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A New Age for Distance Learning

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Introduction to Geology & Minerals

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Contents

Introduction

Ever since humans were found on the planet Earth, they began to think about the origin and age of this planet. Some scientists used religious beliefs to estimate the age of the universe and planet Earth; James Ussher estimated the creation of Earth from Bible teachings as 4004 years B.C (Pierce, 2006). The Mankind began to think about the movement of the planets and their relationship with each other and with the sun, he thought about the birth and death of planets. Ptolemy postulated about AD 150 the geocentric model of universe, in which Earth was the center of the universe and the sun and the rest of the planets rotate around it in circular orbits (Jones, 2008). Copernicus proposed in the 16^{th} century the solar system based on Sun as the center of the universe and all other planets revolve around it in circular orbits (Britannica, 2017).

Johannes Kepler modified Copernicus's heliocentric theory and postulated the well-known Kepler's three laws; the first law states that Earth and other planets rotate around the Sun in an elliptical orbit and the Sun lies in the focus of the orbit. The second law states that the imaginary line between the planet and the Sun, sweeps equal areas at the same time intervals. The third law describes the relationship between the distance of planets in the solar system from the Sun and the rotating period of the planet around the Sun (Britannica, 2018). Isaac Newton in the 17^{th} century, described the gravitational power between planets in space in his law of general gravitation, which states that the gravitational force between two planets in the solar system is directly proportional to their masses and inversely proportional to the square distance between them, or $F= G\ m_1*m_2/\ R^{\wedge 2}$ (F the force in Newton, G the gravitational constant ($G= 6.674\times10^{-11}\ m^3\cdot kg^{-1}\cdot s^{-2}$), m_1 & m_2 the masses of planets in kg, R the distance between planets in meters), (Britannica, 2016).

Pioneer scientists like Galileo, used primitive instrumentation such as binoculars and balloons, to probe the distant early scientists. With sophisticated instrumentation, such as giant telescopes, spacecraft, and remote sensors, scientists are capable to see and investigate far galaxies and observe changes in planets.

In the late 1700s, James Hutton, who was considered as the father of geology, had established the basis of modern Earth geology, when he proposed that the processes that are at work today, were at work in the past, which is summarized as" The present is the key to the past" (Rosenberg, 2018).

Geology is the study of Earth which is considered as the most applicable branch of science, it is drawing attention by most scholars. The aim of geological science it to help human beings to explore the treasures of natural resources, that would help humans to make use of these resources in the proper way without making damage and adverse effects to the environment. The geological science had branched into many specialized subjects which increased the benefits and to created research topics in many areas, for example:

- Hydrogeology, which concerns about water resources existence and exploitation.
- Stratigraphy, which concerns about different rock layers and tectonic plates and their movements.
- Paleontology, which concerns about fossils found inside sedimentary rocks, their types and ages.
- Petroleum geology, which concerns about oil and gas resources and their exploitation

- Mineralogy, which concerns about different types of minerals, their chemical and physical properties, their mining and uses.
- Seismology, which concerns about earthquakes, their start points and their effect on tectonic layers. Also, it concerns about volcanoes and their eruption places and the study of lava and magma.
- Petrology, which concerns about types of rocks like igneous, sedimentary and metamorphic rocks, their formation and the rock cycle.
- Crystallography, which concerns about shapes and structure of different types of crystals. The crystalline materials and their properties.

In this course "Introduction to Geology and Minerals"; answers to questions from seven lectures are introduced; the lectures are about the origin of the universe and solar system, theories of continental drift and plate tectonics, the formation of minerals, minerals' classification and identification.

Lecture 1

1. How did Hubble's discovery that the nebulae were actually distant galaxies change our view of the universe?

   Answer:

   Since the fifteenth century, from the time of Copernicus, Galileo and Kepler, the Milky Way was thought to be the only universe and the nebula through which he saw was the Andromeda galaxy. Until 1923, when Edward Hubble who was an astronomer at the Mount

Wilson Observatory, was able to follow through the Hooker telescope at the Observatory, to prove that the nebula that was seen in the Milky Way is only distant galaxies. Hubble used the help of Henrietta Leavitt's discoveries, whom she discovered that some of the stars called Cepheids, had an intermittent flash, and because of the time lag between the flash and its disappearance, she was able to calculate the distance of theses Cepheids (Resnick, 2016). Hubble benefited from Leavitt's formula in proving that there were other galaxies other than Milky Way. This is what changed our view of the universe.

2- When you view a distant star, how can it be possible that the star does not actually exist?

Answer:

Stars are like humans, a dynamic system, they are like fire, and fire need fuel to burn, and the fuel, at last, is depleted. Stars use hydrogen as fuel and the hydrogen atoms are converted to helium atoms and they release a big amount of energy. The core of the star undergoes gravitational collapse and begins to heat up (Renton, 2006).

The mass of the planet is measured in Solar Mass (SM) units, our Sun is 1 SM. Stars with less than 1SM are called flyweight stars and those between 4 SM-8 SM are medium weight stars, and above 8 SM are heavyweight stars. The life expectancy of a star is the inverse of its mass, so the larger the star means the shorter its life.

What we actually see, is the light of the star, which had exploded in a previous time, but because it is very far away, it takes time for the light to reach us, we may see light of stars that have been dead since hundreds of years. For example, Sirius is 8.6 light years away from earth, which means that when seeing the shine of Sirius, we actually see it before 8.6 years (Powell, 2018).

Lecture 2

1. What role did stars play in the formation of Earth?

   Answer:

   Stars, like our sun, are composed of hydrogen and helium, the core of stars is like a big nuclear reactor in which nuclear fusion of four hydrogen atoms produce one helium atom. At any unexpected time, the fuel of the reactor ends and the star dies.

   4.6 billion years ago, a very big star explosion occurred and all of its particles spread in the space as dust, this supernova dust began to spin in a spiral way, which forms a gravitational force that causes the heavy dust particles to collapse and the sun is formed. The gravity action continued to clump other particles forming other large bodies which they became the solar planets including earth. The heavier dust particles are attracted by gravity forces and formed the terrestrial planets, which are Mercury, Venus, Earth, and Mars, are formed from rocks. The lighter dust particles formed the Jovian planets which are gaseous planets and they are Jupiter, Saturn, Uranus, and Neptune (Renton, 2006).

2. What is the significance of the larger dimensions of the Jovian planets relative to the terrestrial planets?

   Answer:

   The Jovian Planets in the solar system, like Jupiter, Saturn, Uranus and Neptune are composed of iced gases. They don't have a solid surface, the solid material is found in the core of Jupiter only. They differ in many things compared with terrestrial planets, Mercury, Venus, Earth, and Mars. They differ in mass, volume, chemical composition and in the speed of rotation around themselves; for example, Jupiter rotation period is 18 hours compared to Earth 24 hours (Harington, 2018). They have a larger mass and a larger diameter which makes their life expectancy very short compared with terrestrial planets. As the life expectancy is the inverse of their Solar Mass(SM).

Lecture 3

1. What were the basic problems faced by the early proponents of continental drift in attempting to convince early earth scientists that it existed?

   Answer:

   It was believed that all landmasses were one piece surrounded by the ocean, it was like one island in the big ocean. Until the 20th century, when cartographers prepared to draw world maps, they found similarities in the Atlantic margins of South America and Africa. These observations drew the attention of scientists and observers. Edward Sues proposed that all continents in the southern hemisphere, were one giant continent which he named Gondwana (Renton, 2006). About 180 million years, Gondwana split into today's known continents, Africa, Latin America, Australia, New Zealand, Madagascar, India subcontinent and Arabia Peninsula. In the Northern hemisphere, another giant continent named Laurasia. Both Gondwana and Laurasia formed the supercontinent Pangaea (Papas, 2013). Alfred Wegener, a German researcher, geophysicist, and meteorologist, was one of those scientists, who proposed the theory of continental drift in 1912. His theory opposed the existing theories of geology, such as the theory of geosyncline, which was used to explain the formation of sedimentary layers and the formation of mountains (Drayer, 2018). The continental drift theory was opposed also, by revolutionary scientists such as Gaylord Simpson, who was an American paleontologist, and believer in stable continents and mammals transfer from one continent to another (Wells, 2012). The continental drift theory failed to explain the thick sedimentation layers formation in the continents.

One of the problems that faced the continental drift theory, is what power and what mechanism used to explain the movements of the continents, which caused the continental drift.

Another problem is to provide scientific reasoning for the application of that power or energy which can have that tension to move continents apart (Renton, 2006).

2. What types of evidence did Wegener present to support his idea that South America and Africa were once joined?

Answer:

Alfred Wegener proposed the continental drift theory, which assumes that all continents were connected in one supercontinent during the Permian age 250million years ago (King, n.d), which he named Pangaea. The supercontinent split into the known continents of Africa and Latin America.

Wegener brought some pieces of evidence to support his assumptions:

- The geological formations fit in the coastline of West Africa and the east coastline of Latin America, for example, the rock strata of Karroo system in South Africa match the system of Santa Catarina in Brazil, and besides the mountain ranges in Ghana and Brazil are the same (Sant, 2018).

- The fossil relevance, which is found in separate continents parts of Africa, Latin America, Australia, and India, for example, the remains of the reptile-like Mesosaurus, were found only in Africa and Latin America. This reptile used to live in fresh water, and it is impossible for it to swim the entire Atlantic Ocean if the continents were in the same position as they appear now. Important fossil evidence is the plant Glossopteris, which was a dominant plant in the Permian Age (250-300Million years), this plant was about 30m high and had bulk seeds. The fossils of this plant were found only in the southern continents, Australia, Africa, Latin America, and India. It is impossible for the bulk seeds of this plant, to drift by the tide or flown across the Atlantic. This evidence assumes that continents must have been joined together during the Permian Age (Sant, 2018).

Lecture 4

1. Considering where we are today in a Wilson cycle and the present rate at which the Americas are moving westward, will the Pacific Ocean ever close?

   Answer:

   The planet Earth is a dynamic system, it is full of energy that has an influence on the changes that happen on earth crust every day.

   Planet Earth is constructed of a core, which entirely composed of molten iron with an average density of about 12g/cm3 (Renton, 2006). Above the core, floats the inner mantle, which is composed of peridotite, which is an igneous rock made of Olivine and Pyroxene which are mainly rocks rich in iron, with an average density of about 6g/cm3 (Renton, 2006). Over the inner mantle comes a plastic layer called asthenosphere, which is the source of kinetic energy in the mantle of the planet. There are convection cells that work to transfer heat from the core through the asthenosphere to heat water, the hot water rises up and when it cools, it comes down again through the convection cells. This process of rising and descending of water causes cracks in the lithosphere layer. The cracks in the lithosphere allow the formation of rift zones in the ocean and in the ground surface which also causes the eruption of hot springs from the heated groundwater and the eruption of lava above the ground and in the bottom of oceans. This whole process of lithosphere cracking and the tension caused on it by the energy in the asthenosphere causes the movement in the tectonic plates and hence the continental drift. The Canadian geologist Wilson proposed Wilson's cycle of tectonic plates in which it began in the supercontinent Pangaea surrounded by the big ocean. The tectonic plates in the lithosphere moved since 250 million years and formed the known continents. According to Wilson, the movement of tectonic plates will stop and the close up of oceans will start in about 50 million years. So, in another 250 million years the Pacific Ocean will close up and the continents will gather again in a supercontinent. The pieces of evidence for Wilson's proposal are obvious in the subduction zones along the Islands of Indonesia which proves the movement of Australia towards Asia and the evidence that the Arctic Ocean had stopped opening (Renton, 2006).

2. How can you explain the fact that there are no oceanic crustal rocks older than 250 million years while continental crustal rocks have been found that are older than 4 billion years?

   Answer:

   According to Harry Hess, who was an American geologist and a US Navy officer during World War II, and was also considered as the father of plate tectonics theory. Hess postulated that the breakdown of ocean lithosphere is consumed down in the mantle and then in the core of the planet. This consumption of old ocean lithosphere is faster than the formation of new ocean crust. The area, where consumption of seafloor occurs, is called subduction zone (Renton, 2006). So the oldest rocks of ocean crust are found only during the formation of tectonic plates about 200 million years, while the older rocks of the ocean were being consumed through subduction zones, and the continental rocks, which were formed with the formation of planet Earth, 4 billion years ago, and they are kept until now without consumption.

Lecture 5

1. What is the fundamental difference between ionic and covalent bonding, and how does bonding affect chemical reactivity of a compound?

   Answer:

   All matter, either living or nonliving, solid, liquid or gas is formed of elements, such as carbon C, sodium, Na, calcium Ca, potassium K, Iron Fe, Aluminum Al,, Silicon Si, Oxygen O, Hydrogen…etc.; The element is a pure raw material that can't be analyzed or fractured into simpler materials, it is formed of atoms. Atoms are formed of nucleus and electrons energy distributed in levels called orbitals, the nucleus contains protons and neutrons and it is positively charged the number of protons is called the atomic number and it is a characteristic of each element. The total number of protons and neutrons is called the atomic mass. Electrons are negatively charged and spin around the nucleus in orbitals that have different energy levels. In a neutral atom, electrons are equal to the protons, but the number of neutrons is equal to the number of protons or more.

Some atoms may have different number of neutrons, which are called isotopes. The isotopes of an element have the same chemical characteristics and differ in the physical characteristics.

Electrons rotate around the nucleus in a quantized energy levels (Orbitals) and they are given the letters K, L, M, N, O, P, Q. or 1,2,3,4,5,6,7, each energy level has a specific capacity of electrons which is illustrated in the formula, $2n^2$. Where n is the number of energy level, for example, K=1 contains $2x1^{\wedge 2}$ = 2 electrons, L= 2 contains $2x2^{\wedge 2}$ = 8 electrons and Q = 7 contains $2x7^{\wedge 2}$ = 98 electrons.

The filling of electrons in the energy levels is sequential, which means that we fill the energy level K, then L and then M and so on, the last energy level must contain only 8 electrons or less, which is known as the octet rule. The number of electrons in the final energy level, are called valence electrons, which give the element its physical and chemical characteristics.

Each atom tends towards energy stability by have 8 electrons in its final energy level either by losing, gaining or sharing electrons from other similar or different atoms. Some elements have naturally electrons in their final orbital, these elements are called noble elements like Argon (Ar), Krypton (Kr), Neon (Ne)…etc.

If an atom loses electrons to another atom, then the number of protons in the nucleus becomes more than the electrons in the orbitals, so the atom will be positively charged, it will form a positive ion or cation, and if the atom gains electrons, then the electrons will be more than protons and the atom will be negatively charged and will form a negative ion or anion. The strength of positive or negative charge depends on the number of electrons lost or gained.

The loss, share and gain of electrons between atoms is called chemical bonding and it depends on many factors, such as electronegativity, electron affinity, atomic radius and the number of valence electrons. For example, atoms with high atomic number, have more orbitals and the valence electrons are far away from the effect of the positive charge of the protons in the nucleus. So the tendency of the atom to lose some or all of all its valence electrons to another atom or atoms will take place. The bond formed between losing and gaining atoms is called ionic bond. If an atom can't lose any of its valence electrons and can't have electrons to fulfill the octet rule, this atom can share some or all of its valence electrons with one or more atoms, the chemical bond between sharing atoms is called covalent bond.

The ionic bond has a dipole moment is a weaker bond compared to covalent bond, as the ionic bond can be broken completely by any polar solvent such as water, but the covalent is affected partially with polar solvents.

The compounds formed by ionic bonds, or ionic compounds, have chemical and physical characteristics different from compounds, nonionic compounds, and formed by covalent bonds, for example, ionic compound are soluble in polar solvents like water and they can conduct electricity, and they are insoluble in nonpolar solvents like ether, while nonionic compounds are insoluble in polar solvents like water and soluble in nonpolar solvents and they can't conduct electricity. The pollution of soil and water with ionic compounds is faster than nonionic compounds and the interaction between ionic species and geological formations is more than nonionic species. Also the solubility and erosion is more in geological formation, which have ionic bonds between its elements. The physical properties of geological formations, such as hardness is more in compounds with covalent bonds than compounds with ionic bonds between their elements.

The reactivity of chemical compounds, depends on the percentage of ionic bonding, which means the more ionic bonds in a compound, the more reactive the compound and the more covalent bonds in a compound, the less reactive is the compound.

2. What changes must take place for a solute to precipitate from a solution?

Answer:

Chemicals tend to dissolve in solvents, ionic compounds tend to dissolve in polar solvents, for example, sodium chloride NaCl, dissolves in water, nonionic compounds dissolve in nonpolar solvents like naphthalene dissolves in ether, the general rule for solubility of chemical compounds says "Like Dissolves Like".

The solubility of a substance in a solvent is defined as the maximum amount of that solute that can dissolve in a proper volume of solvent under certain temperature and pressure. Any excess amount of solute will cause precipitation of the solute; also any decrease of solvent due to evaporation will cause precipitation of solute. An increase in temperature also causes an increase in solubility. When a solute is dissolved in a solvent, a complete dissociation of ionic compounds into cations and anions. The equilibrium constant that explains the solubility of an ionic compound is called solubility product constant Ksp.

For example, when sodium chloride dissolved in water, it dissociates into sodium ions and chloride ions as in the following equation:

$NaCl_s \longrightarrow Na^+_{aq} + Cl^-_{aq}$ $K_{sp} = [Na^+] [Cl^-]$

From literature Ksp of sodium chloride in water at 25 °C = 36 (Francis, 2003), which means that 36 grams of sodium chloride, can be dissolved in 100ml of pure water, and an increase in sodium chloride will shift the solubility product to the lift and sodium chloride precipitates again. Also, an increase of the concentration of either sodium ion or chloride ion at the same conditions of temperature and pressure, will shift the solubility equilibrium to the left and sodium chloride will precipitate and saturation conditions of the solute will take place.

Solubility product constant Ksp is a very important parameter in the prediction and interpretation of minerals formation.

Lecture 6

1. The plagioclase feldspars, anorthite and albite, represent end members of an isomorphous series. What is an isomorphous series?

   Answer:

   Minerals are the building block of rocks, they are formed from different elements. Minerals may consist of one element, like diamond, sulfur, graphite, or from a combination of different elements like gypsum, halite, fluorite, apatite…etc. elements of a mineral, are arranged in a well-defined crystal structure, which gives it some chemical and physical properties. Each mineral has its own crystal structure, but in some cases some minerals differ slightly in the percentage of some elements in their chemical compositions. These minerals may have similar physical properties like, hardness, crystal structure, density, streak cleavage, taste and color. These minerals are called isomorphous minerals like plagioclase feldspars series, which means that they have the same physical and chemical properties and many case they can't be differentiated from each other.

Plagioclase feldspars series are a group of minerals which they have the general chemical formula (Na, Ca) $Al_{1-2}Si_{3-2}O_8$, They differ in the percentage of sodium Na, calcium Ca and Aluminum Al, for example Albite is the first mineral of plagioclase feldspar series with the chemical formula ($Na_{100\%}$, $Ca_{0\%}$) Al Si_3O_8, and Anorthite is the end mineral of the series with the chemical formula ($Na_{0.05}Ca_{0.95}Al_{1.95}Si_{2.05}O_8$) (Barthelmy, 1997).

The other intermediate minerals in the series are a mixture of Albite (Ab) and Anorthite (An). These minerals are Oligoclase (70-90% Ab; 10-30% An), Andesine (50-70% Ab; 30-50% An), Labradorean (30-50% Ab; 70-50% An) and Bytownite (10-30% Ab; 70-90% An).

The plagioclase feldspar minerals are the building blocks of many igneous like diorite, gabbro, rhyolite, granite, andesite and basalt, they are also found in metamorphic rocks like gneiss (King, n.d)

2. What different types of silicate crystal structures are represented by the ferromagnesian silicate minerals?

Answer:

Silicon comes in period 2 and group 4 in the periodic table. Silicon is like carbon by which, both have 4 electrons as valence electrons. These electrons can't lose 4 electrons or gain 4 electrons, but instead, they share their valence electrons by covalent bonds with other elements. The common shape of group 2 elements is a tetrahedral structure. Which means that silicon atom comes in the center of a tetrahedron and other elements are on the corners of the tetrahedron.

Silicate minerals are characterized by the anion SiO_4^{-4}, which has the shape tetrahedron, other elements, which are cations like sodium, aluminum, calcium, magnesium, and Iron, are bound with the silicate anion SiO_4^{-4}. If Iron Fe is present in the silicate mineral, then the mineral is called ferromagnesian mineral, for example, Olivine ((Fe, Mg)$_2$ (SiO_4^{-4}), pyroxene and hornblende.

Silicate minerals have five types of crystal structure, three of them for ferromagnesian minerals and the other two for non-ferromagnesian minerals.

The ferromagnesian minerals have the following crystal types:

- Single independent tetrahedron type, in which a single tetrahedron structure is arranged in three dimensional structure and bound to any other cation (Figure 1), for example Olivine ((Fe, Mg)$_2$ (SiO_4^{-4}); the silicon atom is in the center of the tetrahedron, the oxygen atoms on the corners of the tetrahedron and the cations Fe and Mg are bound by ionic bonds with the tetrahedron.

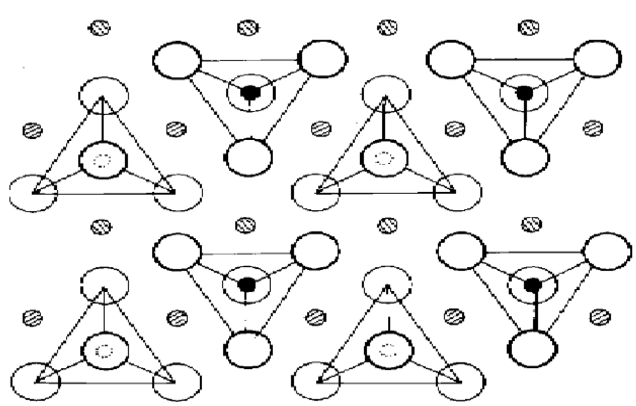

Figure 1: Mineral structure of Olivine, (Landstreet, 2003)

- Tetrahedron chain, in which single tetrahedrons are bound together forming a single chain like saw teeth (Figure 2), the cations bind the repeated tetrahedrons (Renton, 2006), for example, Iron containing pyroxenes like Augite $(Ca,Na)(Mg,Fe,Al)(Si,Al)_2O_6$, (King, n.d)

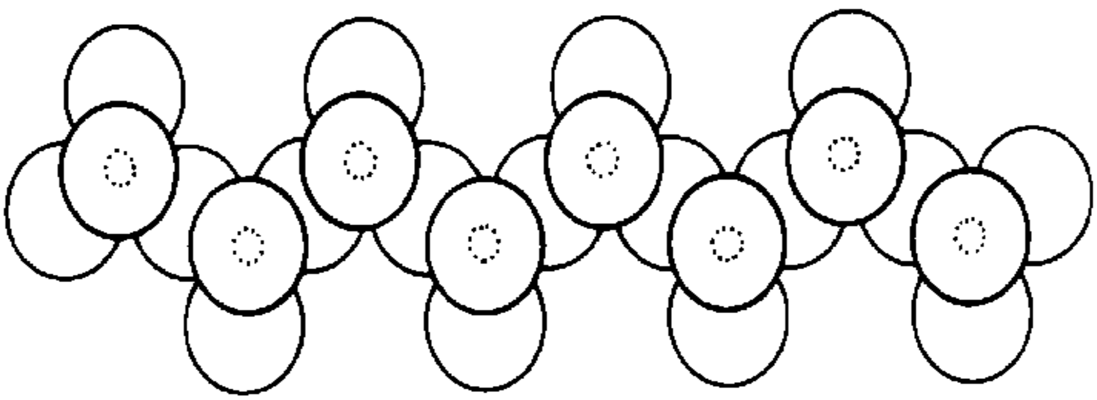

Figure 2: Single chain of pyroxene structure based on silicon tetrahedral structure with Fe and Mg ionic bonding (Landstreet, 2003)

- Tetrahedron double- chain, in which two single chains are bound side by side and parallel to other and then bound by the cations (Figure 3), for example the amphibole mineral, hornblende ($(Ca,Na)_{2-3}(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH,F)_2$) (King, n. d).

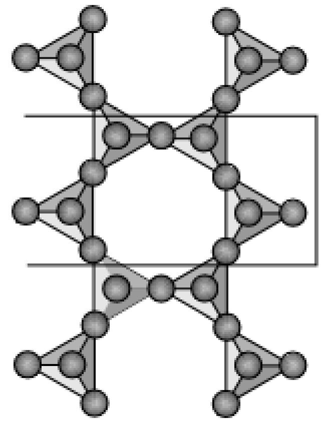

Figure 3: Double chain Silicate structure (Nelson, 2014)

Lecture 7

1. On what criteria are minerals identified?

   Answer:

   The criteria for identification of minerals are crystal structure and chemical composition. The crystal structure can be done by experienced geologist onsite or in the lab by sophisticated instrumentation like optical spectroscopy and X-ray diffraction machines. The machines are costly and require a well-trained technician and they need special requirements for sample preparation.

   The chemical composition of a mineral can be done in a lab by chemical methods such as reactivity of the mineral with different types of acid like hydrochloric acid, nitric acid, and sulfuric acid. Inductively Coupled instrumentation Plasma (ICP) is really fast and accurate instrumentation for the determination of the concentration of different types of cations, which are present in all minerals. The anions are determined in the lab by Capillary Ion Analyzer (CIA), which is a very simple, cheap and accurate instrument for determination of different anions, like for determination sulfates, silicates, phosphates, halides, nitrates.

Carbonates and bicarbonates are determined by titration methods because they interfere with the eluent solution of CIA.

2- Of the various physical properties, which would be most easily determined “in the field” to identify a mineral crystal? What about a mineral contained within a rock, such as granite?

Answer:

Minerals have several physical and chemical properties, which differ from one mineral to another. A well-experienced geologist can determine some of the physical and chemical properties in the field using simple tools without the need for laboratory experimentation, these physical properties are:

- Color, many minerals are identified by color, for example, the sulfur mineral has a yellow color, iron-containing minerals have bricks color like magnetite $Fe3O4$. Color alone is not indicative for minerals, as some minerals have many colors because of foreign materials inside crystals
- Taste, some minerals have a salty taste like Halite NaCl and Sylvite KCl, sulfate-containing minerals give a better taste.
- Odor, some minerals like Galina (PbS) and Pyrite ($FeS2$) have rotten eggs odor.
- Magnetism, minerals containing Iron are paramagnetic, like magnetite $Fe3O4$, they are attracted to magnets or a piece of iron.
- Streak, which is the color of the mineral powder when it is applied on a ceramic surface, it could be different from the mineral color, for example, Calcite mineral

(CaCO3) has colors and shapes, but all have the same streak white color, the streak of Galina (PbS) is lead grey. Pyrite is yellow and its streak is black. Gold has a yellow streak but Chalcopyrite ($CuFeS_2$) which looks like gold in color, has a black streak.

- Hardness, this test is a good and indicative physical property; minerals are classified on the Mohs scale for hardness from 1 to 10. Talc is given number 1 and Diamond is the hardest mineral with a Mohs's scale of 10, other minerals lie between these values.

- Cleavage, which is the ability of minerals to break into plane surfaces and not all minerals have cleavage property. This test can be done in the field with a small hammer. Some minerals are crushed into small pieces if they are hammered. A well-experienced mineralogist can identify some minerals from the cleavage surfaces, for example, Halite cleavage into plane surfaces along the axis of the cubic crystal between sodium and chlorine atoms, and Mica cleavage into sheets.

- Luster, which describes the ability of the mineral surface to reflect light. Some minerals have metallic lusters like gold, copper, and silver, some are metallic like lead others are greasy, like Nepheline $(Na,K)AlSiO_4$, and Euxenite $(Y,Ca,Ce)(Nb,Ta,Ti)_2O_6$, other minerals have a dull earthy luster like Howlite $Ca_2B_5SiO_9(OH)_5$ (Barthelmy, 1997)

- Tenacity, which is the resistance of the mineral towards breaking, crushing, cutting bending, for example, graphite shows curved edges upon cutting with a knife. Once the mineral reaches the tenacious limit, it fractures into different shapes, which is considered a physical property that can be observed in the field, they shape and type of fracture provides data on different minerals, for example, Asbestos $Mg_3Si_2O_5(OH)_4$, fractures into fibrous and thin elongated fractures, while diamond resists fracture (Barthelmy, 1997).

If a mineral is trapped within an igneous rock like granite, many of its physical properties can't be determined in the field, color streak and shape of the mineral are useful identification tools for the mineral.

Conclusion

Geology is an important subject for environmental science students, as it concerns with interactions with geological formations with water, air, and soil. It is the task of an environmental scientist to predict the natural causes of pollution in groundwater from the different geological formations. Geology is important in the prediction of earthquakes and volcanoes eruption and it is a good warning to save lives and properties. It is also good in the exploitation of minerals and Earth treasure and gives mineralogist the proper knowledge to reduce adverse effects in the environment.

This course was very interesting, and it opened wide doors of knowledge about the universe and the solar system including our planet Earth. It supports environmental science students with basic concepts in geology and all its branches, and their applications for the better exploitation of natural resources. By the end of this course, students will acquire basic geological techniques in classification, identification of various types of rocks and their origins, the physical and chemical properties of minerals, minerals interactions and their role in rocks formation. Students will be able to differentiate between different types of crystal shapes and their geometrical properties.

Other lecture from Renton's book "The Nature of Earth: An Introduction to Geology", that were not discussed in this essay, are of great interest to environmental science students in the fields of identification of rocks and their types and origins, groundwater its sources and exploitation, soil and weathering effect, climate change and its effect on environment, earthquakes and volcanoes and their effects on geological formations of Earth.

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