**](http://easy-english.com.ua/past-continuous/)  *I was writing a letter from 4 to 5*  *p. m.*  *Я писав листа з четвертої до п’ятої вечора.* | [**Present**](http://easy-english.com.ua/present-continuous/)[**Continuous**](http://easy-english.com.ua/present-continuous/)  *I am writing a letter now.*  *Я зараз пишу листа.* | [**Future**](http://easy-english.com.ua/future-continuous/)[**Continuous**](http://easy-english.com.ua/future-continuous/)  *I will be writing a letter at this time tomorrow.*  *Завтра в цей час я писатиму листа.* | [**Future in the**](http://easy-english.com.ua/future-continuous-in-the-past/)[**Past**](http://easy-english.com.ua/future-continuous-in-the-past/)[**Continuous**](http://easy-english.com.ua/future-continuous-in-the-past/)  *Не said he would be writing a letter at that time the next day.*  *Він сказав, що завтра в цей час писатиме листа.* |
| Доконаний час  Приклад | [**Past Perfect**](http://easy-english.com.ua/past-perfect/)  *By the time you came I had written a letter.*  *До того часу як ти прийшов, я написав листа.* | [**Present**](http://easy-english.com.ua/present-perfect/)[**Perfect**](http://easy-english.com.ua/present-perfect/)  *I have written a letter.*  *Я написав листа.* | [**Future Perfect**](http://easy-english.com.ua/future-perfect/)  *I will have written a letter to her by tomorrow.*  *До завтра я напишу їй листа.* | [**Future in the**](http://easy-english.com.ua/future-perfect-in-the-past/)[**Past Perfect**](http://easy-english.com.ua/future-perfect-in-the-past/)  *Не said he would have written a letter to her by the next day.*  *Він сказав, що до завтра напише їй листа.* |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Доконаний тривалий час  Приклад | [**Past Perfect**](http://easy-english.com.ua/past-perfect-continuous/)[**Continuous**](http://easy-english.com.ua/past-perfect-continuous/)  *By the time you came I had been writing a letter for an hour already.*  *До того часу як ти прийшов. я вже годину писав листа.* | [**Present**](http://easy-english.com.ua/present-perfect-continuous/)[**Perfect**](http://easy-english.com.ua/present-perfect-continuous/)[**Continuous**](http://easy-english.com.ua/present-perfect-continuous/)  *I have been writing a letter for two hours already.*  *Я пишу листа вже дві години.* | [**Future Perfect**](http://easy-english.com.ua/future-perfect-continuous/)[**Continuous**](http://easy-english.com.ua/future-perfect-continuous/)  *By 10 p. m. I will have been writing a letter for two hours already.*  *До десятої вечора я писатиму листа вже дві години.* | [**Future in the**](http://easy-english.com.ua/future-perfect-continuous-in-the-past/)[**Past Perfect**](http://easy-english.com.ua/future-perfect-continuous-in-the-past/)[**Continuous**](http://easy-english.com.ua/future-perfect-continuous-in-the-past/)  *Не said he would have been writing a letter for an hour by 10 p. m.*  *Він казав, що до десятої вечора він годину писатиме їй листа.* |

### SIMPLE PRESENT

***Exercise I. Choose the correct form of the following verbs:***

wake(s) up - open(s) - speak(s) - take(s) - do(es) - cause(s) - live(s) - play(s) - close(s) - live(s) - drink(s)

* + 1. Ann hand ball very well.
    2. I never coffee.
    3. The swimming pool at 7:00 in the morning.
    4. It at 9:00 in the evening.
    5. Bad driving many accidents.
    6. My parents in a very small flat.
    7. The Olympic Games place every four years.
    8. They are good students. They always their homework.
    9. My students a little English.
    10. I always early in the morning.

***Exercise II. Put the verbs between brackets in the correct form:***

1. Jane (not/drink) tea very often.
2. What time (the banks/open) Britain?
3. Where (John/come) from?
4. It (take) me an hour to get to work.
5. She (not/wake) up early on Sundays.

***Exercise III. Choose the right verbs to complete the sentences. Sometimes you need the negative:***

write - turn - eat - tell - rise

1. The earth around the sun.
2. The sun in the east.
3. Vegetarians meat.
4. A liar is someone who the truth.
5. A novelist novels.

**SIMPLE PAST**

***Exercise IV. Put the verbs into the Simple Past:***

1. Last year I (go) to England on holiday.
2. It (be) fantastic.
3. I (visit) lots of interesting places. I (be) with two friends of mine.
4. In the mornings we (walk) in the streets of London.
5. In the evenings we (go) to pubs.
6. The weather (be) strangely fine.
7. It (not / rain) a lot.
8. But we (see) some beautiful rainbows.
9. Where (spend/you) your last holiday?

***Exercise V. Write the past forms of the irregular verbs.***

|  |  |
| --- | --- |
| **Infinitive** | **Simple Past** |
| meet |  |
| drive |  |
| speak |  |
| put |  |
| write |  |
| sing |  |
| do |  |
| sit |  |
| stand |  |
| run |  |

***Exercise VI. Complete the table in Simple Past*.**

|  |  |  |
| --- | --- | --- |
| **Affirmative** | **Negative** | **Interrogative** |
| He wrote a book. |  |  |
|  | He did not sing |  |
|  |  | Was she pretty? |

***Exercise VII. Put the sentences into Simple Past*.**

1. We move to a new house. →
2. They bring a sandwich. →
3. He doesn't do the homework. →
4. They sell cars. →
5. Does he visit his friends? →

***Exercise VIII. Write sentences in Simple Past*.**

1. Janet / miss / the bus →
2. She / tidy / her room →
3. Nancy / watch / not / television→
4. She / read / a book →

***Exercise IX. Choose "Was“ or "Were“:***

1. The teacher nice.
2. The students very clever.
3. But one student in trouble.
4. We sorry for him.
5. He nice though.

### SIMPLE FUTURE

***Exercise X. Put the verbs into the correct form (Simple Future) James, 18 years old, asked an ugly fortune teller about his future. Here is what she told him:***

1. You (be) very happy.
2. You (get) a lot of money.
3. You (buy) a beautiful house.
4. Your friends (envy) you.
5. You (meet) a beautiful girl.
6. You (marry) her.
7. You and your wife (travel) around the world.
8. People (serve) you.
9. They (not/refuse) to make you happy.
10. But all this (happen/only) when you are 70 years old.

**PRESENT CONTINUOUS**

***Exercise I. Put the verbs into the Present Continuous:***

1. Listen to the birds. They (sing) .
2. Look at that one. It (fly) high in the sky.
3. The other one (play) with a worm.
4. I feel happy because I (have) a good time here in these woods.

***Exercise II. Put the verbs into the correct tense (Simple Present or Present Continuous*)**

1. Look! Sara (go) to the movies.
2. On her right hand, Sara (carry) her handbag.
3. The handbag (be) very beautiful.
4. Sara usually (put) on black shoes but now she (wear)

white trainers.

1. And look, she (take) an umbrella.

***Exercise III. Choose the correct answer (Simple Present or Present Continuous*)**

1. It (rains; is raining) cats and dogs. We'd better stay at home.
2. I (watch; am watching) TV every day in the morning.
3. (Do you come; are you coming) to the party tonight?
4. The children are at the stadium. They (watch; are watching) a football match.
5. I (do not go; am not going) to the cinema often.
6. She usually (comes; is coming) late to school.
7. He (is exercising; exercises) regularly.
8. John is busy. He ( Is working; works) at the moment.
9. Be quiet! The baby (is sleeping; sleeps).
10. She (is traveling; travels) to New York next weekend.

***Exercise IV. Choose the right form of the verbs:***

1. I (fly) by plane tomorrow.
2. Hi, what time (the train/pull out) this evening?
3. (you/travel) tomorrow to Paris?
4. I (to go) the cinema tonight.
5. They always (have) breakfast at 07.30
6. We (go) out this weekend.
7. The library (open) at 8.30 and (close) at 7.30
8. The parents (have) a meeting on Saturday.

### PAST CONTINUOUS

***Exercise V. Put the verbs into the correct form (Past Continuous).***

1. When I phoned my friends, they (play) monopoly.
2. Yesterday at six I (prepare) dinner.
3. The kids (play) in the garden when it suddenly began to rain.
4. I (practice) the guitar when he came home.
5. We (not / cycle) all day.
6. While Alan (work) in his room, his friends (swim) in the pool.
7. I tried to tell them the truth but they (not / listen) .
8. What (you/do) yesterday?
9. Most of the time we (sit) in the park.
10. I (listen) to the radio while my sister (watch) TV.
11. When I arrived, they (play) cards.
12. We (study) English yesterday at 4:00 pm.

***Exercise VI. Write correct sentences:***

***Yesterday at 6 pm your family were doing different things*. (*Write positive sentences in Past Continuous*).**

1. My mother/read/a novel.
2. My father/watch/a movie.
3. My elder sister/writing/in her diary.
4. My two brothers/listen/to the radio.
5. My little sister and I/not/watch/a movie.
6. We/talk/about school.

### FUTURE CONTINUOUS

***Exercise VII. Put the verbs into the correct form (Future Continuous).***

1. Tomorrow morning we (work).
2. This time next week we (have) a party.
3. At midnight I (sleep).
4. This evening we (watch) a talk show.
5. They (not/do) their homework this afternoon.
6. He (listen) to the music.
7. I (read) a book this evening.
8. (walk/you) home this afternoon?
9. He (not/draw) tomorrow morning
10. They (argue) again?

### PRESENT PERFECT

***Exercise I. Write sentences in Present Perfect*.**

1. They/play/football -
2. He/speak/English -
3. I/write/a poem -
4. We/not/wash/the car -
5. Nancy/not/meet/her friends-

***Exercise II. Write questions in Present Perfect*.**

1. They/finish/their homework -
2. She/visit/her friend-
3. The maid/clean/the house -
4. He/drive/the van -
5. You/ever/write/a poem -

***Exercise III. Put the verbs into the correct form (Present Perfect or Simple Past).***

1. I (not/work) today.
2. We (buy) a new car last week.
3. We (not/plan) our holiday yet.
4. She (not/see) her mother for a long time.
5. He (write) a beautiful poem yesterday.

***Exercise IV. Put the verbs into the correct form (Present Perfect or Continuous).***

1. I think the waiter (forget) us. We (wait) here for over half an hour and nobody (take) our order yet.
2. I think you're right. He (walk) by us at least twenty times. He probably thinks we (order, already) .

***Exercise V. Write the past participle of the following irregular verbs*.**

speak - catch -eat - understand - begin -

### PAST PERFECT

***Exercise VI. Complete the sentences in Past Perfect (affirmative form.)***

1. I lost the key that he (give) to me.
2. He told me that he (see) the film.
3. I went outside as I (hear) a noise.
4. When they came home, Liza (cook) dinner.
5. We could not send you a postcard because we (lose) your address.

***Exercise VII. Complete the sentences in Past Perfect (negative).***

1. The waiter served something that we (not/order).
2. He went to the country which he (not/visit) before.
3. She picked out the red dress, which she (not/wear) for ages.
4. He (not/swim) in the beach before that day.
5. His mother was angry because he (not/do) the shopping for her.

***Exercise VIII. Complete the questions in Past Perfect.***

1. (you/finish) your homework before you went to the cinema?
2. Why (you/not /clean) the bathroom before you took a bath?
3. (you/have) breakfast before you left the house?
4. (she/manage) to find a place to stay when she went to London?
5. Where (she/stay) before she moved to live with her friend?

***Exercise IX. Put the verbs into the correct form (Past Perfect or The Simple Past)***

1. The storm (destroy) the house that they had built.
2. The children (clean) the blackboard they had used to do the mathematics exercise.
3. When she went out to play, she (do / already) her homework.
4. She (eat) all of the food that we had made.
5. He took off the jacket he (put on) before.

### FUTURE PERFECT. FUTURE PERFECT CONTINUOUS.

***Exercise X. Put the verbs into the correct form (Future Perfect).***

1. By 9 o'clock, we (finish) our homework.
2. They (leave) the classroom by the end of the hour.
3. We (go) home by next week.
4. She (return) from the excursion by 6 o'clock.
5. (buy/he) the new house by October?
6. The sun (not / rise) by 4 o'clock.
7. (you/do) the shopping by 3 o'clock?

***Exercise XI. Put the verbs into the correct form (Future Perfect Continuous)***

1. By the end of the month I (live) in this town for ten years.
2. By the end of this week we (work) on the project for a month.
3. By July the fifth they (study) English for 3 years.
4. By 10 o'clock she (watch) TV for 4 hours.
5. She (sleep) for 10 hours by 11 o'clock.
6. We (look for) him for 40 days by next Saturday.
7. They (wait) for the president for 5 hours.

***Exercise XII. Put the verbs in brackets in the correct tense (Future Perfect Simple or Continuous)***

1. By 2018 we (live) in Madrid for 20 years.
2. He (write) a book by the end of the year.
3. (finish, you) this novel by next week?
4. He (read) this book for 15 days by the end of this week.
5. They (be) married for 40 years by the end of this month.
6. (be, she) pregnant for three months this week?

### TENSES

***Exercise I. Put the verbs into the correct tense (Simple Present or Present Continuous)***

1. Look! Sara (go) to the movies.
2. On her right hand, Sara (carry) her handbag.
3. The handbag (be) very beautiful.
4. Sara usually (put) on black shoes but now she (wear) white trainers.
5. And look, she (take) an umbrella because it (rain)

***Exercise II. Put the verbs into the correct tense (Simple Past or Past Perfect)***

1. When he (wake up), his mother (already/prepare) breakfast.
2. We (go) to London because our friends (invite) us.
3. He (hear) the news, (go) to the telephone and (call) a friend.
4. When she (start) learning English she (already /learn) French.
5. Jane (already / type) three pages when her computer (crash).
6. By the time the doctor (arrive) at the house the patient (die) .
7. Before that day we (never / think) of traveling to Japan.
8. I (know) him a long time before I (meet) his family.
9. They (not/know) where to meet because nobody (tell) them.
10. It (be) cloudy for days before it (begin) to rain.

***Exercise III. Put the verbs into the correct tense (Simple Past or Present Perfect).***

1. I (just/finish) my homework.
2. Mary (already/write) five letters.
3. Tom (move) to his home town in 1994.
4. My friend (be) in Canada two years ago.
5. I (not/be) to Canada so far.
6. But I (already/travel) to London a couple of times.
7. Last week, Mary and Paul (go) to the cinema.
8. I can't take any pictures because I (not/buy) a new film yet.
9. (they/spend) their holidays in Paris last summer?
10. (you/ever/see) a whale?

***Exercise VI. Put the verbs into the correct tense (Simple Past or Past Continuous)*.**

1. The receptionist (welcome) the guests and (ask) them to fill in the form.
2. The car (break) down and we (have) to walk home.
3. The boys (swim) while the girls (sunbath).
4. My father (come) in, (look) and (tell) me to tidy up my room.
5. While one group (prepare) dinner the others (collect) wood for the campfire.
6. While the parents (have) breakfast the children (run) about.
7. Martha (turn) off the light and (go) to bed.

***Exercise V. Put the verbs into the correct tense (Simple Future or Future Perfect)***

1. Tomorrow I think I (start) my new project.
2. I (finish) it by the end of this month.
3. The teacher (probably/assign) a test to his students next Monday.
4. He (correct) it by the end of next week.
5. My friend (certainly/get) a good mark.
6. By 9 o'clock, we (finish) our homework.
7. They (leave) the classroom by the end of the hour.
8. I think I (start) my trip tomorrow

### GRAMMAR TESTS

**TEST 1**

1. I have bought a computer, is more expensive than this one.
   1. who **b)** which **c)** that
2. There some books on the shelves.
   1. isn’t **b)** are **c)** aren’t
3. When I was a teenager I a lot. But I don’t do it now.
   1. smoke **b)** was smoking **c)** used to smoke
4. There isn’t coffee in the cup.
   1. any **b)** some **c)** a
5. She us tomorrow.
   1. will call **b)** calls **c)** call
6. The meeting is cancelled. You prepare your presentation.
   1. don’t need **b)** mustn’t **c)** don’t have to
7. He too much.
   1. talk **b)** talking **c)** talks
8. I go out today.
   1. not can **b)** canot **c)** cannot
9. she her friends yesterday?
   1. did … saw **b)** did … see **c)** did … sees
10. My name’s Mark.
    1. sister’s husband’s **b)** sister husband’s **c)** sister’s husband
11. I’m actor.
    1. a **b)** an **c)** the
12. Oh, we don’t have any bread at home. I go and buy some.
    1. am going to **b)** would **c)** will
13. We like . (Mark and Alice)
    1. you **b)** us **c)** them
14. We want to meet Monday.
    1. at **b)** in **c)** on
15. Put postcards on the table.
    1. this **b)** those **c)** that
16. This armchair is than that armchair.
    1. comfortabler **b)** most comfortable **c)** more comfortable
17. I think that picture is .
    1. worse **b)** the worst **c)** worst
18. I am going to travel all August.
    1. That year **b)** This year **c)** In this year
19. They like a lot.
    1. ski **b)** skying **c)** skiing
20. I like picture most of all.
    1. the first **b)** the one **c)** first
21. Mark anything to me.
    1. didn’t wrote **b)** not write **c)** didn’t write
22. many people at the airport.
    1. there was **b)** It was **c)** there were
23. I am busy at the moment. I an important email.
    1. am writing **b)** writing **c)** write
24. How money did you spend?
    1. much **b)** few **c)** many
25. We to the USA this month. We have already reserved a hotel in New York.
    1. are going **b)** will go **c)** go
26. We have eggs in the fridge.
    1. any **b)** little **c)** a few
27. I a cup of coffee now.
    1. I liked **b)** I would like **c)** I like
28. you ever to Turkey?
29. Has … been **b)** Have … be to **c)** Have … been
30. If you don’t have your pen, take .
    1. my **b)** me **c)** mine
31. He when the phone rang.
    1. was sleeping **b)** were sleeping **c)** sleeped
32. We didn’t go on a picnic the rain.
    1. because **b)** that’s why **c)** because of
33. Sleeping pills are as as warm milk and honey if you can’t fall asleep at night.
    1. better **b)** good **c)** best
34. You see, this car is than that one.
    1. less more expensive **b)** much more expensive **c)** much expensive
35. They don’t have money to buy a house. If they enough money, they buy one.
    1. have, will **b)** had, will **c)** had, would
36. They come the USA.
    1. from **b)** in **c)** at
37. What’s name? Is she Natalia?
    1. her **b)** his **c)** your
38. Next month I will go on holiday. When I on holiday, I to Paris.
    1. went, will fly **b)** go, would fly **c)** go, will fly
39. She broke her friend’s clock yesterday. I think she buy him a new one.
    1. shall **b)** should **c)** has to
40. His boss asked him to make a report. He stay after work today.
    1. must **b)** has to **c)** should
41. ‘Romeo and Juliet’ by Shakespeare.
    1. was written **b)** was being written **c)** was wrote
42. When I arrived at home, my parents to bed.
    1. have gone **b)** had gone **c)** did go
43. She doesn’t like sandwiches .
    1. Me too. **b)** So do I. **c)** Neither do I.
44. I have to do today.
    1. nothing **b)** anything **c)** everything
45. She thanked me for her a lift.
    1. gave **b)** to give **c)** giving
46. He promised in time.
    1. to come **b)** coming **c)** come
47. We our friends tonight.
    1. see **b)** are seeing **c)** are see
48. She likes him his brother.
    1. neither … nor **b)** both … or **c)** either … nor
49. She her room all day but she still has a lot to paint.
    1. has painted **b)** has been painting **c)** paints
50. They to finish the work in time.
    1. must **b)** were able **c)** could
51. We’ll do you like.
    1. wherever **b)** where that **c)** whatever
52. Let’s call him. He be at home now.
    1. has to **b)** must **c)** is allowed to
53. If they , the accident .
    1. haven’t argued, wouldn’t happen **b)** hadn’t argued, wouldn’t happen

**c)** hadn’t argued, wouldn’t have happened

1. You haven’t been to Australia, ?
   1. haven’t you **b)** did you **c)** have you
2. I didn’t know anything about it. You me.
   1. should told **b)** should have told **c)** should be telling
3. you try, you learn.
   1. the hardest, the fastest **b)** the harder, the faster **c)** the hard, the fast
4. He to be very rich.
   1. is thinking **b)** thinks **c)** is thought
5. I know him.
   1. hardly **b)** hard **c)** harder
6. In my opinion, they’re not to come to us today.
   1. definitely **b)** likely **c)** like
7. You call her.
   1. had better **b)** would better **c)** have better
8. My car broke and I it .
   1. am repaired **b)** had … repaired **c)** would … be repaired
9. I wish he so rude yesterday.
   1. hasn’t been **b)** haven’t been **c)** hadn’t been
10. By the time you come we everything.
    1. will have finished **b)** will finish **c)** will finished

### TEST 2

***Choose the correct variant***

1. The United Nations Organization was … in 1945 with the objective of averting another major world war.

fount

found

founded

1. Have you … the answer?

fount

found

founded

1. Every nation has … customs and traditions.

*its*

*it's*

*its'*

1. Have you seen my key? … disappeared.

its

it's

its'

1. … about time you washed that coat.

its

it's

its'

1. … might be snacks if you wait a bit.

there

their theirs

1. Where will he sleep?’ ‘Well, … one bedroom.’

theirs

there there's

their

1. Have you ever visite … place?

their

theirs there there's

1. I have brought my piano. Where is …?

yours'

yours

your's

your

1. … the most wonderful person I have ever met.

you're

your

your

yuor

1. Can you lend me … pen?

yours

your

you're

your’s

1. … no use trying to complain.

there's

there

theirs

their

1. I don’t know … I will have time.

weather

whether

whither

wither

1. … is that car? who's

whose

hose

wose

1. I’ve got a cousin … never been to a concert.

whose

who's

wose

1. There is no … between this and that.

difference

deference

diference

diferences

1. In summer, the …is hot.

weather

whether

wheter

whethers

1. I will let you do this now but don’t take it as a …, because I will not let you do it again.

president

precedent

precident

presidant

1. The … is survived by his wife and two children.

deceased

diseased

deseased

decease

1. A sick man needs a … room.

quite

quit

quiet

quites

# SEQUENCE OF TENSES (УЗГОДЖЕННЯ ЧАСІВ)

***Вивчіть два основних правила.***

**Правило 1.** Якщо дієслово головного речення має форму теперішнього чи майбутнього часу, то дієслово підрядного речення буде мати будь-яку форму, котра вимагається змістом речення. Тобто жодних змін не відбудеться, узгодження часів тут не набирає сили.

**Правило 2.** Проте, якщо дієслово головного речення має форму минулого часу (за звичай, це Past Simple), то дієслово підрядного речення повинно бути у формі одного з минулих часів. Тобто, в даному випадку час підрядного речення зміниться. Всі ці зміни відображені у таблиці нижче (показані найбільш поширені часи).

**ТАБЛИЦЯ 1. УЗГОДЖЕННЯ ЧАСІВ**

|  |  |  |
| --- | --- | --- |
| ***Перехід із одного часу в інший*** | ***Приклад*** | |
| ***Present Simple – Past Simple*** | ***He can speak French. – Він може розмовляти французькою.*** | ***Boris said that he could speak French. – Борис сказав, що він може розмовляти французькою.*** |
| ***Present Continuous - Past Continuous*** | ***They are listening to him.- Вони слухають його.*** | ***I thought they were listening to him. – Я думав, що вони його слухають.*** |
| ***Present Perfect – Past Perfect*** | ***Our teacher has asked my parents to help him. – Наш вчитель попросив моїх батьків допомогти йому.*** | ***Mary told me that our tacher had asked my parents to help him. – Марія сказала мені, що наш вчитель попросив моїх батьків допомогти йому.*** |
| ***Past Simple – Past Perfect*** | ***I invited her. – Я запросив її.*** | ***Peter didn't know that I had invited her. – Пітер не знав, що я запросив її.*** |
|  | ***She was crying. - Вона плакала.*** | ***John said that she had been crying . – Джон сказав, що вона плакала.*** |
| ***Present Perfect Continuous –*** | ***It has been raining. – Йде дощ.*** | ***He said that it had been raining. – Він сказав, що йшов дощ.*** |
| ***Perfect Continuous*** |  |  |
| ***Future Simple – Future inthe Past*** | ***She will show us the map. – Вона покаже нам карту.*** | ***I didn't expect she would show us the map. – Я не очікував, що вона покаже нам карту.*** |

Однак, в певних випадках узгодження часів не використовується.

|  |  |
| --- | --- |
| ***1. Якщо в підрядному реченні повідомляється загальновідоме твердження або факт.*** | ***We convinced him how important learning English is. – Ми переконали його в тому, наскільки важливим є вивчення англійської.*** |
| ***2. Якщо в підрядних реченнях присудок виражено дієсловом умовного способу.*** | ***If your father were kind, he would let us stay here. – Якби твій тато був добрим, він би дозволив би нам залишитися тут.*** |
| ***3. Якщо у складі присудку підрядного речення є модальне дієслово.*** | ***Mary said that he must call her. – Марія сказала, що він повинен подзвонити їй.*** |

*Слід запам’ятати, що при узгодженні часі змінюються також деякі слова (обставини часу та місця).*

***Таблиця 3. Зміна обставин часу та місця при узгодженні часів***

|  |  |
| --- | --- |
| ***this*** | ***that*** |
| ***these*** | ***those*** |
| ***here*** | ***there*** |
| ***now*** | ***then*** |
| ***yesterday*** | ***the day before*** |
| ***today*** | ***that day*** |
| ***tomorrow*** | ***the next (the following) day*** |
| ***last week/year*** | ***the previous week/year*** |
| ***ago*** | ***before*** |

|  |  |
| --- | --- |
| ***next week/year*** | ***the following week/year*** |

На зміну обставин часу слід звернути особливу увагу.

### SEQUENCE OF TENSES

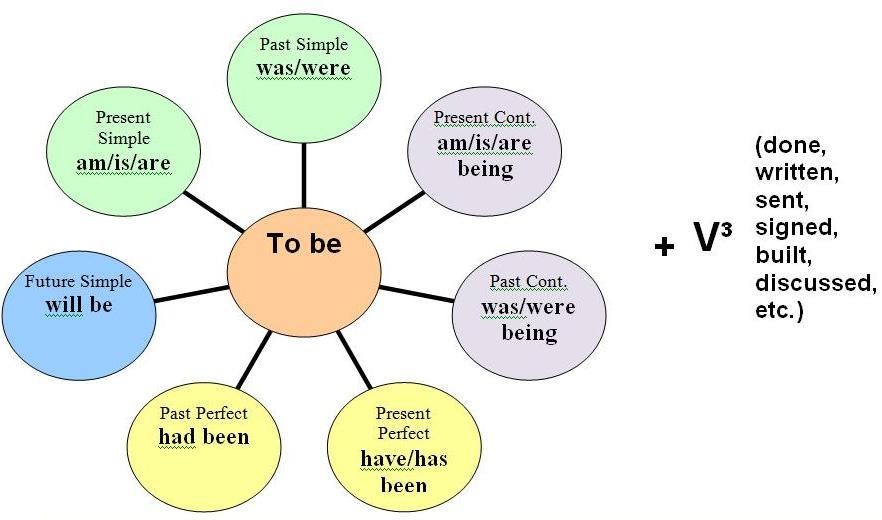
1. ***Mark the sentences where the verb can be used in Present Tenses:***
   1. Aristotle discovered that the Earth (be) round.
   2. I thought you (invite) her to the cinema.
   3. I met the girl who (live) near here.
   4. He told me he (be preparing) for his exams.
   5. You made me understand how important education (be).
2. ***Complete the sentences:***

*e.g. I think I know the answer.*

I thought … – I thought I knew the answer.

1. He realizes he will be alone. He realized…
2. We hope she will be waiting for us at six o'clock. We hoped…
3. He proves he is the best. He proved…
4. She imagines she can do that. She imagined…
5. We understand we need more money. We understood…
6. ***Choose the correct variant of the verb and translate the sentences into Ukrainian*:**
   1. I knew that my sister … (have/has/had) a problem.
   2. I know that my sister … (have/has/had) a problem.
   3. I knew that my sister … (will have/would have/had) a problem soon.
   4. He said he … (lived/has lived/had lived) in Moscow since 2005.
   5. She asks me if the flight … (has been cancelled/had been cancelled/been cancelled).
   6. She asked me if the flight … (has been cancelled/had been cancelled/was cancelled).
   7. Nobody knew what … (will happen/would happen/happens) next.
   8. Mike said that he … (hasn’t met/didn’t meet/hadn’t met) Helen since they parted.
   9. Kelly said that she … (didn’t want/doesn’t want/hadn’t wanted) to wear her hat.
   10. We didn’t expect that he … (showed/will show/would show) us the film.

# PASSIVE VOICE



|  |  |  |  |
| --- | --- | --- | --- |
| **TENSES** | **ACTIVE** | **PASSIVE** | **Note: the action is done to the subject** |
| **Present Indefinite** | ask(s) | am  is ask**ed**  are | **He asks** Він питає  **He is asked** Його питають |
| **Past Indefinite** | ask**ed** | was  ask**ed**  were |
| **Future Indefinite** | will ask | will be ask**ed** |
| **Present Continuous** | am  is ask**ing** are | am  is being ask**ed**  are | **He is asking** Він зараз питає  **He is being asked** Його зараз питають |
| **Past Continuous** | was  ask**ing**  were | was  being ask**ed**  were |
| **Future Continuous** | will be ask**ing** |  |
| **Present Perfect** | have  ask**ed**  has | have  been  ask**ed**  has  been | **He has asked** Він вже запитав  **He has been asked** Його вже спитали |
| **Past Perfect** | had ask**ed** | had been  ask**ed** |
| **Future Perfect** | will have ask**ed** | will have been ask**ed** |

### PASSIVE VOICE - PRESENT/PAST SIMPLE USE: AM/IS/ARE/WAS/WERE

1. ***For each sentence, choose either the active or the passive form of the verb… and the correct tense.***
   1. Rose by the snake. (scare-past)
   2. Many in Japan. (make-present)
   3. The cinema by the police. (close-past)
   4. The work three times a day. (do-present)
   5. The pictures by Picasso. (paint-past)
   6. The cheese by the mice. (eat-past)
   7. These knives to cut up food. (use-present)
   8. They the question two times. (ask-past)
   9. Our house in 1902. (build-past)
   10. Computers all over the world. (use-present)
   11. An ovation to the actors. (give-present)
   12. A bicycle from her. (steal-past)
2. ***Open the brackets put the verb into the correct form.***
   1. That door (paint) yesterday.
   2. Michelangelo (paint) the Sistine Chapel.
   3. Michael Schumacher (drive) for Ferrari in 2003.
   4. In the UK, everyone (drive) on the left.
   5. Inter-city trains (usually/drive) by men.
   6. The 'La Stamp a' newspaper (read) by two million people in Italy.
   7. My car (steal)! Call the police!!!
   8. The thieves (steal) the gold last week.
   9. The Queen (open) the bridge tomorrow.
   10. The bridge (destroy) by the storm last night.
   11. I (learn) Japanese when I was in Tokyo.
   12. I (teach) by an old Japanese man.
   13. This letter (should/type), not handwritten!
   14. The new secretary (type) at 100 wpm.
3. ***Rewrite the sentences in passive voice***.
   1. He opens the door.
   2. We set the table.
   3. She pays a lot of money.
   4. I draw a picture.
   5. They wear blue shoes.
   6. They don't help you.
   7. He doesn't open the book.
   8. You do not write the letter.
   9. Does your mum pick you up?
   10. Does the police officer catch the thief?
4. ***Make the questions***
   1. In Hong Kong/cars/are/made?
   2. Been/to hospital/taken/has/she?
   3. Can/in five minutes/be/the potatoes/roasted?
   4. The students/prepared/be/will/for the exam?
   5. Served/when/tea/be/will?
   6. Is/provided/today/being/lunch?
   7. Last week/laptops/to them/were/given?
   8. Broad/casted/the video/be/may?
   9. Has/closed/been/the road/for repairs?
   10. He/yesterday/was/by the teacher/asked?
   11. The thieves/caught/were?
   12. In the language lab/were/always/written/the tests?
   13. My apology/accepted/will/be?
   14. Found/are/eagles/in Alaska?
   15. In 1889/built/for the World Exhibition/the Eifel Tower /was?
   16. The workers/will/replace/by/computers/be?
   17. Be/cooked/together/beans and carrots/can?
   18. Yesterday/the accident/was/by the police/seen?
   19. Opened/was/the first underground railway/was?
   20. To the school/returned/are/be/going to/the books?
5. ***Make passive sentences from the following information. You will often have to change the word order to make the most natural sentence.***

***For example:*** *BMW\Germany\make: BMW cars are made in Germany.*

* 1. Fiat cars\Italy\make
  2. Spaghetti\boiling water\cook
  3. Children\schools\educate
  4. Football\every country\play
  5. Racehorses\jockeys\ride
  6. Rolls Royce cars\make\Great Britain
  7. We\teach\our teacher
  8. Spaghetti\make\flour
  9. Switzerland\speak\German
  10. Grapes\wine\make

1. ***Put the sentences into passive voice.***

They speak English and French at this hotel.

English and French at this hotel The little boy broke the window last week.

The window by the little boy last week. Our secretary typed this enquiry.

This enquiry by our secretary. Jill uses the computer quite often

The computer by Jill quite often. The secretary defended some colleagues. Some colleagues’ by the secretary. Picasso painted this picture.

This picture by Picasso. Last year they published ten books.

Ten books (by them) last year. Molly has knitted this cardigan.

This cardigan by Molly.

Next year George will visit Marc in London. Next year Marc by George in London. Jim has opened the window.

The window by Jim. Frank has broken many windows. Many windows by Frank Lucy buys many books.

Many books by Lucy. David has written some letters. Some letters by David.

Benjamin Franklin invented the lightning conductor. The lightning conductor by Benjamin Franklin. All students have learned the irregular verbs.

The irregular verbs by all students.

### TEST

**1 Cape Town by millions of people every year.**

* Visited
* is visited
* visits

**My chocolate by Emily and Patrick.**

* was eat
* was ate
* was eaten

1. **A beautiful picture by Bob.**

* was pain
* was painted
* is pain

1. **Kate to work every day by Kevin.**

* is driven
* is drived
* was drove

1. **The rat by Peter.**

* was killed
* killed
* is killing

1. **Two bars of chocolate daily by Caroline.**

* are ate
* is eaten
* are eaten

1. **The kitchen by Sophie.**

* were cleaned
* is cleaned
* cleaned

1. **The fireworks by everyone.**

* was watching
* was watched
* are watched

# IRREGULAR VERBS

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| N | V1 | V2 | V3 | Значення |
| 1.  2.  3.  4.  5.  6.  7.  8.  9.  10.  11.  12.  13.  14.  15.  16.  17.  18.  19.  20.  21.  22.  23.  24.  25.  26.  27.  28.  29.  30.  31.  32.  33.  34.  35.  36.  37.  38.  39.  40.  41.  42.  43.  44.  45.  46.  47.  48.  49.  50.  51.  52.  53.  54.  55.  56.  57.  58.  59.  60.  61.  62.  63.  64.  65.  66.  67.  68.  69.  70.  71.  72.  73.  74.  75.  76.  77.  78.  79.  80.  81.  82.  83.  84.  85.  86.  87.  88.  89.  90.  91.  92.  93.  94.  95.  96.  97.  98.  99.  100. | arise  be  bear  become  begin  bend  bind  bite  bleed  blow  break  breed  bring  build  burn  buy  cast  catch  choose  come  cost  cut  dig  do  draw  dream  drink  drive  eat  fall  feed  feel  fight  find  flee  fly  forget  get  give  go  grow  hang  have  hear  hide  hold  keep  know  lead  learn  leave  lend  let  light  lose  make  mean  meet  put  read  ride  rise  run  say  see  sell  send  set  shake  shine  shoot  shut  sing  sink  sit  sleep  smell  speak  spend  spoil  spread  spring  stand  steal  strike  strive  swear  swim  take  teach  tear  tell  think  throw  understand  wear  weep  win  wind  write | arose  was, were  bore  became  began  bent  bound  bit  bled  blew  broke  bred  brought  built  burnt  bought  cast  caught  chose  came  cost  cut  dug  did  drew  dreamt  drank  drove  ate  fell  fed  felt  fought  found  fled  flew  forgot  got  gave  went  grew  hung  had  heard  hid  held  kept  knew  led  learnt  left  lent  let  lit  lost  made  meant  met  put  read  rode  rose  ran  said  saw  sold  sent  set  shook  shone  shot  shut  sang  sank  sat  slept  smelt  spoke  spent  spoilt  spread  sprang  stood  stole  struck  strove  swore  swam  took  taught  tore  told  thought  threw  understood  wore  wept  won  wound  wrote | arisen  been  born  become  begun  bent  bound  bitten  bled  blown  broken  bred  brought  built  burnt  bought  cast  caught  chosen  come  cost  cut  dug  done  drawn  dreamt  drunk  driven  eaten  fallen  fed  felt  fought  found  fled  flown  forgotten  got  given  gone  grown  hung  had  heard  hidden  held  kept  known  led  learnt  left  lent  let  lit  lost  made  meant  met  put  read  ridden  risen  run  said  seen  sold  sent  set  shaken  shone  shot  shut  sung  sunk  sat  slept  smelt  spoken  spent  spoilt  spread  sprung  stood  stolen  struck  striven  sworn  swum  taken  taught  torn  told  thought  thrown  understood  worn  wept  won  wound  written | виникати, з’являтися  бути  народжувати  ставати  починати  гнути  зв’язувати, пов’язувати  кусатися  кровоточити  дути  ламати(ся)  виховувати  приносити  будувати  горіти, палити  купувати  кидати  ловити, схоплювати  вибирати  приходити  коштувати  різати  рити, копати  робити  тягнути;  малювати мріяти; бачити уві сні  пити  вести, гнати, керувати  їсти  падати  годувати  відчувати  боротися, битися  знаходити  бігти; рятуватися  літати  забувати  отримувати; ставати  давати  йти, ходити  рости, ставати  вішати, висіти  мати  чути  ховати  тримати  тримати, зберігати  знати  вести, керувати, очолювати  вчити (ся)  залишати, покидати  давати в борг  дозволяти  запалювати  втрачати, програвати  робити  означати, значити  зустрічати  класти  читати  їздити верхи  підніматися  бігти  казати, сказати  бачити  продавати  посилати, надсилати  поміщати; встановлювати  трясти  сяяти, блищати  стріляти  закривати  співати  занурюватися  сидіти  спати  нюхати, пахнути  говорити  витрачати  псувати  поширювати  стрибати, витікати  стояти  красти; викрадати, цупити  ударяти  боротися  клястися  плавати  брати  навчати  розривати, рвати  казати, сказати  думати  кидати  розуміти  носити зношуються  плакати  вигравати, перемагати  крутити, заводити (годинник)  писати |

# PART III. GLOSSARY OF GEOLOGICAL TERMS

|  |  |
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| **Aa** | |
| **a horizon** | the uppermost layer of soil composed of a mixtureof humus and leached and weathered minerals. *(syn:* topsoil) |
| **abrasion** | the mechanical wearing and grinding of rock surfaces by friction and impact |
| **absolute age** | age, or time measured in years |
| **accessory mineral** | a mineral that is common, but usually found only in small amounts |
| **accumulation** | a collection of mineral matter and organic remains on the land surface of the water basin floor |
| **acid precipitation** | a condition in which natural precipitation becomes acidic after reacting with air pollutants. Often called acid rain |
| **active continental margin** | often called acid rain a continental margin characterized by subduction of an oceanic lithospheric plate beneath a continental plate, *(syn*: Andean margin) |
| **active volcano** | a volcano that is erupting or is expected to erupt |
| **alluvial fan** | a fan-like accumulation of sediment created where a steep stream slows down rapidly as it reaches a relatively flat valley floor |
| **alluvium** | deposit formed by constant water flows in river valleys |
| **bayon alluvium** | alluvial deposit formed in dired river beds. It is similar to lake deposits in its major characteristics |
| **flood plain alluvium** | river flood plain alluvial deposit, formed during flood |
| **river-bed alluvium** | alluvial deposit, composing islands, sand banks and spits |
| **alpine glacier** | a glacier that forms in mountainous terrain |
| **Andean margin** | a continental margin characterized by subduction of an oceanic lithospheric plate beneath a continental plate, *(syn*: active continental margin) |
| **angle of repose** | the maximum slope or angle at which loose material remains stable |

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| **angular unconformity** | an unconformity in which younger sediment or sedimentary rocks rest on the eroded surface of tilted or folded older rocks |
| **anticline** | a fold in rock that resembles an arch; the fold is convex upward, and the oldest rocks are in the middle |
| **aquifer** | a porous and permeable body of rock that can yield economically significant quantities of ground water |
| **artesian well** | a well drilled into an artesian aquifer in which the water rises without pumping and in some cases spurts to the surface |
| **aseismic ridge** | a submarine mountain chain with little or no earthquake activity |
| **ash (volcanic)** | fine pyroclastic material less than 2 mm in diameter |
| **asthenosphere** | the portion of the upper mantle beneath the lithosphere. It consists of weak, plastic rock and extends from a depth of about 100 kilometers to about 350 kilometers below the surface of the Earth |
| **atmosphere** | a mixture of gases, mostly nitrogen and oxygen, that envelops the Earth |
| **Bb** | |
| **B horizon** | the soil layer just below the A horizon, called the subsoil, where ions leached from the A horizon accumulate |
| **bar** | an elongate mound of sediment, usually composed of sand or gravel, in a stream channel or along a coastline |
| **basalt plateau** | a sequence of horizontal basalt lava flows that were extruded rapidly to cover a large region of the Earth’s surface, *(syn*: flood basalt, lava plateau) |
| **base level** | the deepest level to which a stream can erode its bed. The ultimate base level is usually sea level, but this is seldom attained |
| **basement rocks** | the older granitic and related meta-morphic rocks of the Earth’s crust that make up the foundations of continents |
| **basin** | a circular or elliptical synclinal structure, commonly filled with sediment |

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| **bed** | the floor of a stream channel. Also the thinnest layer in sedimentary rocks, commonly ranging in thickness from a centimeter to a meter or two |
| **bedding** | layering that develops as sediment is deposited |
| **bedrock** | the solid rock that underlies soil |
| **biogeochemical cycle** | the movement of nutrients through the atmosphere, biosphere, hydrosphere, and solid Earth in response to physical, biological, and chemical processes |
| **biomass energy** | electricity or other forms of energy produced by combustion of plant fuels |
| **bioremediation** | use of microorganisms to decompose a ground- water contaminant |
| **biosphere** | the thin zone near the Earth’s surface that is inhabited by life |
| **brittle fracture** | the rupture that occurs when a rock breaks sharply |
| **Cc** | |
| **C horizon** | the lowest soil layer, composed mainly of partly weathered bedrock grading downward into unweathered parent rock |
| **capacity** | the maximum quantity of sediment that a stream can carry |
| **capillary action** | the action by which water is pulled upward through small pores by electrical attraction to the pore walls |
| **carbonate rocks** | rocks such as limestone and dolomite, made up primarily of carbonate minerals |
| **carbonization** | a process in which a fossil forms when the volatile components of the soft tissues are driven off, leaving behind a thin film of carbon |
| **carst** | a process of rocks dissolution and formation of voids of different shape and size in them |
| **cast** | a fossil formed when sedimentary rock or mineral matter fills a natural mold |
| **catastrophism** | a principle that states that catastrophic events have been important in Earth history and modify the path of slow change |

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| **cavern** | an underground cavity or series of chambers created when ground water dissolves large amounts of rock, usually limestone, *(syn:* cave) |
| **cementation** | the process by which clastic sediment is lithified by precipitation of a mineral cement among the grains of the sediment |
| **chert** | a hard, dense, sedimentary rock composed of microcrystalline quartz, *(syn:* flint |
| **clastic sediment** | sediment composed of fragments of weathered rock that have been transported and deposited at the Earth’s surface |
| **clastic sedimentary rocks** | rocks composed of lithified clastic sediment |
| **cleavage** | the tendency of some minerals to break along certain crystallographic planes |
| **cobbles** | rounded rock fragments in the 64- to 256-mm size range, larger than pebbles and smaller than boulders |
| **columnar joints** | the regularly spaced cracks that commonly develop in lava flows, forming five- or six sided columns |
| **compaction** | a process whereby the weight of overlying sediment compresses deeper sediment, decreasing pore space and causing weak lithification |
| **compressive stress** | stress that acts to shorten an object by squeezing it |
| **confining stress** | stress produced when rock or sediment is buried |
| **conglomerate** | a coarse-grained clastic sedimentary rock, composed of rounded fragments larger than 2 mm in diameter, cemented in a fine-grained matrix of sand or silt |
| **constructive plate boundary** | a site where two tectonic plates are moving apart, and each is being added by the formation of new oceanic lithosphere |
| **contact metamorphism** | an ore deposit formed by contact metamorphism |
| **continental drift** | the theory proposed by Alfred Wegener that continents were once joined together and later split and drifted apart. The continental drift theory has been replaced by the more complete plate tectonics theory |

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| **continental shelf** | a shallow, nearly level area of continental crust covered by sediment and sedimentary rocks that is submerged below sea level at the edge of a continent between the shoreline and the continental slope |
| **continental slope** | the relatively steep (3° to 6°) underwater slope between the continental shelf and the continental rise |
| **core** | the innermost region of the Earth, probably consisting of iron and nickel |
| **corrasion** | the process of mechanical erosion of rocks by clastic material transported by wind |
| **country rock** | the older rock intruded by a younger igneous intrusion or mineral deposit |
| **cross-bedding** | an arrangement of small beds lying at an angle to the main sedimentary layering |
| **crust** | the Earth’s outermost layer, about 5 to 80 kilometers thick, composed of relatively low density silicate rocks |
| **crystal** | a solid element or compound whose atoms are arranged in a regular, orderly, periodically repeated array |
| **crystal face** | a planar surface that develop if a crystal grows freely in an uncrowded environment |
| **crystal habit** | the shape in which individual crystals grow and the manner in which crystals grow together in aggregates |
| **crystal settling** | a process in which the crystals that solidify first from a cooling magma settle to the bottom of a magma chamber because the solid minerals are more dense than liquid magma |
| **Curie point** | the temperature below which rocks can retain magnetism |
| **current** | a continuous flow of water in a concerted direction |
| **Dd** | |
| **debris flow** | a type of mass wasting in which particles move as a fluid and more than half of the particles are larger than sand |
| **deflation** | erosion by wind |
| **deformation** | folding, faulting and other changes in shape of rocks or minerals in response to mechanical forces, such as those that occur in tectonically active regions |

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| **delta** | the nearly flat, alluvial, fan-shaped tract of land at the mouth of a stream |
| **diluvium (diluvium)** | genetic type of sediments occurring in the result of accumulation of eroded loose products of weathering by rain and thawing waters |
| **deposition** | the laying-down of sediment by any natural agent |
| **depositional environment** | any setting in which sediment is deposited |
| **desert** | a region with less than 25 cm of rainfall a year. Also defined as a region that supports only a sparse plant cover |
| **desertification** | a process by which semiarid land is converted to desert, often by improper farming or by climate change |
| **diagenesis** | the chemical and physical processes that turn an unconsolidated sediment into a hard sedimentary rock |
| **dike (dyke)** | a sheet-like igneous rock that cuts across the structure of country rock |
| **dike swarm** | a group of dikes that form in parallel or radial sets |
| **dip** | the angle of inclination of bedding, measured from the horizontal |
| **directed stress** | stress that acts most strongly in one direction |
| **displacement (dislocation)** | tectonic disturbance in original occurrence of rock thickness caused by tectonic activity |
| **disseminated ore deposit** | a large low grade ore deposit in which generally fine-grained metal-bearing minerals are widely scattered throughout a rock body in sufficient concentration to make the deposit economical to mine |
| **dissolution** | the process by which soluble rocks and minerals dissolve in water or water solutions |
| **dissolved load** | the portion of a stream’s sediment load that is carried in solution |
| **divergent plate boundary** | the boundary or zone where lithospheric plates separate from each other (syn: spreading center, rift zone) |
| **Ee** | |
| **Earth** | A heavenly body, which belongs to the |

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|  | group of terrestrial planets, the third planet of the Solar System | |
| **earthquake** | a sudden motion or trembling of the Earth caused by the abrupt release of slowly accumulated elastic energy in rocks | |
| **echo sounder** | an instrument that emits sound waves and then records them after they reflect off the sea floor. The data is then used to record the topography of the sea floor | |
| **eluvium** | residual products of weathering emergent coastline | |
| **eon** | the longest unit of geologic time. The most recent, the Phanerozoic Eon, is further subdivided into eras and periods | |
| **epeirogey** | deformation of the Earth’s crust resulting in formation of continents and oceanic basins | |
| **epicenter** | the point on the Earth’s surface directly above the focus of an earthquake | |
| **epidemiology** | the study of the distribution of sickness in a population | |
| **epoch** | the smallest unit of geologic time. Periods are divided into epochs | |
| **era** | a geologic time unit. Eons are divided into eras, and in turn eras are subdivided into periods | |
| **erosion** | the removal of weathered rocks and minerals by moving water, wind, ice, and gravity | |
| **evaporite deposit** | a chemically precipitated sedimentary rock that formed when dissolved ions were concentrated by evaporation of water | |
| **exfoliation** | weathering in which concentric plates or shells split from the main rock mass like the layers of an onion | |
| **extensional stress** | tectonic stress in which rocks are pulled apart | |
| **external mold** | a fossil cavity created in sediment by a shell or other hard body part that bears the impression off the exterior of the original | |
| **extrusive rock** | an igneous rock formed from material that has erupted onto the surface of the Earth | |
| **Ff** | | |
| **facies** | a rock or rock complex formed in similar environment and having similar | |
|  | characteristics(composition, texture, fauna, set, etc.) | |
| **fan** | fan-shaped accumulation of sediment in the result of its transportation by various geological processes (alluvial, deluvial, avalanche sedimentation | |
| **fault** | a fracture in rock along which one rock has moved relative to rock on the other side | |
| **fault creep** | a continuous, slow movement of solid rock along a fault, resulting from a constant stress acting over a long time | |
| **fault zone** | an area of numerous closely spaced faults | |
| **faunal succession** | (See principle offaunal succession.) | |
| **fissility** | fine layering along which a rock splits easily | |
| **fission (nuclear)** | the spontaneous or induced splitting by particle collision of a heavy nucleus into a pair of nearly equal fission fragments plus some neutrons. Fission releases large amounts of energy (see fusion) | |
| **fjord** | a long, deep, narrow arm of the sea bounded by steep walls, generally formed by submergence of a glacially eroded valley. (Also spelled fiord.) | |
| **flood** | a period characterized by the greatest amount of water in rivers due to snow melting and hard rains | |
| **flow** | mass wasting in which individual particles move downslope as a semi-fluid, not as a consolidated mass | |
| **fold** | a bend in rock | |
| **foliation** | layering in rock created by metamorphism | |
| **footwall** | the rock beneath an inclined fault | |
| **formation** | a lithologically distinct body of sedimentary, igneous, or metamorphic rock that can be recognized in the field and can be mapped | |
| **fossil** | any preserved trace, imprint, or remains of a plant or animal | |
| **fossil fuel** | fuels formed from the partially decayed remains of plants and animals. The most commonly used fossil fuels are petroleum, coal, and natural gas | |
| **fractional crystallization** | crystallization from a magma in which early formed crystals are prevented from reacting with the magma, resulting in the evolution of a final magma that is enriched in silica and other components of granite | |
| **fracture** | (a) The manner in which minerals break other than along planes of cleavage, (b) A crack, joint, or fault in bedrock | |
| **frost wedging** | a process in which water freezes in a crack in rock and the expansion wedges the rock apart | |
| **fuel rod** | a 2-meter-long column of fuel-grade uranium pellets used to fuel a nuclear reactor | |
| **fusion** | the combination of two light nuclei to form a heavier nucleus. Fusion releases large amounts of energy. (See fission.) | |
| **Gg** | | |
| **gabbro** | igneous rock that is mineralogically identical to basalt but that has a medium- to coarse-grained texture because of its plutonic origin | |
| **gem** | a mineral that is prized primarily for its beauty. Any precious or semiprecious stone, especially when cut or polished for ornamental use | |
| **geochronologic scale** | a scale of relative geologic time which shows the sequence of basic stages of geologic history of the earth and evolution of life. It is divided into eon, eras, periods, epochs | |
| **geologic column** | a composite columnar diagram that shows the sequence of rocks at a given place or region arranged to show their position in the geologic time scale | |
| **geologic structure** | any feature formed by rock deformation, such as a fold or a fault. Also, the combination of all such features of an area or region | |
| **geologic time** | the period from the moment of the Earth’s crust formation (about 4,5 billion years ago up to the present day) | |
| **geologic time scale** | a chronological arrangement of geologic time subdivided into units | |
| **geology** | the study of the Earth, including the materials that it is made of, the physical and chemical changes that occur on its surface and in its interior, and the history of the planet and its life forms | |
| **geosphere** | more or less concentric layers enveloping the Earth, which alter with depth in vertical section of the planet. They have different chemical, physical and biological properties | |
| **outer geospheres** | atmosphere, hydrosphere | |
| **inner geospheres** | the Earth’s crust and mantle. Synonym: the Earth’s envelopes | |
| **glacier** | a massive, long-lasting accumulation of compacted snow and ice that forms on land and moves downslope or outward under its own weight | |
| **gneiss** | a foliated rock with banded appearance formed by regional metamorphism | |
| **graben** | a wedge-shaped block of rock that has dropped downward between two normal faults | |
| **grabed bedding** | a type of bedding in which larger particles are at the bottom of each bed, and the particle size decreases towards the top | |
| **gradient** | the vertical drop of a stream over a specific distance | |
| **granitic layer** | the layer which lies in the Earth’s crust of continental type below sedimentary layer composed of rocks similar to granites. It’s thickness ranges from 10 km beneath continental plains to 40 km beneath mountain ranges | |
| **ground water** | water contained in soil and bedrock. All subsurface water | |
| **Hh** | | |
| **Hadean Eon** | the earliest time in the Earth ’s history, from about 4.6 billion years ago to 3.8 billion years ago | |
| **half life** | the time it takes for half of the nuclei of a radioactive isotope in a sample to decompose | |
| **hanging valley** | a tributary glacial valley whose mouth lies high above the floor of the main valley | |
| **hanging wall** | the rock above an inclined fault | |
| **hardness** | the resistance of the surface of a mineral to | |
|  | scratching | |
| **headward erosion** | the lengthening of a valley in an upstream direction | |
| **horn** | a sharp, pyramid-shaped rock summit formed by glacial erosion of three or more cirques into a mountain peak | |
| **hornfels** | a splintery, spotty rock produced by contact metamorphism | |
| **horst** | a block of rock that has moved relatively upward and is bounded by two faults | |
| **hydrothermal metamorphism** | changes in rock that are primarily caused by migrating hot water and by ions dissolved in the hot water, *(syn*: hydrothermal alteration) | |
| **hydrothermal vein** | a sheet-like mineral deposit that fills a fault or other fracture, precipitated from hot water solutions | |
| **Ii** | | |
| **ice age** | a time of extensive glacial activity, when alpine glaciers descended into lowland valleys and continental glaciers spread over the higher latitudes | |
| **ice sheet** | a glacier that forms a continuous cover of ice over areas of 50,000 square kilometers or more and spreads outward under the influence of its own weight, *(syn:* continental glacier) | |
| **igneous rock** | rock that solidified from magma | |
| **index fossil** | a fossil that dates the layers in which it is found. Index fossils are abundantly preserved in rocks, widespread geographically, and existed as a species or genus for only a relatively short time | |
| **industrial mineral** | any rock or mineral of economic value exclusive of metal ores, fuels, and gems | |
| **intermediate rocks** | igneous rocks with chemical and mineral compositions between those of granite and basalt | |
| **internal mold** | a fossil that forms when the inside of a shell fills with sediment or precipitated minerals | |
| **internal processes** | Earth processes and movements that are initiated within the Earth – for example, formation of magma, earthquakes, mountain building, and tectonic plate movement | |
| **internal zone** | the part of a beach that lies between the high and low tide lines | |
| **intracratonic basin** | a sedimentary basin located within a craton | |
| **intrusion** | a term used to denote various in shape and composition igneous rocks, formed at considerable depth in conditions of abyssal facies | |
| **intrusive rock** | a rock formed when magma solidifies within bodies of preexisting rock | |
| **isotopic method** | a method based on time calculation of radioactive elements contained in rocks. At present U- Pb, Rb-Sr, K-Ar, C13-C14 methods are videly used | |
| **Jj** | | |
| **joint** | a fracture that occurs without movement of rock on either side of the break | |
| Kk | | |
| **kame** | a small mound or ridge of layered sediment deposited by a stream at the margin of a melting glacier or in a low place on the surface of a glacier | |
| **rarst topography** | a type of topography formed over limestone or other soluble rock and characterized by caverns, sinkholes, and underground drainage | |
| **key bed** | a thin, widespread, easily recognized sedimentary layer that can be used for correlation | |
| **Ll** | | |
| **L wave** | an earthquake wave that travels along the surface of the Earth, or along a boundary between layers within the Earth, *(syn*: surface wave) | |
| **landslide** | a general term for the downslope movement of rock and regolith under the influence of gravity | |
| **laterite** | a highly weathered soil rich in oxides of iron and aluminum that usually develops in warm, moist tropical or temperate regions | |
| **layer thickness** | the shortest perpendicular distance between a roof and a foot of a layer | |
| **layering** | internal texture (structure) of a layer, | |
|  | reflected in alternation of thin layers (from a fraction of mm to a few cm) | |
| **lava** | fluid magma that flows onto the Earth ’s surface from a volcano or fissure. Also, the rock formed by solidification of the same material | |
| **lava plateau** | a sequence of horizontal basalt lava flows that were extruded rapidly to cover a large region of the Earth’s surface, *(syn*: flood basalt, basalt plateau) | |
| **leaching** | the dissolution and downward movement of soluble components of rock and soil by percolating water | |
| **limb** | the side of a fold in rock | |
| **lithification** | the conversion of loose sediment to solid rock | |
| **lithosphere** | the cool, rigid, outer layer of the Earth, about100 kilometers thick, which includes the crust and part of the upper mantle | |
| **loam** | Soil that contains a mixture of sand, clay, and silt and a generous amount of organic matter | |
| **loess** | a homogenous, unlayered deposit of windblown silt, usually of glacial origin | |
| **luster** | the quality and intensity of light reflected from the surface of a mineral | |
| **Mm** | | |
| **mafic rock** | dark-colored igneous rock with high magnesium and iron content, and composed chiefly of iron and magnesium-rich minerals | |
| **magma** | molten rock generated within the Earth | |
| **magmatic arc** | a narrow, elongate band of intrusive and volcanic activity associated with subduction | |
| **magmatic reversal** | a change in the Earth’s magnetic field in which the north magnetic pole becomes the south magnetic pole, and vice versa | |
| **magnetometer** | an instrument that measures the Earth’s magnetic field | |
| **manganese nodule** | a manganese-rich, potato-shaped rock found on the ocean floor | |
| **mantle** | a mostly solid layer of the Earth lying beneath the crust and above the core. The | |
|  | mantle extends from the base of the crust to a depth of about 2900 kilometers | |
| **mantle convection** | the convective flow of solid rock in the mantle | |
| **mantle plume** | a rising vertical column of mantle rock | |
| **mass wasting** | the movement of earth material down-slope primarily under the influence of gravity | |
| **meander** | one of a series of sinuous curves or loops in the course of a stream | |
| **mesa** | a flat-topped mountain or a tableland that is smaller than a plateau and larger than a butte | |
| **metamorphic facies** | a set of all metamorphic rock types that formed under similar temperature and pressure conditions | |
| **metamorphic grade** | the intensity of metamorphism that formed a  rock; the maximum temperature and pressure attained during metamorphism | |
| **metamorphic rock** | a rock formed when igneous, sedimentary, or other metamorphic rocks recrystallize in response to elevated temperature, increased pressure, chemical change, and/or deformation | |
| **metamorphism** | the process by which rocks and minerals change in response to changes in temperature, pressure, chemical conditions, and/or deformation | |
| **metasomatism** | metamorphism accompanied by the introduction of ions from an external source | |
| **migmatite** | a rock composed of both igneous and metamorphic-looking materials. It forms at very high metamorphic grades when rock begins to partially melt to form magma | |
| **mineral** | a naturally occurring inorganic solid with a characteristic chemical composition and a crystalline structure | |
| **mineral deposit** | a local enrichment of one or more minerals | |
| **mineral reserve** | the known supply of ore in the ground | |
| **mineralization** | a process of fossilization in which the organic components of an organism are replaced by minerals | |
| **mobilism** | a collective term used to denote a group of tectonic hypotheses about horizontal movement of the Earth’s crust | |
| **moment magnetude scale** | a scale used to measure and express the energy released during an earthquake | |
| **monocline** | a fold with only one limb | |
| **mountain chain** | a number of mountain ranges grouped together in an elongate zone | |
| **mountain range** | a series of mountains or mountain ridges that are closely related in position, direction, age, and mode of formation | |
| **mud cracks** | irregular, usually polygonal fractures that develop when mud dries. The patterns may be preserved when the mud is lithified | |
| **Nn** | | |
| **Nappe** | tectonic cover, thrust with great amplitude | |
| **nonconformity** | a type of unconformity in which layered sedimentary rocks lie on igneous or metamorphic rocks | |
| **nonfoliated** | the lack of layering in metamorphic rock | |
| **nonrenewable resource** | a resource in which formation of new deposits occurs much more slowly than consumption | |
| **normal fault** | a fault in which the hanging wall has moved downward relative to the footwall | |
| **Oo** | | |
| **O horizon** | the uppermost soil layer, consisting mostly of litter and humus with a small proportion of minerals | |
| **obsidation** | a black or dark-colored glassy volcanic rock, usually of rhyolitic composition | |
| **occurence** | spatial location of geologic bodies in the Earth’s crust composed of rocks and position in respect to country rocks and bed rocks | |
| **oceanic bed** | the greatest fragment of the Earth’s relief occupying a large part of ocean floor which is characterized by oceanic type of the Earth’s crust | |
| **oceanic crust** | the 7- to 10-kilometer-thick layer of sediment and basalt that underlies the ocean basins | |
| **oil shale** | a kerogen-bearing sedimentary rock that yields liquid or gaseous hydrocarbons when heated | |
| **oil trap** | any rock barrier that accumulates oil or gas by preventing its upward movement | |
| **ore** | a natural material that is sufficiently enriched in one or more minerals to be mined profitably | |
| **original horizontality (principle of)** | (See principle of original horizontality.) | |
| **orogenesis** | intensive short-duration irreversible tectonic movement of geosyncline zone, resulting in folding and considerable changes in tectonic compositions | |
| **orogeny** | the process of mountain building; all tectonic processes associated with mountain building | |
| **orographic lifting** | lifting of air that occurs when air flows over a mountain | |
| **oxidation** | the loss of electrons from a compound or element during a chemical reaction. In the weathering of common minerals, oxidation usually occurs when a mineral reacts with molecular oxygen | |
| **Pp** | | |
| **P wave** | (Also called a compressional wave.) A seismic wave that causes alternate compression and expansion of rock | |
| **paleoclimatology** | the study of ancient climates | |
| **paleomagnetism** | the study of natural remnant magnetism in rocks and of the history of the Earth’s magnetic field | |
| **paleontology** | the study of life that existed in the past | |
| **parent rock** | any original rock before it is changed by metamorphism or other geological processes | |
| **partial melting** | the process in which a silicate rock only partly melts as it heated, to form magma a that is more silica-rich than the original rock | |
| **pebble** | a sedimentary particle between 2 and 64 millimeters in diameter, larger than sand and smaller than a cobble | |
| **pedalfer** | a soil type that forms in humid environments, characterized by abundant iron and aluminum | |
| **permineralization** | fossilization that occurs when mineral matter is deposited in cavities or pores | |
| **phenocryst** | a large, early-formed crystal in a finer matrix in igneous rock | |
| **pillow lava** | lava that solidified under water, forming spheroidal lumps like a stack of pillows | |
| **pipe** | a vertical conduit below a volcano, through which magmatic materials passed. It is usually filled with solidified magma and/or brecciated rock | |
| **placer deposit** | a surface mineral deposit formed by the mechanical concentration of mineral particles (usually by water) from weathered debris | |
| **plastic deformation** | a type of deformation in which the material changes shape permanently without fracture | |
| **plate** | a relatively rigid independent segment of the lithosphere that can move independently of other plates | |
| **plate boundary** | a boundary between two lithospheric plates | |
| **plate tectonics theory** | a theory of global tectonics in which the lithosphere is segmented into several plates that move about relative to one another by floating on and gliding over the plastic asthenosphere. Seismic and tectonic activity occur mainly at the plate boundaries | |
| **plateau** | a large elevated area of comparatively flat land | |
| **platform** | the part of a continent covered by a thin layer of nearly horizontal sedimentary rocks overlying older igneous and metamorphic rocks of the craton | |
| **plunging fold** | a fold with a dipping or plunging axis | |
| **pluton** | an igneous intrusion | |
| **plutonic rock** | an igneous rock that forms deep (a kilometer or more) beneath the Earth’s surface | |
| **polymorph** | a mineral that crystallizes with more than one crystal structure | |
| **porosity** | the proportion of the volume of a material that consists of open spaces | |
| **porphyry copper deposit** | a large body of porphyritic igneous rock that contains disseminated copper sul-fide minerals usually mined by surface mining methods | |
| **pyroclastic rock** | any rock made up of material ejected explosively from a volcanic vent | |
| **Qq** | | |
| **quartz sandstone** | sandstone containing more than 90 percent quartz | |
| **Rr** | | |
| **radial drainage pattern** | a drainage pattern formed when a number of streams originate on a mountain and flow outward like the spokes on a wheel | |
| **radiometric age dating** | the process of measuring the absolute age of geologic material by measuring the concentrations of radioactive isotopes and their decay products | |
| **radon** | a radioactive gas formed by radioactive decay of uranium that commonly accumulates in some igneous and sedimentary rocks | |
| **regional burial metamorphism** | metamorphism of a broad area of the Earth’s crust caused by elevated temperatures and pressures resulting from simple burial | |
| **regional dynamothermal metamorphism** | metamorphism accompanied by deformation affecting an extensive region of the Earth’s crust | |
| **regional metamorphism** | metamorphism that is broadly regional in extent, involving very large areas and volumes of rock. Includes both regional dynamothermal and regional burial metamorphism | |
| **regolith** | the loose, unconsolidated, weathered material that overlies bedrock | |
| **relative age** | age expressed as the order in which rocks | |
|  | formed and geological events occurred, but not measured in years | |
| **relief** | the vertical distance between a high and a low point on the Earth’s surface | |
| **remediation (of a contaminated aquifer)** | the treatment of a contaminated aquifer to remove or decompose a pollutant | |
| **remote sensing** | the collection of information about an object by instruments that are not in direct contact with it | |
| **replacement** | fossilization in which the original organic material is replaced by new minerals | |
| **reserves** | known geological deposits that can be extracted profitably under current conditions | |
| **reservoir rock** | porous and permeable rock in which liquid petroleum or gas accumulates | |
| **reverse fault** | a fault in which the hanging wall has moved up relative to the footwall | |
| **reversed polarity** | magnetic orientations in rock which are opposite to the present orientation of the Earth ’s field. Also, the condition in which the Earth’s magnetic field is opposite to its present orientation | |
| **Richter scale** | a numerical scale of earthquake magnitude measured by the amplitude of the largest wave on a standardized seismograph | |
| **rift** | a zone of separation of tectonic plates at a divergent plate boundary | |
| **rift zone** | the boundary or zone where lithospheric plates rift or separate from each other, *(syn*: divergent plate boundary, spreading center) | |
| **ring of fire** | the belt of subduction zones and major tectonic activity including extensive volcanism that borders the Pacific Ocean along the continental margins of Asia and the Americas | |
| **rock** | a naturally formed solid that is an aggregate of one or more different minerals | |
| **rock cycle** | the sequence of events in which rocks are formed, destroyed, altered, and reformed by geological processes | |
| **Ss** | | |
| **salinization** | a process whereby salts accumulate in soil when water, especially irrigation water, evaporates from the soil | |
| **salt cracking** | a weathering process in which salty water migrates into the pores in rock. When the water evaporates, the salts crystallize, pushing grains apart | |
| **saltation** | sediment transport in which particles bounce and hop along the surface | |
| **saturated zone** | the region below the water table where all the pores in rock or regolith are filled with water | |
| **scarp** | a line of cliffs created by faulting or by erosion | |
| **schist** | a strongly foliated metamorphic rock that has a well developed parallelism of minerals such as micas | |
| **sea arch** | an opening created when a cave is eroded all the way through a narrow headland | |
| **sea stack** | a pillar of rock left when a sea arch collapses or when the inshore portion of a headland erodes faster than the tip | |
| **sea floor spreading** | the hypothesis that segments of oceanic crust are separating at the mid-oceanic ridge | |
| **secondary recovery** | production of oil or gas as a result of artificially augmenting the reservoir energy by injection of water or other fluids. Secondary recovery methods are usually applied after substantial depletion of the reservoir | |
| **sediment** | solid rock or mineral fragments transported and deposited by wind, water, gravity, or ice, precipitated by chemical reactions, or secreted by organisms, and that accumulate as layers in loose, unconsolidated form | |
| **sedimentary level** | the upper layer of the Earth’s crust composed of sedimentary rocks. Its thickness varies from0 to a few kilometers | |
| **sedimentary rock** | a rock formed when sediment is lithified | |
| **sedimentary structure** | any structure formed in sedimentary rock during deposition or by later sedimentary processes; for example, bedding | |
| **seismic method** | a method based on investigation of velocity of seismic waves propagation in the Earth’s interior in the result of earthquakes and explosions | |
| **seismic tomography** | a technique whereby seismic data from many earthquakes and recording stations are analyzed to provide a three-dimensional view of the Earth’s interior | |
| **seismic wave** | all elastic waves that travel through rock, produced by an earthquake or explosion | |
| **serpentinite** | a usually chrysotile and antigorite, commonly derived from alteration of peridotite or sea floor basalt | |
| **shear stress** | stress that acts in parallel but opposite directions | |
| **shield** | a large region of exposed basement rocks that are commonly of Precambrian age | |
| **shield volcano** | a large, gently sloping volcanic mountain formed by successive flows of basaltic magma | |
| **sialic rock** | a rock such as granite and rhyolite that contains large proportions of silicon and aluminum | |
| **sill** | a tabular or sheetlike igneous intrusion that lies parallel to the grain or layering of country rock | |
| **sinkhole** | a circular depression in karst topography caused by the collapse of a cavern roof or by dissolution of surface rocks | |
| **slaty cleavage** | metamorphic foliation aligned in a plane perpendicular to the direction of maximum tectonic compressive stress | |
| **slide** | any type of mass wasting in which the rock or regolith initially moves as coherent blocks over a fracture surface | |
| **slip** | the distance that rocks on opposite sides of a fault have moved | |
| **slip face** | the steep lee side of a dune that is at the angle of repose for loose sand so that the sand slides or slips | |
| **slump** | a type of mass wasting in which the rock and regolith move as a consolidated unit with a backward rotation along a concave fracture | |
| **smectite** | a type of clay mineral that contains the abundant elements weathered from feldspar and silicate rocks | |
| **soil horizon** | a layer of soil that is distinguishable from other horizons because of differences in appearance and in physical and chemical properties | |
| **solar wind** | a stream of ions and electrons shot into space by violent storms occurring in the outer regions of the Sun’s atmosphere | |
| **solifluction** | the slow mass wasting of water-saturated soil that commonly occurs over permafrost | |
| **sorting** | a process in which flowing water or wind separates sediment according to particle size, hape, or density | |
| **source rock** | the geologic formation in which oil or gas originates | |
| **specific gravity** | the weight of a substance relative to the weight of an equal volume of water | |
| **speleothems** | any mineral deposit formed in caves by the action of water | |
| **spit** | a long ridge of sand or gravel extending from shore into a body of water | |
| **stalactite** | an icicle-like dripstone deposited from drops of water that hang from the ceiling of a cavern | |
| **stalagmite** | a deposit of mineral matter that forms on the floor of a cavern by the action of dripping water | |
| **stock** | an igneous intrusion with an exposed surface area of less than 100 square kilometers | |
| **strain** | the deformation (change in size or shape) that results from stress | |
| **stratification** | the arrangement of sedimentary rocks in strata or beds | |
| **stratified drift** | sediment that was transported by a glacier and then transported, sorted, and deposited by glacial meltwater | |
| **stratigraphic scale** | a scale which reflects substantial rock com plexes. It is divided into groups, systems, divisions | |
| **stratigraphic method** | a method based on the study of position of rock layers in the earth’s crust | |
| **streak** | the color of a fine powder of a mineral usually obtained by rubbing the mineral on an unglazed porcelain streak plate | |
| **striations** | parallel scratches in bedrock caused by rocks embedded in the base of a flowing glacier | |
| **strike** | the compass direction of the line produced by the intersection of a tilted rock or structure with a horizontal plane | |
| **strike-slip fault** | a fault on which the motion is parallel with its strike and is primarily horizontal | |
| **subsidence** | settling of the Earth’s surface which can occur as either petroleum or ground water is removed by natural processes | |
| **supergene (ore)** | an ore deposit that has been enriched by weathering processes that leach metals from a metal deposit, carry them downward, and re-precipi tate them to form more highly concentrated ore | |
| **surface mine** | a hole excavated into the Earth ’s surface for the purpose of recovering mineral or fuel resources | |
| **surface processes** | all processes that sculpt the Earth’s surface, such as erosion, transport, and deposition | |
| **syncline** | a fold that arches downward and whose center contains the youngest rocks | |
| **Tt** | | |
| **tactile** | a rock formed by contact metamorphism of carbonate rocks. It is typically coarse- grained and rich in garnet | |
| **talus slope** | an accumulation of loose angular rocks at the base of a cliff that has fallen mainly as a result of frost wedging | |
| **tectonics** | a branch of geology dealing with the broad architecture of the outer part of the Earth; specifically the relationships, origins, and histories of major structural and deformational feature | |
| **terrigenous sediment** | sea-floor sediment derived directly from land | |
| **tertiary recovery** | production of oil or gas by artificially augmenting the reservoir energy, as by | |
|  | injection of steam or detergents. Tertiary recovery methods are usually applied after secondary recovery methods have been used | |
| **thermoremanent magnetism** | the permanent magnetism of rocks and minerals that results from cooling through the Curie point | |
| **thrust** | a low-angle fault which has pushed older rocks over younger rocks | |
| **thrust fault** | a type of reverse fault with a dip of 45° or less over most of its extent | |
| **trace fossil** | a sedimentary structure consisting of tracks, burrows, or other marks made by an organism | |
| **Uu** | | |
| **ultrabasic** | term describing rock that has even less silica than a basalt, such as peridotite | |
| **ultramaflc rock** | rock composed mostly of minerals containing iron and magnesium for example, peridotite | |
| **unconformity** | a gap in the geological record, such as an interruption of deposition of sediments, or a break between eroded igneous and overlying sedimentary strata, usually of long duration | |
| **underground mine** | a mine consisting of subterranean passages that commonly follow ore veins or coal seams | |
| **uniformitarianism** | the principle that states that geological change occurs over long periods of time, by a sequence of almost imperceptible events. In addition, processes and scientific laws operating today also operated in the past and thus past geologic events can be explained by forces observable today | |
| **upper mantle** | the part of the mantle that extends from the base of the crust downward to about 670 kilometers beneath the surface | |
| **Vv** | | |
| **vein** | a fracture that has become filled by minerals precipitated from solution, commonly quartz or calcite, and sometimes including are minerals. Coarse veins described as pegmatite may crystallize from the last fraction of melt remaining as an igneous intrusion cools down | |
| **vent** | a volcanic opening through which lava and rock fragments erupt |
| **viscosity** | the property of a substance that offers internal resistance to flow |
| **volcanic rock** | a rock that formed when magma erupted, cooled, and solidified within a kilometer or less of the Earth’s surface |
| **volcano** | a hill or mountain formed from lava and rock fragments ejected through a volcanic vent |
| **Ww** | |
| **weathering** | the decomposition and disintegration of rocks and minerals at the Earth’s surface by mechanical and chemical processes |
| **chemical weathering** | the chemical decomposition of rocks and minerals by exposure to air, water and other chemicals in the environment |
| **crustal weathering** | a complex of rocks occurring in the upper part of the lithosphere due to the transformation of igneous, metamorphic and sedimentary rocks under the influence of various agents of weathering |
| **differential weathering** | the process by which certain rocks weather more rapidly than adjacent rocks, usually resulting in an uneven surface |
| **frost weathering** | the desintegration of rocks under the influence of frozen water in rock cracks |
| **mechanical weathering** | the disintegration of rock into smaller pieces by physical processes |
| **organic weathering** | weathering caused by plants and animals effect on the litosphere. It leads to physical and chemical decomposition of rocks under the influence of living organisms |
| **spheroidal weathering** | weathering in which the edges and corners of a rock weather more rapidly than the flat faces, giving rise to a round shape |
| **thermal weathering** | the disintegration of rocks under the influence of frozen water in rock cracks |
| **welded tuff** | a hard, tough glass-rich pyroclastic rock formed by cooling of an ash flow that was hot enough to deform plastically and partly melt after it stopped moving; it often appears layered or streaky |
| **wetlands** | known as swamps, bogs, marshes, sloughs, mud flats, and flood plains, wetlands develop where the water table intersects the land surface. Some are water soaked or flooded throughout the entire year; others are dry for much of the year and wet only during times of high water. Still others are wet only during exceptionally wet years and may be dry for several years at a time |

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