WEATHERING

WEATHERING:

Weathering breaks rocks into smaller pieces. It is the effect of rainfall and temperature on rocks. Weathering occurs in situ. This means the rocks stay in the same place and are not moved. This is different from erosion. Erosion is when rocks are moved around or hit by something moving so that they break into smaller pieces.

TYPES OF WEATHERING

Rocks can be weathered in three ways:

i. **Physical (or mechanical) weathering** causes rocks to disintegrate. This means the rocks fall apart into smaller pieces.

ii. **Chemical weathering** causes rocks to decompose. This means the minerals that make up the rock are changed by a chemical reaction.

iii. **Biological weathering** is when plants cause rocks to break up.

Physical weathering

1. **Physical weathering:**

Physical weathering causes rocks to disintegrate in situ. This means the rocks break up. They form smaller pieces of rock with sharp edges. Physical weathering happens when there are changes in temperature over a short period of time. The temperature needs to be fluctuating. Two types of physical weathering are freeze-thaw weathering and exfoliation.

2. **Freeze-thaw weathering:**

Freezing is when water becomes ice. This happens at a temperature of 0°C. Water expands when it becomes ice, taking up more space. Thawing is when ice turns to water. This happens when the temperature rises above 0°C. Freeze-thaw weathering occurs when the temperature keeps fluctuating above and below 0°C. When the temperature drops below 0°C water in a crack in a rock will freeze. The ice thaws during the day when the temperatures rise. The water freezes when the temperature drops again at night and the ice widens the crack even more. This is freeze-thaw weathering.

3. **Exfoliation**

Exfoliation is when pieces of the outer layer of rock breaks away. Exfoliation happens in places where there is a very big difference in temperature between the night and day. This is most common in deserts. During the day in deserts the temperature may rise to over 40°C. At night the temperature may drop to below 5°C. During the day the heat causes the outer layers of the rocks to expand. At night the cold temperature causes the outer layers of the rocks to get smaller and they contract. This makes it weaker until it breaks up.

4. **Chemical weathering:**

The composition of a rock is the chemicals or minerals that it is made from. Chemical weathering causes rocks to decompose. This means the composition of the rocks is changed, because chemical reactions have occurred. Chemical weathering usually needs water from rainfall, and warm temperatures. Carbonation and oxidation are types of chemical weathering.

5. **Carbonation:**

Carbonation is the chemical weathering of chalk and limestone rocks by rainfall. Chalk and limestone are made of calcium carbonate. When rain falls on chalk and limestone a chemical reaction occurs. The air contains gases such as water vapour and carbon dioxide. Water vapour reacts with carbon dioxide to form carbonic acid. All rainfall contains carbonic acid. This reacts with the calcium carbonate. The mineral changes and becomes soluble in water. This means the rock dissolves in rainwater and is washed away. Carbonation is when chalk and limestone are dissolved in rainwater.

6. **Oxidation:**

Oxidation is a chemical reaction between some minerals in rocks and the oxygen in the air. Oxidation changes iron minerals in rocks from a light grey colour to a brown-red colour. This is called rusting. The change in colour shows the change in the composition of the rock. This chemical reaction causes the rock to break up.

7. **Biological weathering:**

Biological weathering is when plants cause rocks to break up. The roots of plants cause rocks to disintegrate. Plant roots grow down through soil and rocks to find water and minerals. The roots can grow through cracks in rocks to find groundwater. As the roots grow the cracks are made wider and eventually the rock breaks up. Dead plants can cause chemical weathering. The plants produce acids when they rot. These acids may cause a chemical reaction in the rocks.

8. **Climate and rate of weathering:**

Climate is the average rainfall and temperature of a place over a long period of time. The rate of weathering is the speed of weathering. Heat causes chemical reactions to occur faster. Most chemical weathering needs rainfall. Chemical weathering occurs fastest where it is warm and there is a lot of rainfall. This means chemical weathering will occur quickly in warm, wet places such as rainforests in the tropics. In cool, wet places chemical weathering will occur slowly, for instance in Britain and New Zealand. Physical weathering occurs fastest in places where temperatures rapidly fluctuate over a short time. Rainfall is not always necessary. Freeze-thaw weathering occurs most rapidly where temperatures fluctuate just above and below 0°C over a short time. Rainwater is needed. Exfoliation happens most rapidly where there are large changes in temperature between night and day. It does not need rainfall.

9. **Rock type and mineral composition:**

Certain rock types are made up of different minerals. This is the mineral composition of the rock. Certain rock types are more affected by certain types of weathering. Limestone is composed of calcium carbonate. This means that it can be weathered by carbonation. However granite is not affected by carbonation as it does not contain calcium carbonate. Rocks containing iron minerals will be weathered by oxidation.

10. **Rock type and lines of weakness:**

Lines of weakness are cracks in rocks which are attacked by weathering. Water and air can enter these cracks and break down the rock by physical or chemical weathering. A rock with lots of lines of weakness will be more easily weathered. Chalk and limestone are sedimentary rocks. They are formed in layers. Each layer is separated by a bedding plane. These are horizontal lines of weakness in the rock.

There are also vertical lines of weakness called joints. Rain water flows through limestone through the joints and bedding planes. The rock is weathered by carbonation. Limestone caves are formed by carbonation. Granite is an igneous rock. It is formed when magma slowly cools as it rises towards the surface of the earth. As it cools horizontal bedding planes and vertical joints form. These are lines of weakness in the rock. Granite is weathered to form tors.

Weathering

This article is about weathering of rocks and minerals. For weathering of polymers, see Polymer degradation and Weather testing of polymers.

A natural arch produced by erosion of differentially weathered rock in Jebel Kharaz (Jordan)

Weathering is the breaking down of rocks, soil, and minerals as well as wood and artificial materials through contact with the Earth's atmosphere, waters, and biological organisms. Weathering occurs in situ (on site), that is, in the same place, with little or no movement, and thus should not be confused with erosion, which involves the movement of rocks and minerals by agents such as water, ice, snow, wind, waves and gravity and then being transported and deposited in other locations.

Two important classifications of weathering processes exist – physical and chemical weathering; each sometimes involves a biological component. Mechanical or physical weathering involves the breakdown of rocks and soils through direct contact with atmospheric conditions, such as heat, water, ice and pressure. The second classification, chemical weathering, involves the direct effect of atmospheric chemicals or biologically produced chemicals also known as biological weathering in the breakdown of rocks, soils and minerals.[1] While physical weathering is accentuated in very cold or very dry environments, chemical reactions are most intense where the climate is wet and hot. However, both types of weathering occur together, and each tends to accelerate the other. For example, physical abrasion (rubbing together) decreases the size of particles and therefore increases their surface area, making them more susceptible to rapid chemical reactions. The various agents act in concert to convert primary minerals (feldspars and micas) to secondary minerals (clays and carbonates) and release plant nutrient elements in soluble forms.

The materials left over after the rock breaks down combined with organic material creates soil. The mineral content of the soil is determined by the parent material; thus, a soil derived from a single rock type can often be deficient in one or more minerals needed for good fertility, while a soil weathered from a mix of rock types (as in glacial, aeolian or alluvial sediments) often makes more fertile soil. In addition, many of Earth's landforms and landscapes are the result of weathering processes combined with erosion and re-deposition.

Contents

Physical weathering

Physical weathering, also called mechanical weathering or disaggregation, is the class of processes that causes the disintegration of rocks without chemical change. The primary process in physical weathering is abrasion (the process by which clasts and other particles are reduced in size). However, chemical and physical weathering often go hand in hand. Physical weathering can occur due to temperature, pressure, frost etc. For example, cracks exploited by physical weathering will increase the surface area exposed to chemical action, thus amplifying the rate of disintegration.

Abrasion by water, ice, and wind processes loaded with sediment can have tremendous cutting power, as is amply demonstrated by the gorges, ravines, and valleys around the world. In glacial areas, huge moving ice masses embedded with soil and rock fragments grind down rocks in their path and carry away large volumes of material. Plant roots sometimes enter cracks in rocks and pry them apart, resulting in some disintegration; the burrowing of animals may help disintegrate rock However, such biotic influences are usually of little importance in producing parent material when compared to the drastic physical effects of water, ice, wind, and temperature change.

Thermal stress

Thermal stress weathering (sometimes called insolation weathering)[2] results from the expansion and contraction of rock, caused by temperature changes. For example, heating of rocks by sunlight or fires can cause expansion of their constituent minerals. As some minerals expand more than others, temperature changes set up differential stresses that eventually cause the rock to crack apart. Because the outer surface of a rock is often warmer or colder than the more protected inner portions, some rocks may weather by exfoliation – the peeling away of outer layers. This process may be sharply accelerated if ice forms in the surface cracks. When water freezes, it expands with a force of about disintegrating huge rock masses and dislodging mineral grains from smaller fragments.

Thermal stress weathering comprises two main types, thermal shock and thermal fatigue. Thermal stress weathering is an important mechanism in deserts, where there is a large diurnal temperature range, hot in the day and cold at night.[3] The repeated heating and cooling exerts stress on the outer layers of rocks, which can cause their outer layers to peel off in thin sheets. The process of peeling off is also called exfoliation. Although temperature changes are the principal driver, moisture can enhance thermal expansion in rock. Forest fires and range fires are also known to cause significant weathering of rocks and boulders exposed along the ground surface. Intense localized heat can rapidly expand a boulder.

The thermal heat from wildfire can cause significant weathering of rocks and boulders, heat can rapidly expand a boulder and thermal shock can occur. The differential expansion of a thermal gradient can be understood in terms of stress or of strain, equivalently. At some point, this stress can exceed the strength of the material, causing a crack to form. If nothing stops this crack from propagating through the material, it will result in the object's structure to fail.

Frost weathering

A rock in Abisko, Sweden fractured along existing joints possibly by frost weathering or thermal stress

Main article: Frost weathering

Frost weathering, frost wedging, ice wedging or cryofracturing is the collective name for everal processes where ice is present. These processes include frost shattering, frost-wedging and freeze–thaw weathering. Severe frost shattering produces huge piles of rock fragments called scree which may be located at the foot of mountain areas or along slopes.

Frost weathering is common in mountain areas where the temperature is around the freezing point of water. Certain frost-susceptible soils expand or heave upon freezing as a result of water migrating via capillary action to grow ice lenses near the freezing front.[4] This same phenomenon occurs within pore spaces of rocks. The ice accumulations grow larger as they attract liquid water from the surrounding pores. The ice crystal growth weakens the rocks which, in time, break up.[5] It is caused by the approximately 10% (9.87) expansion of ice when water freezes, which can place considerable stress on anything containing the water as it freezes.

Freeze induced weathering action occurs mainly in environments where there is a lot of moisture, and temperatures frequently fluctuate above and below freezing point, especially in alpine and periglacial areas. An example of rocks susceptible to frost action is chalk, which has many pore spaces for the growth of ice crystals. This process can be seen in Dartmoor where it results in the formation of tors. When water that has entered the joints freezes, the ice formed strains the walls of the joints and causes the joints to deepen and widen. When the ice thaws, water can flow further into the rock. Repeated freeze–thaw cycles weaken the rocks which, over time, break up along the joints into angular pieces. The angular rock fragments gather at the foot of the slope to form a talus slope (or scree slope). The splitting of rocks along the joints into blocks is called block disintegration. The blocks of rocks that are detached are of various shapes depending on rock structure.

Ocean waves

Wave action and water chemistry lead to structural failure in exposed rocks

Coastal geography is formed by the weathering of wave actions over geological times or can happen more abruptly through the process of salt weathering.

Pressure release

Erosion and tectonics

Pressure release could have caused the exfoliated granite sheets shown in the picture. In pressure release, also known as unloading, overlying materials (not necessarily rocks) are removed (by erosion, or other processes), which causes underlying rocks to expand and fracture parallel to the surface.

Intrusive igneous rocks (e.g. granite) are formed deep beneath the Earth's surface. They are under tremendous pressure because of the overlying rock material. When erosion removes the overlying rock material, these intrusive rocks are exposed and the pressure on them is released. The outer parts of the rocks then tend to expand. The expansion sets up stresses which cause fractures parallel to the rock surface to form. Over time, sheets of rock break away from the exposed rocks along the fractures, a process known as exfoliation. Exfoliation due to pressure release is also known as "sheeting".

Retreat of an overlying glacier can also lead to exfoliation due to pressure release.

Salt-crystal growth

Tafoni at Salt Point State Park, Sonoma County, California.

Salt crystallization, otherwise known as haloclasty, causes disintegration of rocks when saline solutions seep into cracks and joints in the rocks and evaporate, leaving salt crystals behind. These salt crystals expand as they are heated up, exerting pressure on the confining rock.

Salt crystallization may also take place when solutions decompose rocks (for example, limestone and chalk) to form salt solutions of sodium sulfate or sodium carbonate, of which the moisture evaporates to form their respective salt crystals.

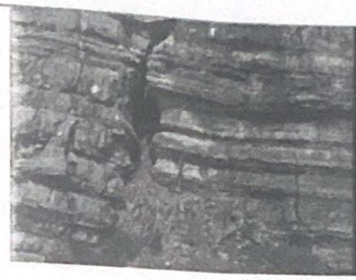
The salts which have proved most effective in disintegrating rocks are sodium sulfate, magnesium sulfate, and calcium chloride. Some of these salts can expand up to three times or even more.

It is normally associated with arid climates where strong heating causes strong evaporation and therefore salt crystallization. It is also common along coasts. An example of salt weathering can be seen in the honeycombed stones in sea wall. Honeycomb is a type of tafoni, a class of cavernous rock weathering structures, which likely develop in large part by chemical and physical salt weathering processes.

Biological effects on mechanical weathering

Living organisms may contribute to mechanical weathering (as well as chemical weathering, see 'biological' weathering below). Lichens and mosses grow on essentially bare rock surfaces and create a more humid chemical microenvironment. The attachment of these organisms to the rock surface enhances physical as well as chemical breakdown of the surface Microlayer of the rock. On a larger scale, seedlings sprouting in a crevice and plant roots exert physical pressure as well as providing a pathway for water and chemical infiltration.

Chemical weathering



Chemical weathering changes the composition of rocks, often transforming them when water interacts with minerals to create various chemical reactions. Chemical weathering is a gradual and ongoing process as the mineralogy of the rock adjusts to the near surface environment. New or secondary minerals develop from the original minerals of the rock. In this the processes of oxidation and hydrolysis are most important. Chemical weathering is enhanced by such geological agents as the presence of water and oxygen, as well as by such biological agents as the acids produced by microbial and plant-root metabolism.

The process of mountain block uplift is important in exposing new rock strata to the atmosphere and moisture, enabling important chemical weathering to occur; significant release occurs of Ca^{2+} and other ions into surface waters.[6]

Dissolution and carbonation

Limestone core samples at different stages of chemical weathering (due to tropical rain and underground water), from very high at shallow depths (bottom) to very low at greater depths (top). Slightly weathered limestone shows brownish stains, while highly weathered limestone transformed into clay.

Rainfall is acidic because atmospheric carbon dioxide dissolves in the rainwater producing weak carbonic acid. In unpolluted environments, the rainfall pH is around 5.6. Acid rain occurs when gases such as sulfur dioxide and nitrogen oxides are present in the atmosphere. These oxides react in the rain water to produce stronger acids and can lower the pH to 4.5 or even 3.0. Sulfur dioxide, SO_2, comes from volcanic eruptions or from fossil fuels, can become sulfuric acid within rainwater, which can cause solution weathering to the rocks on which it falls.

Some minerals, due to their natural solubility (e.g. evaporites), oxidation potential (iron-rich minerals, such as pyrite), or instability relative to surgical conditions (see Goldich dissolution series) will weather through dissolution naturally, even without acidic water.

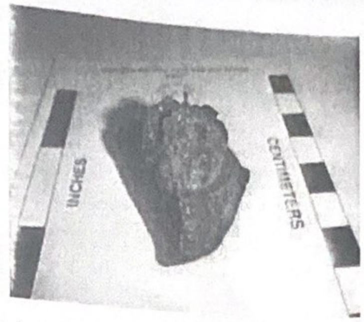
One of the most well-known solution weathering processes is carbonation, the process in which atmospheric carbon dioxide leads to solution weathering. Carbonation occurs on rocks which contain calcium carbonate, such as limestone and chalk. This takes place when rain combines with carbon dioxide or an organic acid to form a weak carbonic acid which reacts with calcium carbonate (the limestone) and forms calcium bicarbonate. This process speeds up with a decrease in temperature, not because low temperatures generally drive reactions faster, but because colder water holds more dissolved carbon dioxide gas. Carbonation is therefore a large feature of glacial weathering.

The reactions as follows:

$$CO_2 + H_2O \rightarrow H_2CO_3$$

Carbonation on the surface of well-jointed limestone produces a dissected limestone pavement. This process is most effective along the joints, widening and deepening them.

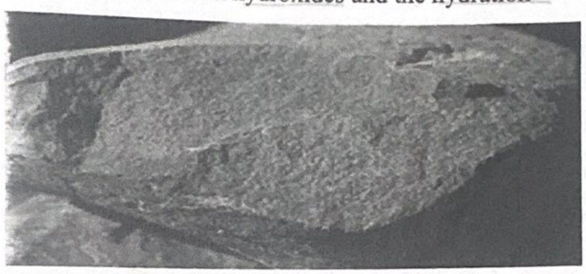
Hydration



Olivine weathering to iddingsitewithin a mantle xenolith

Mineral hydration is a form of chemical weathering that involves the rigid attachment of H+ and OH- ions to the atoms and molecules of a mineral.

When rock minerals take up water, the increased volume creates physical stresses within the rock. For example, iron oxidesare converted to iron hydroxides and the hydration of anhydrite forms gypsum.



A freshly broken rock shows differential chemical weathering (probably mostly oxidation) progressing inward. This piece of sandstone was found in glacial drift near Angelica, New York

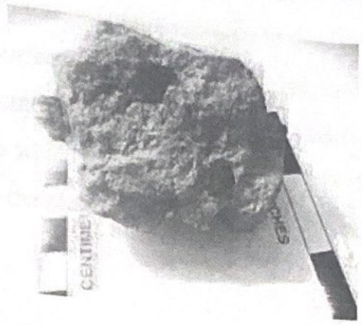
Hydrolysis of silicates and carbonates

Hydrolysis is a chemical weathering process affecting silicate and carbonate minerals. In such reactions, pure water ionizes slightly and reacts with silicate minerals. An example reaction:

This reaction theoretically results in complete dissolution of the original mineral, if enough water is available to drive the reaction. In reality, pure water rarely acts as a H^+ donor. Carbon dioxide, though, dissolves readily in water forming a weak acid and H^+ donor.

This hydrolysis reaction is much more common. Carbonic acid is consumed by silicate weathering, resulting in more alkaline solutions because of the bicarbonate. This is an important reaction in controlling the amount of CO_2 in the atmosphere and can affect climate.

Aluminosilicates when subjected to the hydrolysis reaction produce a secondary mineral rather than simply releasing cations.



Oxidation

Oxidized pyrite cubes

Within the weathering environment chemical oxidation of a variety of metals occurs. The most commonly observed is the oxidation of Fe^{2+} (iron) and combination with oxygen and water to form Fe^{3+} hydroxides and oxides such as goethite, limonite, and hematite. This gives the affected rocks a reddish-brown coloration on the surface which crumbles easily and weakens the rock. This process is better known as 'rusting', though it is distinct from the rusting of metallic iron. Many other metallic ores and minerals oxidize and hydrate to produce colored deposits, such as chalcopyrites or $CuFeS_2$ oxidizing to copper hydroxide and iron oxides.

Biological weathering

A number of plants and animals may create chemical weathering through release of acidic compounds, i.e. the effect of moss growing on roofs is classed as weathering. Mineral weathering can also be initiated or accelerated by soil microorganisms. Lichens on rocks are thought to increase chemical weathering rates. For example, an experimental study on hornblende granite in New Jersey, USA, demonstrated a 3x – 4x increase in weathering rate under lichen covered surfaces compared to recently exposed bare rock surfaces.[7]

The most common forms of biological weathering are the release of chelating compounds (i.e. organic acids, siderophores) and of acidifying molecules (i.e. protons, organic acids) by plants so as to break down aluminium and iron containing compounds in the soils beneath them. Decaying remains of dead plants in soil may form organic acids which, when dissolved in water, cause chemical weathering.[8] Extreme release of chelating compounds can easily affect surrounding rocks and soils, and may lead to podsolisation of soils.[9]