Geo Factsheet

Number 18

Weathering

Weathering can be defined as the disintegration of rocks in situ. Three types of weathering occur - physical (mechanical), chemical and biological - but it is important to realise that the overall weathering process involves an *interaction* of these three types. The efficiency of weathering processes depends upon the interaction between climate, the properties of the rock and local factors such as relief.

Physical weathering (PW)

PW can be defined as the disintegration of rock without any significant change in the chemical or mineral composition of the rock.

PW involves four main process:

- Ice wedging and crystallisation
- Salt crystallisation
- Insolation weathering
- Surface unloading

Ice wedging

When water freezes, for example in a rock crack, it expands by 9%. The resulting pressure of the ice wedge commonly rises to 7-15kg/cm^2 which may exceed the tensile strength of the rock, causing the rock to crack and open. Steep mountain slopes and cliffs are particularly susceptible and **talus** slopes or **screes** - heaps of angular rubble which slide underfoot - may form. **Ice crystals** may form in the pore spaces of rocks, increasing the chances of a fracture along any line of weakness.

Salt crystallisation

The evaporation of water from rock surfaces in semi-arid environments leads to increasingly concentrated solutions within the rock. Eventually, crystallisation of the salts will occur with a dramatic increase in volume, hence pressure. This pressure may fracture the rock.

Insolation weathering

Since rock is a poor conductor, hot days will result in the outer parts of a rock becoming much hotter than its interior. At night, loss of surface heat by radiation will reverse the temperature gradient. Such differential heating and cooling could, theoretically, lead to alternate and differential expansion and contraction of different parts of the rock (and of the different minerals within a rock).

> ***Exam Hint*** *- Weaker candidates clearly do not understand the crucial difference between weathering and erosion . . . Even those who appreciate the three main types of weathering fail to show that they understood how these three interact.*

The resulting stresses and tensions have been shown to be insufficient in themselves to cause rock disintegration but, once water is present, such processes become very significant. It has been shown that even in deserts insolation weathering is an insignificant process until water, perhaps in the form of a rare but rapidly-cooling downpour, becomes available.

Surface unloading

When rocks which have been formed under great pressures are exposed to the surface, perhaps through erosion of overlying material, sudden pressure changes can cause dramatic expansion of the outer, newly-exposed layers. This expansion causes joints to form at right angles to the direction of pressure release - huge sheets of rocks peel off like onion layers. This is known as **exfoliation** and can be clearly seen in landscapes containing **inselbergs** e.g. North Mozambique.

Chemical weathering (CW)

Chemical weathering involves the decomposition of rocks by the action of air, water or acid.
Five main processes are involved:

- Hydration
- Hydrolysis
- Oxidation
- Carbonation
- Solution

Hydration

This is often classified as a physical process since disintegration of the rock or mineral is due to the volume charge which occurs when water molecules are absorbed into the crystal matrix of the rock.

e.g. $SiO_2 + 2H_2O \rightarrow Si(OH)_4$

Hydrolysis

One or more minerals are split by chemical reaction with water. For example, the hydrolysis of feldspars e.g. orthoclase feldspar ($KAlSi3O_8$) produces clay minerals such as kaolinite ($Si_4Al_4O_{10}\{OH\}_8$) along with hydrogen ions and silicic acid, both of which may be leached away. The clay mineral, in the form of a colloidal suspension, may then be broken down further into aluminium hydroxide and silicic acid.

In tropical climates the aluminium hydroxide may accumulate at or near the surface forming **bauxite**, the **ore** from which aluminium is commercially extracted.

Oxidation

Oxygen, in gaseous form or dissolved in water will react with many metal ions contained in minerals.

$$\underset{\text{grey-green iron II oxide}}{4FeO} + 3H_2O + O_2 \rightarrow \underset{\text{rusty iron III oxide}}{2Fe_2O_3.3H_2O}$$

Carbonation

This involves the reaction of minerals with carbonic acid, which naturally forms when carbon dioxide dissolves in moisture.

$$CO_2 + H_2O \rightarrow \underset{\text{carbonic acid}}{H_2CO_3}$$

For example, acid rain aggressively weathers chalk;

$$CaCO_3 + H_2O + \underset{\text{from respiration or decay}}{CO_2} \rightarrow \underset{\text{calcium bicarbonate, soluble and leached away}}{Ca(HCO_3)_2}$$

Solution

Many minerals are soluble and are removed when they dissolve in water. Acidification of water will usually accelerate this process.

To summarise, chemical weathering causes rock disintegration by:

- Weakening the coherence of minerals
- Dissolution and removal of minerals
- Mineral expansion through combination with oxygen or water.

Biological weathering

Biological weathering refers to the breakdown of rocks and minerals as a result of the activities of plants, animals and micro-organisms. Plant roots can force open cracks as they grow and expand, lichens (associations of an alga and a fungi) decompose rocks by selectively absorbing minerals, and many bacteria are capable of oxidising or reducing certain minerals during their nutrition. Clearly, biological weathering involves a combination of physical and chemical processes.

Factors affecting the rate of weathering

Minerals and rocks vary greatly in their susceptability to weathering (Table.1)

Table 1.

Mineral weathering	Rock weathering
(Decreasing resistance to weathering)	
Quartz Feldspar Biotite Hornblende Pyroscene Oliviine	Granite Diorite Gabbro

Igneous rocks which contain quartz may therefore be very slow to weather. Besides mineral composition, the rate of weathering of rocks is also heavily influenced by climate, relief and human activity (Table.2).

Weathering therefore involves an interaction between biological, physical and chemical processes. Physical disintegration increases the surface area of rocks or mineral fragments which can then be chemically decomposed and this, in turn, makes further physical breakdown easier. Cracks, joints and exfoliation planes all make it easier for air, water and roots to enter and accelerate weathering (Fig.1)

The products of weathering

Weathered material **(saprolite)** may accumulate at the site of weathering and exceed 100 metres in depth on gentle slopes.

In general, weathering products include fragments of rocks and minerals along with both soluble and insoluble decomposition products. The nature of these products varies greatly depending upon rock composition, climate and relief.

In the **humid tropics** high temperatures, rainfall and carbon dioxide levels mean that **chemical weathering** predominates. The soluble products of weathering may be leached. For example, at a surface pH of 5-9, silica is much more soluble than aluminium and will be removed preferentially with the result that **gibsitic** and **kaolinitic** clays form. Conversely, in **hot arid** areas, physical processes such as salt crystallisation, thermal expansion and contraction and exfoliation dominate. Evaporation of water from rock surfaces draws water from within the rock to the surface. Minerals such as metal halides and magenese oxides are contained within this water and are left behind on the rock surface when the water evaporates. The soft halides are easily removed by the wind but this leaves others behind as a red brown varnish.

Fig 1. The interaction of weathering processes

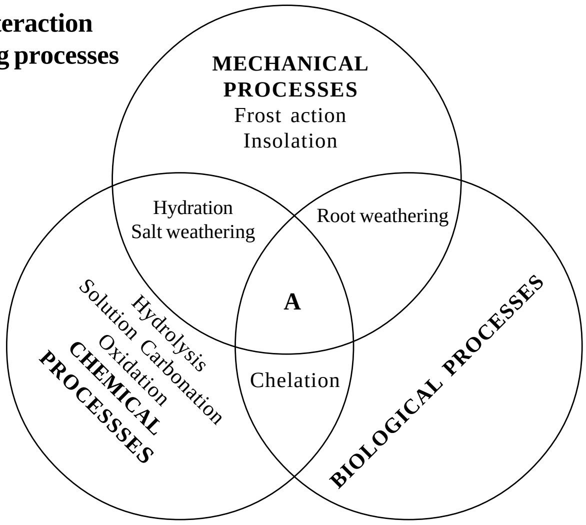

Table 2. Factors affecting rate of weathering

FACTOR		EXAMPLE / EXPLANATION
Soil & Topography	Mineral composition	Igneous rocks containing quartz may weather very slowly
	Rock porosity	Greater porosity allows easier entry of air, water, roots and soil organisms
	Nature of cement	Some cements within sedimentary rocks are more susceptible to chemical weathering than others
	Degree of rock fracturing	Fractures represent weak points which physical, chemical and biological processes can exploit
	Relief	On slopes, weathered material moves downhill, exposing fresh rock to agents of weathering
Climate	Availability of water	Essential for most physical weathering processes-hydration, hydrolysis, carbonation and solution
	Frequency and extent of frosts/freezing	Frequent expansion/contraction very effective at fragmenting rocks
	Diurnal temperature range	Influences exfoliation and alternate expansion/contraction of minerals
	Mean daily temperature	Rate of chemical reactions increase as temperature increases. Water and temperature regulate biotic activity, hence physical weathering processes such as root penetration and chemical weathering as a result of carbon dioxide production in respiration
Human Activity	Soil cultivation	Cultivation may significantly change the composition of soil air (which influences chemical weathering) and the entry of water/organisms
	Acidification	Release of carbon dioxide and oxides of sulphur and nitrogen from fossil fuel combustion has increased the production of acid rain

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