Fig. 3.16 The Mid-Atlantic Rift at Thingvellir, Iceland. The North American Plate is on one side of the rift and the Eurasian Plate is on the other

Weathering

Weathering is the decay and disintegration of rocks *in situ*, involving physical, chemical and biological processes. It excludes the erosional effects of running water, rivers, the sea, glaciers and the wind. The weathering processes do not transport the products away.

Rocks and minerals become adjusted to surface environments different from those in which they were formed. The products cover the Earth's surface as part of the **regolith** and go on to form new rocks. The regolith is the surface cover of loose, unconsolidated material including alluvium, glacial deposits, wind-blown sand, peat, scree and soil.

Physical weathering

Freeze–thaw

This process is also known as **frost shattering**. Water trickles into cracks such as joints during the day. At night this water freezes, expands by about 10 per cent and widens the crack. The stress produced by the expansion is greater than the resistance of the rock. Repeated freezing and thawing results in disintegration and the production of **scree** (**talus**) and **felsenmeer** (block fields). In temperate areas such as the highlands in the UK, these features are largely relics of the past periglacial climate rather than actively forming today. The critical feature for the process to be active is the number of freeze-thaw cycles rather than the intensity of the frost. This means that the processes is not active in winters in continental interiors where there is constant frost.

The shape and size of the particles produced by the process is controlled by the nature of the rock, especially lines of weakness such as joints, bedding planes and cleavage.

Scree is angular rock fragments. It falls from cliffs in areas of freeze-thaw action, falls down gulleys and is deposited as cone or fan shapes which may coalesce with one another. Such slopes are prominent features of many mountainous areas.

Fig. 3.17 Scree slopes in north-west Scotland

Heating and cooling (thermal fracture)

Large diurnal ranges of temperature in deserts cause rocks and minerals to expand during the day and contract during the night, resulting in disintegration.

Granular disintegration

This process is partly responsible for producing sand in deserts. Rates of expansion and contraction vary between:

- different minerals
- different axes of a crystal
- crystals of different sizes.

Also, different coloured minerals absorb and emit heat at different rates. A pale-coloured rock like granite will reflect more heat than a dark-coloured one like basalt (see the albedo effect in Chapter 2). Complex stresses are set up in rocks which results in disintegration to produce mineral grains and the great sand seas or **ergs** found in some deserts.

Fig. 3.18 A sandy desert surface in Namibia

Block disintegration

This produces rock fragments not mineral grains and results in the features of the stony deserts known as **reg**. Scree slopes at the foot of cliffs and boulder fields are produced.

Fig. 3.19 A rocky desert surface in Namibia

Salt crystal growth

This process happens when salt solutions in the pores or joints of a rock crystallise. The crystals then expand and force the rock apart. The most effective salts are sodium sulfate, magnesium sulfate, sodium carbonate and calcium chloride. The process is particularly effective in temperatures of around 27 °C where temperature fluctuations produce expansion rates of up to 300 per cent.

Pressure release (dilatation)

This process, also known as **unloading**, affects areas where the ground surface is lowered by erosion. This removes weight from previously deeply buried rocks, e.g. a granite pluton which formed at immense pressure, several kilometres below the Earth's surface. This removal of weight leads to the expansion of the upper parts of the granite and allows cracks to occur parallel to the ground surface, sometimes known as **pseudo-bedding planes**. A similar process may occur where horizontal pressure is released by rock falls on a cliff face, allowing the growth of vertical cracks which, in turn, leads to further rock falls. This mechanism is significant after glaciation has occurred and can be caused by quarrying (see pages 87–90 on mass movement).

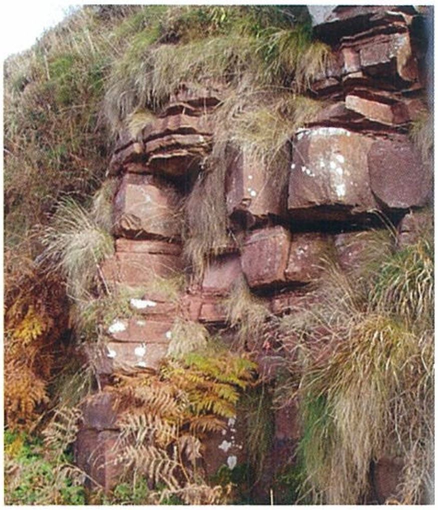

Fig. 3.20 In these alternating layers of sandstone and shales, the latter have been weathered more rapidly and have crumbled. The cliff surface is indented along the shale layers where vegetation is growing

Chemical weathering

Hydrolysis

This is when a mineral is broken down by a reaction with water. It is important in the silicate minerals that form most rocks, especially the mineral feldspar. The process usually occurs in acid conditions.

$$2KAlSi_3O_8 + 11H_2O + 2CO_2 \longrightarrow Al_2Si_2O_5(OH)_4$$

kaolinite (clay)

feldspar

+ $4H_4SiO_4$ silicic acid

+ $2K^+$

+ $2HCO_3^-$

ions in solution

The reaction shown above also includes some carbonation. The reaction produces a clay residue and various solutions which are removed in the groundwater and can be found in analysis of river water. You may see the variations in the formula written for hydrolysis.

Other clays are produced from other silicate minerals, e.g. montmorillonite.

Hydration and dehydration

Wetting and drying can cause the addition or removal of water from the molecules of some minerals, causing expansion or contraction which assist disintegration. The calcium sulfate minerals anhydrite and gypsum are affected.

$$\underset{\text{anhydrite}}{CaSO_4} + 2H_2O \leftrightarrow \underset{\text{gypsum}}{CaSO_4.2H_2O}$$

Carbonation

This process affects the carbonate minerals that make up limestone, especially calcite, calcium carbonate. Rainwater contains the weak acid, carbonic acid, which forms as the rain absorbs atmospheric carbon dioxide. Carbonic acid then attacks the carbonate minerals.

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

$$\underset{\text{carbonic acid}}{H_2CO_3} + \underset{\text{calcite}}{CaCO_3} \rightarrow \underset{\text{calcium hydrogen carbonate}}{Ca(HCO_3)_2}$$

Calcium hydrogen carbonate is removed in solution (sometimes known as hard water) and is washed away down rivers. The muddy insoluble impurities in the limestone are left as a clay residue. The process is responsible for the characteristic limestone scenery known as karst. The chemical weathering of limestone is accelerated by pollutants such as sulfur dioxide and oxides of nitrogen.

Fig. 3.21 Spheroidal weathering of basalt. Water has penetrated the rectangular joints allowing chemical weathering to produce rounded blocks

11. Physical and chemical weathering are often considered separately; however, in nature the two are often linked. Explain how chemical processes can have a physical effect.

Organic action – vegetation roots

Biological weathering can have a physical effect on rocks as seen in the wedging effect of tree roots. Where the soil is shallow, the seeds and roots of trees find their way into natural cracks in the bedrock. As the seeds germinate and the roots get bigger, they make the cracks wider and deeper, eventually breaking up the bedrock. This effect can often be seen in road cuttings and quarries.

Other biological effects tend to assist chemical processes, for example as follows:

- → The release of humic acids by decaying vegetation encourages hydrolysis.
- → The release of carbon dioxide by plants encourages carbonation.
- → A blanket of vegetation traps water and encourages a variety of chemical processes.

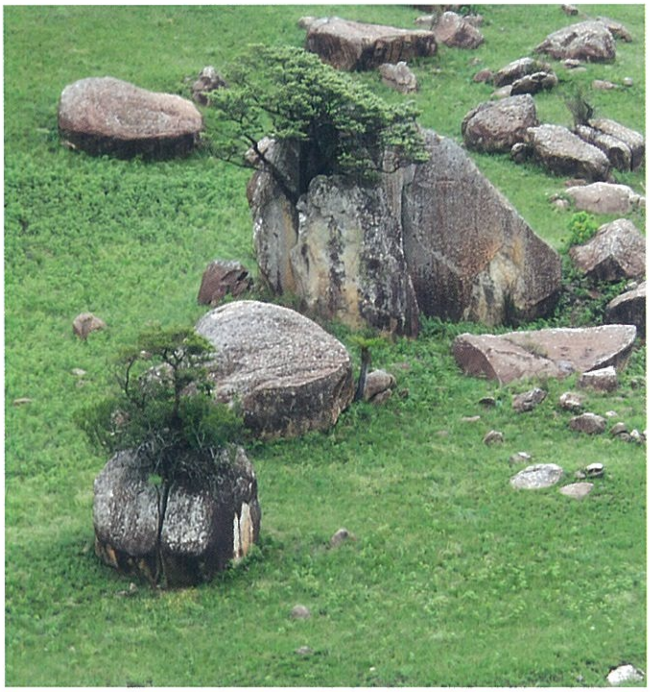

Fig. 3.22 The wedging effect of tree roots, Drakensberg Mountains, South Africa

Factors influencing weathering

Climate	Climate determines which weathering processes will occur and the rate at which they occur. This is considered in more detail below.
Rock structure	Weaknesses such as joints, bedding planes and cleavage allow water penetration and increase both physical and chemical effects (see Fig. 3.20). These weaknesses also control the size and shape of the weathered fragments. Good examples are the spheroidal weathering of dolerite, the formation of tors in granite and the formation of scree slopes.
Rock texture	In general, coarse-grained rocks weather faster than their fine-grained equivalents because the weathering of one mineral in the rock tends to weaken the fabric of the rock to a greater degree. Igneous rocks have a greater resistance to physical disintegration than sedimentary rocks because of the greater strength of interlocking crystalline textures in comparison with granular ones.
Rock composition	The minerals which form at the highest temperatures are the least stable at surface temperatures. This means that minerals in the dark-coloured rocks such as basalt weather faster than those in pale-coloured rocks such as granite.

	Minerals in basalt	Minerals in granite
Most susceptible	olivine plagioclase feldspar pyroxene	biotite
Least susceptible		orthoclase feldspar muscovite quartz