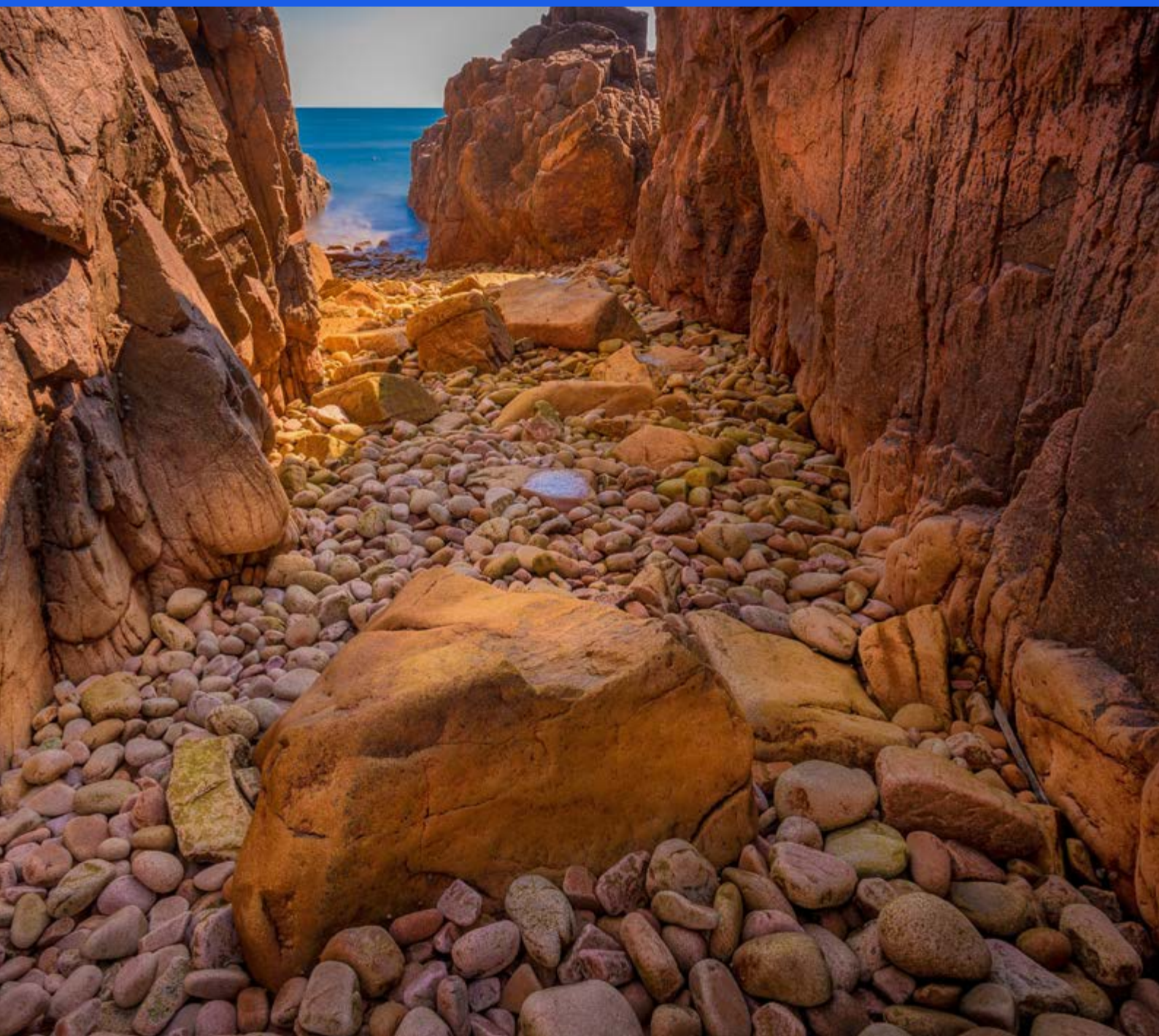
Geography Year 1

SECTION 7

ROCKS AND PROCESSES OF WEATHERING



THE EARTH AND ITS NEIGHBOURHOODS

Rocks, Weathering, Soil and Mass Wasting

Introduction

This section covers the study of rocks, focusing on their characteristics, formation, and economic importance. Rocks are aggregates of minerals in the Earth's crust and are commonly used as construction materials. You will explore the three main types of rocks: igneous, sedimentary, and metamorphic. Understanding their formation and properties helps in identifying them in your community and deepens your knowledge of the Earth's landscape features.

The section also discusses Weathering and its processes. Weathering is the breakdown of rocks which shapes the Earth's surface over time. Understanding weathering is important because of its role in the formation of soil, landforms, and the different landscapes over the Earth's surface.

At the end of this section, you will be able to:

- Discuss the three types of rocks, their characteristics, formational processes, and their importance.
- Explain weathering and the factors affecting its processes.
- Evaluate the three weathering processes (physical, chemical, and biological weathering).

Key Ideas

- Rocks are naturally occurring solid substances that make up the Earth's crust.
- There are three groups of rocks, igneous, sedimentary and metamorphic, and these groups are based on their mode of formation.
- Many rocks are of economic importance to humans.
- Weathering is the breakdown of rocks.
- The three main types of weathering are physical, chemical, and biological.
- The factors that influence weathering include climate, rock composition, topography, and time.

ROCKS FORMATION, CHARACTERISTICS AND IMPORTANCE

Meaning of Rocks

A rock is defined as the naturally occurring combination of solid substances that is made up of one or more minerals. There are many different minerals, but each one has its own chemical composition and crystal structure. Quartz is the most common mineral on Earth and is composed of silicon dioxide (SO_2). The crystal structure of quartz is very strong, atoms being arranged in triangular pyramids or tetrahedra. Common sand is made up of quartz grains. The Earth's crust is made up entirely of different rocks. These rocks can be identified according to their texture, structure, colour, permeability, mode of formation, and degree of resistance to erosion.

Types of Rocks

There are three types of igneous, sedimentary and metamorphic rocks.

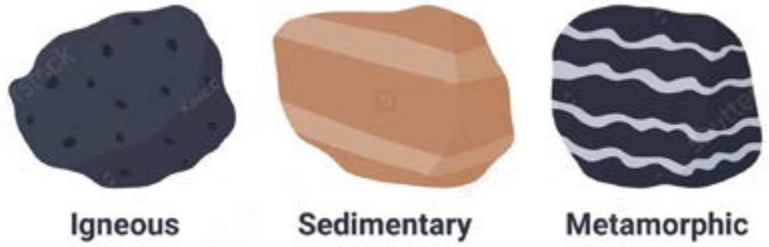


Fig. 7.1: The three types of rocks

Click on these links to watch videos on the meaning, types, and processes of rock formation:

Igneous Rocks

When rocks forming the Earth's crust rub together during movements, for example at tectonic plate boundaries, heat is created by frictional forces, and this causes melting. The melted rock is called magma. Magma is less dense than the surrounding rocks and begins to rise towards the surface. Igneous rocks are created when this magma cools and solidifies. The term "igneous" comes from the Latin word ignis, meaning fire. These rocks can form deep within the crust, near the surface, or on the surface, depending on where the magma cools.

Characteristics/Description/Features of Igneous Rocks

Igneous rocks are the most common type of rocks in most communities in Ghana. The following characteristics will help you to identify an igneous rock.

1. **They are crystalline in structure**: As liquid rock or magma cools crystals grow. These crystals are of one or more minerals which interlock to form a well-structured solid with no spaces. The interlocking crystals give some igneous rocks a shiny and attractive appearance. Slow cooling can result in the growth of large crystals.

Fig. 7.2: Rock containing crystalized minerals

2. **They are not in layers.**
3. **They do not contain fossils.**
4. **They are dense and hard.**
5. **Igneous rocks are impervious**: They are 'waterproof'. There are no spaces between the crystal so water cannot pass through them. However cracks in igneous rocks make them **permeable**, which means water can pass between these cracks.
6. **Most igneous rocks are resistant** to weathering and erosion.
7. **Igneous rocks can be classified as either acidic or basic:** Acidic igneous rocks contain more silica (quartz) than basic igneous rocks.

Types of Igneous Rocks

The following are the types of Igneous Rocks:

1. **Intrusive Igneous (Plutonic) Rocks:** These are rocks formed when the magma cools slowly and solidifies deep within the earth's crust. They are only exposed to the surface of the earth after a long period of erosion. Examples include granite, diorite, and gabbro. Due to the slowness of the cooling and solidification, large crystals are formed. Examples of such rocks are shown in Figure 7.3.

Granite *Diorite* *Gabbro*

Fig. 7.3: Some examples of intrusive igneous rocks

2. **Extrusive Igneous (Volcanic) Rocks:** These are formed when magma reaches the surface of the Earth. These igneous rocks tend to have smaller crystals because of the faster cooling and solidification of the magma. Examples include basalt, rhyolite, andesite, pumice, and obsidian.

Andesite *Basalt* *Obsidian*

Fig. 7.4: Some examples of extrusive igneous rocks

Sedimentary Rocks

The word sedimentary is from the Latin word, *sedimentum* which means *to settle down*. These are rocks formed in a geological cycle which includes the processes of rock erosion, particle deposition, and lithification (compacting and cementing of particles). Sedimentary rocks may be formed from the broken-down bits of any rock types, but also dead materials from plants and animals (which is called coal). Water plays an important part in the process of sedimentary rock formation including the erosion of rocks by water or ice and the transport of particles by rivers to the sea where they collect in ocean basins. Most sedimentary rocks have layers. A layer is a stratum and several layers strata.

Strata: layers of rocks

Fig. 7.5: Sedimentary rock revealing some characteristics such as the layers. The lines between the layers are called bedding planes

Characteristics/Description/Features of Sedimentary Rocks

1. **Sedimentary rocks are stratified:** This means they are arranged in layers. *Look at Figure 7.5. Have you seen the layers?*
2. They may be coarse or fine-grained, depending upon the size of particles during the deposition stage.
3. Most are non-crystalline.
4. They may contain fossils or remains of plants and animals.
5. They are less resistant to erosion.
6. They are porous and permeable. Their structure and layers, allow water pass through them.

Classification of Sedimentary Rocks

Sedimentary rocks are classified into three types based on their formation and the types of sediments involved.

1. **Mechanically Formed Sedimentary (Clastic) Rocks:** Clastic means to be formed of the fragments of other rocks. These rocks are formed in layers. Mechanical processes of weathering transport and deposition lead to their formation. They can be categorised according to the *grain size* of the rock. For example, *Argillaceous rocks* are fine-grained clastic rocks composed of clay. Examples are shale and mudstone.*Arenaceous rocks* are medium-grained clastic rocks composed of sand. Examples are sandstone, siltstone. *Rudaceous rocks* are *coarse-grained* clastic rocks composed of large stones and pebbles stuck together by finer material. Examples are conglomerate and breccia.

Shale *Sandstone*

Fig. 7.6: Some examples of mechanically formed sedimentary rocks

2. **Organically Formed Sedimentary (Bioclastic Rocks):** Bioclastic means formed from the remains of living organisms. The processes of erosion and transport of particles do not feature in the formation of these rocks. Organic materials are compacted by the weight of overlying sediments and cemented together. These rocks are made from the remains of living organisms such as plants, animals, and marine organisms, including seashells and corals.Examples are coal, made from plants that lived in swampy forests, and chalk or limestone both formed from the remains of corals and shellfish.

Shale *Coal* *Shelly limestone*

Fig. 7.7: Some examples of organically formed sedimentary rocks

3. **Chemically Formed Sedimentary Rocks (Evaporites):** They are formed when mineral crystals are precipitated chemically from solution usually under the conditions of high temperatures and extreme evaporation. They are formed in low lying lakes and seas. Examples are halite/rock salt (sodium chloride) and gypsum (calcium sulphate).

halite *gypsum*

Fig. 7.8: Some examples of chemically formed sedimentary rocks

Metamorphic Rocks

Metamorphic rocks are formed by the intense heat, pressure and or chemically active fluids. They can be formed from igneous or sedimentary rocks, but even metamorphic rocks themselves can undergo further changes. Ultra-metamorphism is the process where rocks undergo changes at extremely high temperatures and pressures, just below their melting point. Examples of rocks formed by ultra-metamorphism include granulite and eclogite.

Characteristics/Description/Features of Metamorphic Rocks

1. Most are resistant to erosion.
2. They are impervious. Water cannot easily pass through them.
3. They may be foliated or non-foliated. Foliation is a layering which makes them look like sedimentary rocks. An example of s foliated rock is gneiss metamorphosed from granite.
4. Their structure is crystalline, crystals are often well ordered compared to the rocks from which they were formed.
5. New minerals are often formed in metamorphic rocks – garnet and mica in schist for example.

6. They do not contain fossils.
7. They may be fine-grained or coarse-grained depending on the time crystals have to grow.

Types of Metamorphic Rocks according to Mode of Formation

Metamorphic rocks can be formed in the following ways:

1. **Regional/Dynamic Metamorphism:** Rocks are changed at depth by intense pressure over a wide area or region of the Earth's crust. New minerals can be formed. Rocks affected by regional metamorphism tend to show foliation because of the directed pressure (the parallel alignment of minerals). E.g., Gneiss and Schist.

Gneiss Schist

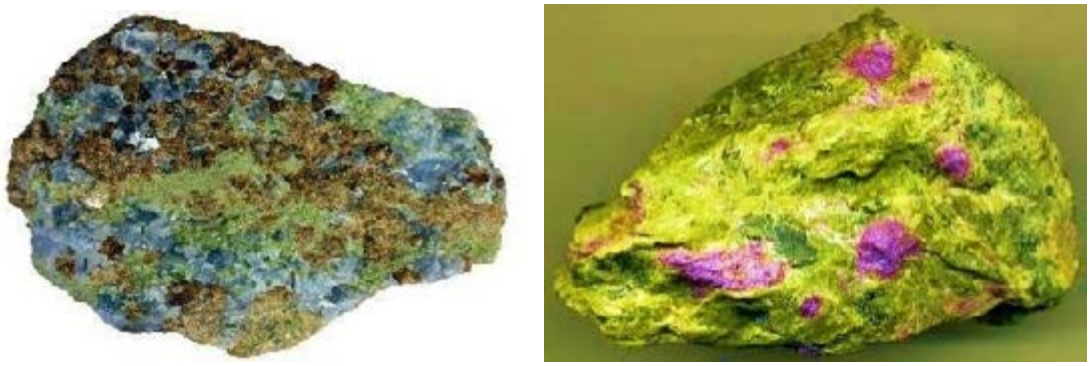
Fig. 7.9: Some examples of metamorphic rocks formed from pressure

2. **Contact/Thermal Metamorphism:** It is a type of metamorphism where rock minerals and texture are changed by intense heat due to contact with magma. Igneous activity is accompanied by intense heat which affects nearby rocks. E.g., quartzite and slate.

White quartzite slate

Fig. 7.10: Some examples of metamorphic rocks formed from intense heat

3. **Thermo-dynamic Metamorphism:** It is a type of metamorphism where rock minerals and texture are changed by the combination of heat and intense pressure. This is common at tectonic plate boundaries where plates are being pushed together to form mountains.
4. **Metasomatism (Hydrothermal) Metamorphism:** It is a type of metamorphism where rock minerals are chemically changed as they come into contact with chemically active fluids (very hot liquids and gases). E.g., Skarn and serpentine.



Skarn *Serpentine*

Fig. 7.11: Some examples of metamorphic rocks formed from chemically active fluids

When an existing rock is metamorphosed or changed into metamorphic rock, it assumes new characteristics. Examples of parent or original rocks and their metamorphosed forms or types are shown in **Table 7.1.**

Table 7.1: Parent or original/pre-existing rocks and their corresponding metamorphic or metamorphosed rock types

Parent/Original Rock	Metamorphic/Metamorphosed Rock
Clay	Slate
Shale	Schist
Limestone/dolostone/gypsum	Marble
Sandstone	Quartzite
Coal	Graphite
Basalt/gabbro	Amphibolite
Conglomerate	Meta-conglomerate
Slate	Phyllite
Granite	Gneiss

Importance and Uses of Rocks

1. **Formation of soil through processes of weathering**. When rocks are broken down, they form soils that support plant growth.
2. **Source of water**. Water from the ground comes from rocks. The water source of rivers and streams such as the Volta, Pra and Tano comes from rocks. The rocks that store and produce water are usually porous sedimentary rock like chalk or sandstone. These rock storages are called aquifers.
3. **Rocks serve as industrial raw materials**. For example, clay, shale, gypsum, and limestone are some of the materials used to produce cement. Fertilisers are made from potash deposits and phosphates are obtained from phosphorite (or phosphate rock), which is a sedimentary rock rich in phosphate minerals.
4. **Rocks are used for construction**. Some are used to build the structures of houses, bridges, and roads. Examples are granite, gneiss and basalt.
5. **Some rocks can be carved and moulded into statues**. Examples are limestone and marble
6. **Some may be used to make ornaments and decorations** such as bowls, pots, and wall tiles. Examples are slate, marble, obsidian, and quartzite.
7. **Some rocks are sources of minerals.** They contain precious minerals such as petroleum, gold and diamonds. Petroleum is found in sedimentary rocks like sandstone, limestone, and shale. Gold is found alongside the minerals quartz and pyrite, or the rock granite. Diamonds can be found in two igneous rocks called kimberlite and lamproite.

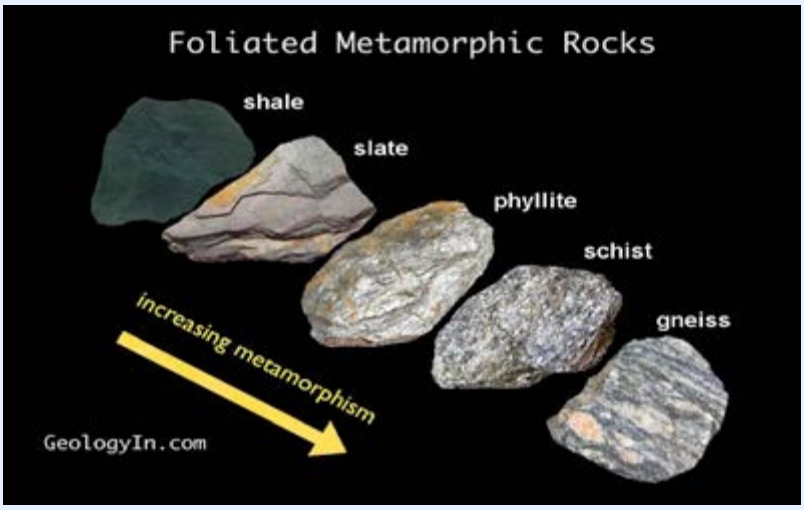
Activity 7.1

1. Take a walk around the school compound and collect different types of rocks into a container, such as a basket, or bucket. Your teacher will help you to make sure you have collected naturally formed rocks, not manufactured building materials like concrete or brick.
   a. Observe characteristics of the rocks, taking into consideration things like visible crystals, texture (size of grains), colour and any other features you can see like layers or foliations.
   b. Make accurate sketches of the rocks.
   c. If it is possible, sort the rocks into the three main types or categories (igneous, sedimentary, and metamorphic).
   d. Record your findings and display them and your rocks for the class to see. Label each rock with the things you observed.
2. Work on your own or with a friend to create your own drawings of one of each of the three types of rocks. If you cannot see and hold a rock, use a book or the Internet to find examples. Make sure to use different colours, a

scale and labels for features like layers or crystals to make your diagram as accurate as possible.

a. Label each diagram and add a scale.
b. Present your diagrams to the class and lead discussions on the importance of the rocks identified in the diagram. Relate your discussions on the importance of rocks to your community.

3. Create a Venn diagram that helps you to compare the three main types of rock to visualize their similarities and differences.
   a. Make sure you use different colours and accurate descriptions to make your diagram easy to follow.
   b. Be specific when writing characteristics, use the correct terms and keep to short phrases.
4. By yourself or with a friend, create a rock museum by displaying different types of rocks from each of the three groups, igneous, sedimentary, and metamorphic.
   a. Choose a type of rock among your collected samples and visit your school library or on the Internet to search for information on the characteristics, and the uses of the rock you have chosen.
   b. Present your findings to your class.
5. Use the diagram below to answer the following questions:



   a. Use the Internet or visit your school or local library to research each of the rocks listed in the diagram.
   b. In your search, find out the following:
      i. the minerals found in each type of rock.
      ii. the type of metamorphism that can form slate, phyllite, schist and gneiss (shale is a sedimentary rock).
   c. Explain using a diagram the meaning of foliation in metamorphic rocks.

THE MEANING AND FACTORS AFFECTING WEATHERING

Meaning of Weathering

Weathering is the physical (or mechanical), chemical or biological breakdown of rock. The layer of loose material covering solid rock which is the product of weathering is called the **regolith.** In mountain areas the broken pieces of rocks collected at the base of steep slopes of bare rock are called **talus or screes**. (For pictures of screes visit https://en.wikipedia.org/wiki/Scree).

Factors Affecting Weathering

- **Climatic Conditions**: High temperatures and rainfall speed up chemical weathering; cold climates favor physical weathering like frost wedging.
- **Type of Vegetation**: Plant roots break rocks apart; some plants release chemicals that aid in weathering.
- **Rock and Mineral Composition**: Softer rocks like limestone weather faster than harder rocks like granite.
- **Topography**: Steeper slopes experience more physical weathering; flatter areas see more chemical weathering.
- **Action of Plants and Animals**: Burrowing animals and plant decomposition contribute to both physical and chemical weathering.
- **Human Activities**: Construction, mining, and pollution accelerate weathering processes.
- **Time**: Weathering occurs over long periods, with older surfaces showing more weathering.

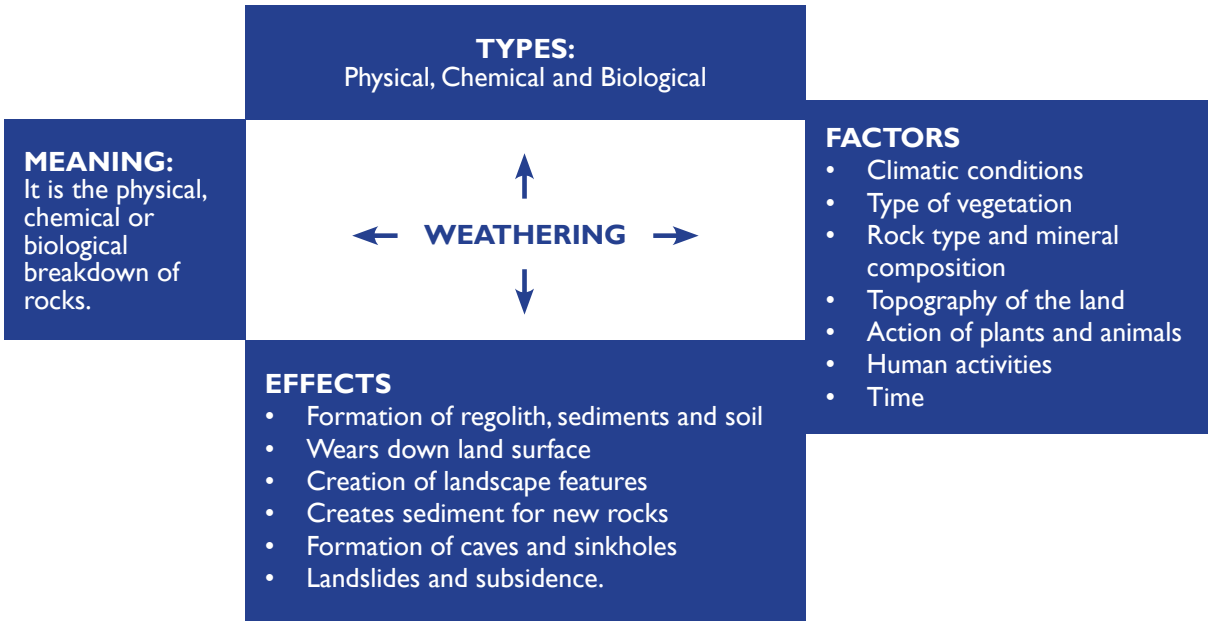


Fig. 7.12: Simple mind map of rock weathering

PROCESSES OF WEATHERING

There are three types or processes of weathering, physical, chemical, and biological.

Physical (or Mechanical Weathering)

Physical weathering is the process where rocks are broken down into smaller pieces without any changes to the rock's chemical composition.

Processes of Physical Weathering

1. Unloading or Pressure Release

As overlying rocks are worn away the rocks exposed expand and crack allowing new spaces for the processes of weathering to begin their actions.

2. Alternate heating and cooling between day and night

In deserts, rocks face intense heat during the day, causing their outer layers to expand faster than the cooler inner layers. At night, the temperature drops quickly, making the outer layers contract faster, creating internal stress. Over time, this repeated heating and cooling causes the rock to crack and split, leading to the outer layers peeling off in a process called exfoliation. This can also break the rock into smaller pieces, and when intrusive igneous rocks undergo this process, they can form exfoliation domes. This kind of weathering is sometimes called onion skin weathering – can you see why from fig. 7.13?

Fig. 7.13: Exfoliation Dome in Yosemite National Park, USA

3. Slaking

Slaking is the process where rocks, especially those containing clay, break down when exposed to water. When rocks like shale get wet, they absorb water and expand, but as they dry out, they contract. This repeated swelling and shrinking causes the rock to weaken and eventually crumble into smaller pieces.

Fig. 7.14: Repeated wetting and drying leading to the process of Slaking

4. Freeze-thaw action (often called ice wedging)

In temperate climates and high mountainous areas, frost is a key factor in breaking down rocks. Rocks have cracks and pores that fill with rainwater or snow. When temperatures drop, this water freezes and expands, increasing stress in the cracks. Repeated freezing and thawing makes these cracks deeper and wider, breaking the rock into fragments. This process is less common in Ghana but can occur on high peaks like Mt. Everest and Mt. Kilimanjaro.

Fig. 7.15: Frost Action/Freeze-thaw action/Ice wedging of rock

5. Haloclasty (breaking down of rocks by salt crystal growth)

In coastal and dry regions, salt crystals can form in rock cracks through evaporation. These crystals create stress, widening the cracks and breaking the rock into smaller pieces, a process called salt weathering or haloclasty.

Fig. 7.16: Salt weathering or Haloclasty

Chemical Weathering

Chemical weathering is the gradual decomposition of rocks due to exposure to air and water which alters the chemical composition of the rocks. The air and water contain chemical elements such as weak acids which are sufficient to set up chemical reactions in the surface layers of exposed rocks. Chemical weathering processes include dissolution, carbonation, oxidation, reduction, hydration, hydrolysis, and chelation.

The Processes of Chemical Weathering

1. Dissolution

This process is when rocks dissolve due to weak acids in rainwater. This process removes minerals from rocks, which are then carried away in water. Sedimentary rocks like limestone, dolomite (found in Ghana's Ashanti region), and chalk are affected. Their main component, calcite, dissolves in weak acid in rain, forming calcium and soluble bicarbonate ions. This can create large caves in tropical areas and cause limescale in water pipes. Other rocks like halite and gypsum can also dissolve in water. The chemical reaction for the dissolving of carbonate rocks like limestone is:

Calcium Carbonate (limestone) + Weak Carbonic Acid → Calcium Bicarbonate (in solution)

$$CaCO_3 + H_2CO_3 \rightarrow Ca(HCO_3)_2$$

The dissolving of carbonate rocks is known as 'carbonation'.

2. Oxidation:

This process involves the reaction of iron minerals with oxygen in the presence of water. It is common in rock which has a high iron content. The chemical reaction for oxidation weathering is:

$$4Fe + 3O_2 + 6H_2O \rightarrow 4Fe(OH)_3$$

In this reaction iron (4Fe) reacts with oxygen ($3O_2$), often in the presence of water ($6H_2O$), to form hydrated iron (III) oxide ($4Fe(OH)_3$), which is commonly known as rust.

3. Hydrolysis:

Hydrolysis is a chemical weathering process where water reacts with minerals in rocks, causing them to break down and form new minerals. For example, when the mineral feldspar found in granite reacts with water, it turns into a clay mineral called kaolinite.

4. Chelation:

Chelation is a chemical weathering process where organic acids from plants and microorganisms bind with metal ions in rocks, making them more soluble and easier to break down. Chelation describes the chemical change and movement of the soluble ions. For example, lichens produce acids that chelate iron and aluminum in rocks, aiding in their decomposition.

Fig. 7.17: Lichens produce acids causing chelation

5. Reduction:

Reduction is a chemical weathering process that occurs in environments with low oxygen levels, such as waterlogged soils or wetlands. In these conditions, minerals like iron oxides lose oxygen and are converted into more soluble forms, such as ferrous iron (Fe^{2+} This change weakens the rock structure and makes possible further breakdown. For example, in waterlogged soils, the reduction of iron oxides can cause the soil to turn a bluish-grey colour, indicating the presence of reduced iron.

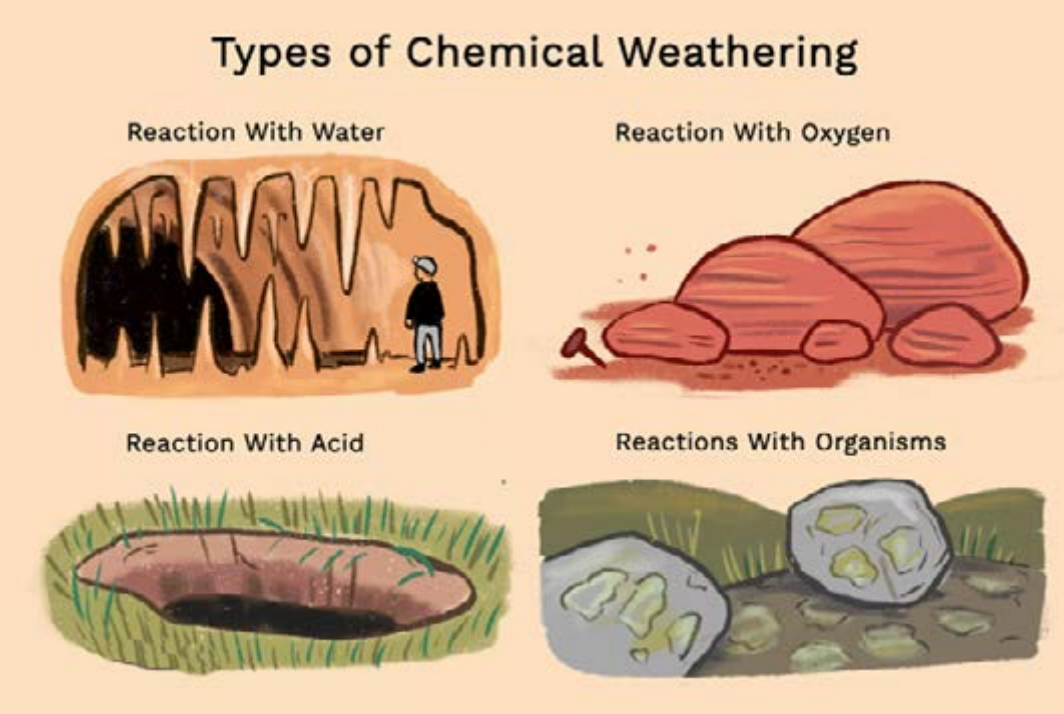


Fig. 7.18: Causes of chemical weathering processes

Biological Weathering Processes

Biological weathering refers to the process by which living organisms break down rocks. Both physical and chemical processes are important in this type of weathering. The main types of Biological Weathering are:

1. Root wedging:

Root wedge weathering occurs when plant roots grow into the cracks of rocks. As the roots expand, they exert pressure on the rock, physical force causing it to crack and break apart further. This process helps to break down rocks into smaller pieces over time.

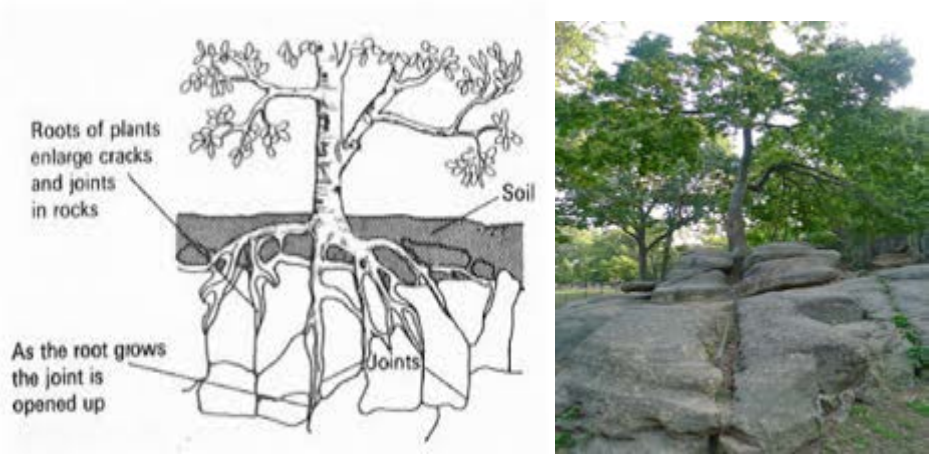


Fig. 7.19: Root Wedging in Rock

2. Burrowing by Organisms:

The digging and tunneling activities of animals expose rocks to weathering processes. Animals such as rodents, earthworms, ants and termites burrow into soil and rocks, opening up their structure and providing the opportunity for water to get in and chemical weathering to take place.

Fig. 7.20: Burrowing of rocks

3. Biodegradation:

This process involves the breakdown of rocks and minerals by microorganisms such as bacteria and fungi. These organisms secrete enzymes that can break down organic compounds in the rocks and minerals, leading to their decomposition. This process is important in the formation of soil.

Fig. 7.21: Biodegradation activity by fungi

4. Lichen and moss growth:

Lichens and mosses are organisms that grow on rocks and minerals. As they grow, they can secrete acids that can break down the rocks and minerals, leading to their decomposition.

Fig. 7.22: image on the left is green moss, image on the right is grey-green lichen

Biomineralisation: refers to the process by which living organisms, such as plants, microorganisms, and animals, contribute to the formation of minerals and the breakdown of rocks through biological activities. Many organisms, such as mollusks and corals, can extract calcium minerals from their environment and use them to build their shells and skeletons. This can lead to the dissolution of minerals from rocks.

Activity 7.2

1. Describe how the three main types of weathering break down rocks.
2. Go around your school compound or neighbourhood to observe and record any effects of weathering or weathering processes you can see. Look for damage caused by roots, animals, or changes in the colour of rocks used in building or roads. Write up your investigation and share it with a friend. Pictures and sketches will form an important part of your evidence.
3. Explain why water is important in weathering.
4. Draw three of pictures to show how a plant can split a rock just by growing in a small crack.
5. Evaluate the effect that temperatures and topography have on weathering.

What did I learn?

Review Questions

REVIEW QUESTIONS 7.1

1. What are the three main types of rocks?
2. How are sedimentary rocks formed?
3. How are igneous rocks formed?
4. How are metamorphic rocks formed?
5. Name some rocks you see being used in your locality for different purposes.
6. Explain how human activities make use of the different rock types. Research using books or the Internet some examples from Ghana to add some interesting details to your answer.

REVIEW QUESTIONS 7.2

1. Explain what weathering is and how it influences the landscape.
2. Describe one physical weathering process.
3. Describe one chemical weathering process.
4. Describe one biological weathering process.
5. Explain the difference between biomineralisation and biodegradation.

Extended Reading

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