# Chapter 2

# Reading landscapes: how landscapes contain evidence of the relationship between past and present processes and the underlying geology

## 2.1 The landscape is subject to processes of weathering, erosion and transportation

All the lumps and bumps you can see in the landscape, all the hills, valleys, ridges, mountains, lowlands, bays and headlands, are caused by just three things: the character and structure of the underlying rocks, the type and power of the surface processes and, nowadays, human activity. This chapter will help you to stand on a hill and make sense of all the lumps and bumps in the landscape that you can see.

In Figure 1.1 tough rocks form the hill the photo is taken from, the ridge in the distance and the hills in the background, while weaker rocks underlie the plain below. The plain is flat because the weaker rocks underlying it were eroded to a lower level before flat-lying sediment was deposited on the top. Human activity has modified all this by building roads and buildings and excavating quarries, and by agricultural activity over thousands of years.

Weathering and erosion remove material from the higher places on Earth and it is transported, largely downhill, to the lower parts, where it is deposited. So higher points become worn down and sediment builds up in the lower parts. Weathering, erosion, transportation and deposition are therefore key elements of the sedimentary cycle.

Weathering attacks all natural rock surfaces as well as all constructions, such as buildings, bridges and dams. **Weathering** is defined as: 'the natural break up and break down of rock and other materials at the Earth's surface, without the removal of solid material'. 'Break up' means that the material is broken into smaller pieces by physical processes, whilst 'break down' is chemical breakdown, into new compounds. During weathering,

Figure 2.1: Natural lumps and bumps in the landscape, caused by the effects of underlying rocks of different toughness and a range of natural surface processes. A view from Glastonbury Tor across the Somerset Levels in South West England.

Figure 2.2: Freeze-thaw weathering has forced the cracks in this rock apart.

material can be dissolved and removed in solution, but any movement away of solid material is erosion and not weathering. Weathering happens in place (*in situ*) and loosens material that is later removed by erosion.

So, **physical weathering** causes the break up of rock surfaces, and the most common type of physical weathering in areas where the weather becomes cold enough to freeze, is **freeze-thaw weathering** (Figure 1.2). Water is a very unusual substance because when it becomes solid, its volume increases (usually when liquids become solid, their volumes decrease). When water freezes, the volume of the ice formed is 9% more than the volume of the original water. This means when water gets into permeable rocks, between the grains or along cracks, and freezes, it expands and pushes the grains and cracks apart. When it melts, a little more water fills the space and later freezes again. Many cycles like this eventually weaken the rock so that pieces break away, so it has most effect where there is frequent freezing and thawing, as on many mountain tops. After being loosened, the broken pieces are moved by erosion, often by gravity, causing them to fall away. So beneath rock faces affected by freeze-thaw weathering, gravity-erosion has usually built up a sloping pile of angular rock fragments, called **scree** (see Figure 1.3). You can see the effects of freeze-thaw weathering on the outsides of walls and buildings as well, with fragments of brick, stone and concrete building up at the bottom of the wall.

Physical weathering also affects rocks in desert areas, because they become very hot in the day and very cold at night (see Figure 1.4). Since different minerals in the rocks expand and contract at different rates, the rock is weakened. This is weathering by heating and cooling, and commonly affects granites, where curved sheets can be broken away in a process called **exfoliation**. Lab experiments show that this doesn't happen to completely dry rocks though, so there must be a little water present (often from dew in deserts), causing some chemical weathering that weakens the rock as well.

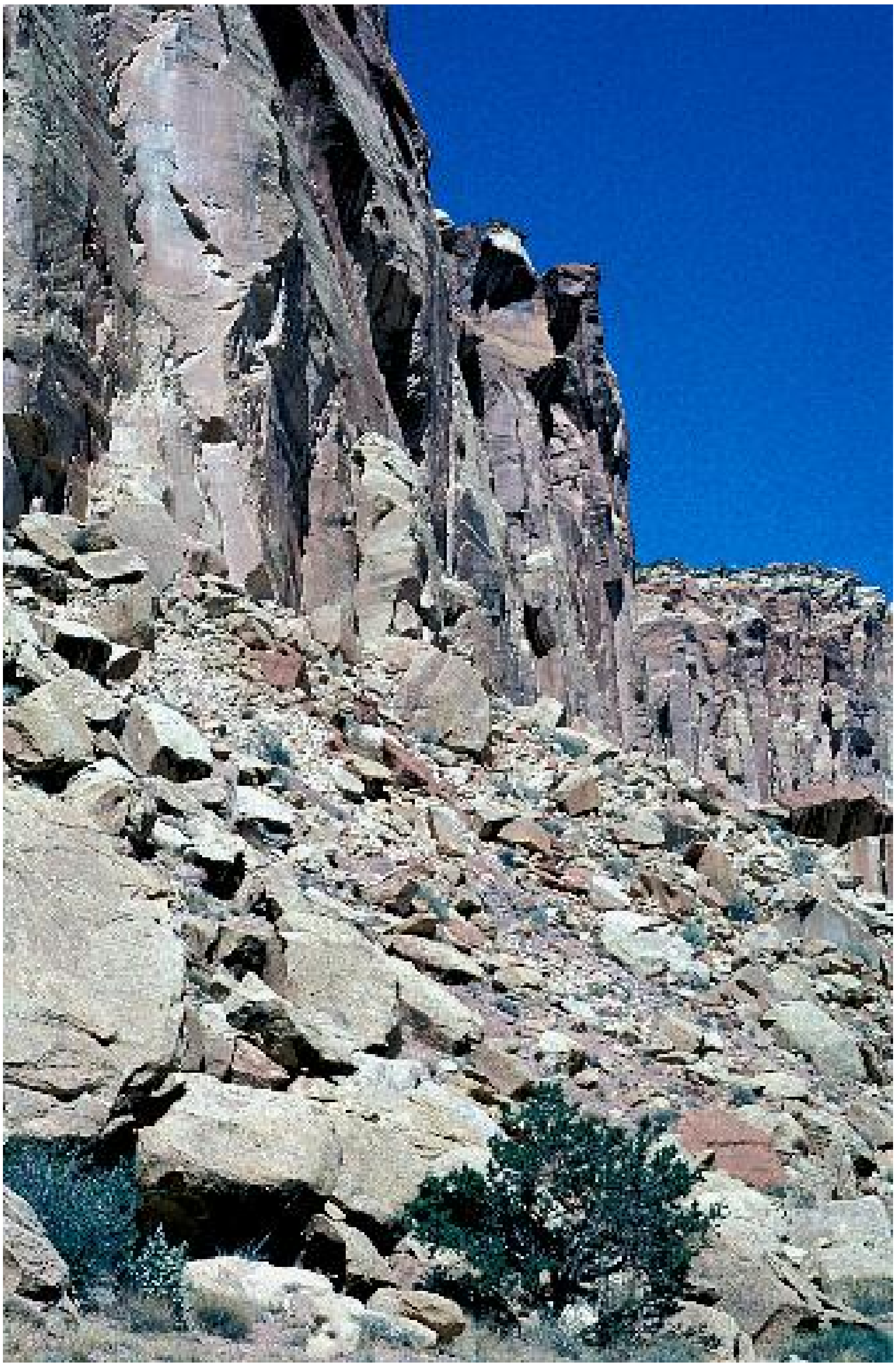

Figure 2.3: Rock fragments loosened by freeze-thaw weathering have been eroded by gravity, falling to make a sloping heap of scree under the rock face.

Figure 2.4: Granite affected by heating and cooling in a desert area. Curved sheets have been broken away in exfoliation.

Figure 2.5: Discolouration caused by chemical weathering along the joints in fine-grained sandstone.

**Chemical weathering** attacks rocks where the rain and soil water contain acid. Natural rainwater contains some dissolved carbon dioxide ($CO_2$). Soil also contains carbon dioxide, produced by all the small animals that live there. When rainwater flows through soil, it dissolves even more carbon dioxide, forming carbonic acid. In polluted areas, rainwater can contain other acids as well; it is then called '**acid rain**'. Acid rain contains dissolved nitrogen compounds forming nitric acid and dissolved sulfur compounds producing sulfuric acid as well as carbonic acid. You can tell when rocks and building materials have been attacked by acid chemical weathering, because the new compounds formed by chemical breakdown are usually of different colours. Any discolouration of rock or building stone surfaces is usually the result of chemical weathering. When the new compounds produced by chemical weathering are carried away in solution, this is part of the weathering process. But when chemical weathering loosens solid material and this is later moved, the movement of the solid materials is erosion. Limestone is strongly attacked by chemical weathering because naturally acid rainwater and acid rain both contain acid that directly attacks the calcium carbonate minerals in the limestone. The one-drop acid test for limestone shows this effect by the fizzing caused by the chemical reaction. Since the solid limestone is removed in solution, this is weathering, involving no erosion.

Chemical weathering is most active in tropical regions where temperatures are high (speeding up chemical reaction) and where there is often abundant water from rainfall. Weathering rates are increased where water can penetrate cracks in rock. Sandstones and igneous rocks often become discoloured along joints (see Figure 1.5). Meanwhile in limestone areas, joints are widened by chemical weathering so that limestone blocks become separated by wide cracks at the surface, as shown in Figure 1.6.

Plants have both physical and chemical weathering effects; together these effects can be called **biological weathering**. Plant roots and rootlets penetrate cracks in the rock and can grow along the edges of grains, forcing them apart. Meanwhile the rootlets release organic acids that chemically attack the rock. Fragments of rock become loosened and new compounds are carried away in solution. A progression of biological effects on

Figure 2.6: The joints in this limestone pavement have been widened by chemical weathering.

Figure 2.7: Lichen growing on a rock surface, with the physical and chemical effects of biological weathering breaking the rock surface down.

rocks can be seen, starting with lichen growing on bare rock surfaces (see Figure 1.7). The material loosened by the lichen growth is colonised by moss, which breaks down the material further. Then other plants, worms and other small animals, colonise this new soil, causing more biochemical effects and a thicker soil develops. Thus, the soil which covers much of our planet and is so important for growing the crops that feed us all, is produced by biological weathering processes. Use the 'Weathering - rocks breaking up and breaking down' activity on the http://www.earthlearningidea.com to match pictures of weathering to the processes that formed them, and see how Darwin 'discovered' how soil formed in 'Darwin's 'big soil idea”.

**Erosion** is: 'the removal of solid material, which has often been loosened by weathering'. Four main agents remove sediment: gravity, flowing water, wind, and ice. Each of these produces sediment which contains clues that tell us how it was transported and deposited, and we can recognise these clues in sediments preserved in the rock record.

If a piece of the roof above you falls down, it has been removed by erosion by gravity. It will be transported by gravity through the air and then be deposited on your head. In a similar way, the rock fragments in Figure 1.3, having been loosened by weathering, fell off and were deposited in the slope of scree under the rock face. Scree deposits are sloping heaps of angular pieces of rock, ranging in size from boulders to mud-grade sediment. They are typical of the poorly-sorted sediments found near their source rock.

Loose material is moved further downhill, either by gravity in landslips, or by being washed down by water. It eventually reaches gullies, streams and rivers, where it is transported by water currents. The sediment is moved by sliding or rolling along the bed, a process called **traction**, or by bouncing along, **saltation**, or is carried along buoyed up by the water current, in **suspension**. Dissolved material is also carried in **solution**. As sediment

Figure 2.8: This river has sorted the sediment into separate areas of gravel and sand and is carrying the mud out of the area.

Figure 2.9: A wind storm, transporting sand and carrying finer sediment out of the region.

particles are carried along, they are rounded and ground down, producing fine-grained sediment. The grinding down or abrasion of pebbles as they are rubbed together is called attrition, and they also grind down and abrade the bedrock they move over. Meanwhile, the water currents sort the sediment into gravels, sands and muds, which are deposited in different areas of the river valley, as shown in Figure 1.8. River sediments are therefore better sorted and more rounded than scree deposits. When they reach the sea, waves and tidal currents abrade and sort the sediments even more, into rounded beach gravels, well-sorted beach and shallow sea sands, and mud deposited in tidal mud flats. So, the more rounded the gravels, the longer the time and distance of their transportation. The level of energy of the water that deposited the sediments can be gauged from their size, since fast-flowing, high-energy currents are needed to carry pebbles, whilst sands are carried and deposited by slower currents. Muds and clays are only deposited by settling out of suspension in quiet conditions. So, the finer the sediment, the lower the energy of the water when the sediment was deposited.

Winds erode and transport sand and mud-grade sediment, as in Figure 1.9. As in water, sand grains are rolled or slid along by traction or bounced along in saltation. The sands are usually deposited in dunes of well-sorted, rounded sand grains. Muds are blown in suspension in the air beyond the area and may eventually be deposited in the sea, where they settle out as deep-sea muds.

Ice erodes sediment by pulling off fragments of bedrock, but mainly by grinding rock fragments across the bedrock surface. The abrasion of the rock surface, and attrition of the rock fragments, produces more sediment, mostly fine-grained clay. All this is carried by the ice, without any sorting or rounding. When the ice melts, the sediment is dumped as heaps of debris (Figure 1.10) that is mainly clay with sand and some boulders, called **till**.

Clearly, the shape and sorting of the sediments deposited by each of the surface processes provide clues to the processes that transported and deposited them.

Figure 2.10: The mixture of boulders and clay transported and deposited by a melting glacier.

## 2.2 Valley shapes generally reflect the mode of their formation

In upland areas, valleys tend to be steep-sided because active erosion is cutting down into the surrounding hills and upland areas. Where rivers are cutting valleys, the sides normally have even slopes, giving the valleys V-shapes. This is because the river cuts down into the valley floor whilst material slumps and slides down the valley sides, keeping the V-shape. In areas where the rocks are very strong, the sides can be near-vertical, and the result is a gorge. You can see the sloping valley sides of the river in Figure 1.8 and even more clearly in Figure 1.11, where the valley has a typical upland river valley V-shape.

Some upland valleys have wide U-shapes since they were carved by glaciers. During the ice age, glaciers flowed down old river valleys, grinding away not only the valley floor, but also the valley walls. This abrasion of the rock surface on both the bottom and sides of the valley produced the typical U-shape you can see in 1.12. So U-shaped valleys are typical of areas that were originally glaciated.

Usually valleys in upland areas are guided by the underlying geology, with the rivers cutting through areas of weaker rocks, such as mudstones or shales, or following other weaknesses in the rock, like faults or joint patterns. Sometimes though, the river pattern seems to have no link to the underlying geology at all, when the drainage pattern is described as **discordant**. This is usually because the rocks you can see today were

Figure 2.11: A V-shaped valley, cut by a river in an upland area.

Figure 2.12: A U-shaped valley, cut through this mountainous area by a glacier during the ice age.

Figure 2.13: A meandering river channel, cut across broad flat valley floor sediments in a lowland area.

Figure 2.14: This plateau is formed of tough, flat-lying lava flows. The rocks of the lowland below were much less resistant to erosion.

originally covered by another set of rocks, and the river developed its pattern on these overlying rocks. Now that it has cut down through the overlying rocks and removed them, the pattern has become superimposed on the geology beneath, with rivers cutting across ridges and other upland areas for no clear geological reason.

The valleys seen in lowland areas are rather different. Here the main process is not erosion, but deposition, and rivers deposit sediment, filling up old valleys rather than eroding new ones. So lowland valleys tend to be broad with flat floors. Sediments are deposited across these flat-bottomed valleys during floods, so that the valley floors gradually build up over time. Between floods, the rivers cut their channels across the flat valley-floor sediments, often in winding meandering patterns (Figure 1.13). So a meandering river pattern is a sign that deposition is the main process active there.

So, the shapes of valleys can give clues to the underlying geology and the processes that are forming them. Similarly the shapes of hills can often tell us about the underlying geological pattern as well.

## 2.3 Landforms often reflect underlying geological structure

When sedimentary sequences have tough layers with weaker rocks between them, several typical landscape features appear, depending on how steeply the rocks dip. Tough rocks stand out as higher land and weaker rocks have been eroded away to make valleys and lowlands.

If the rock sequence is horizontal, the tough rocks form horizontal upland areas called **plateaus**. Tough sandstones and limestones often form plateaus, but plateaus are also commonly formed by widespread lava flows of basalt, since the basalt lavas are usually more resistant to erosion than the surrounding rocks (Figure 1.14).

If the sequence of alternating tough rocks and weaker rocks is dipping at a small angle (usually less than 10°), ridges develop that slope gently downwards in the direction of dip, but are steeper in the other direction. These asymmetrical ridges are called **cuestas** (Figure 1.15). Where there are several tough beds in a sequence, a series of these ridges often forms, called **scarp and vale topography**. The topography, or land surface, has scarps, or cuestas, divided by valleys or vales.

When the sequence dips more steeply than 10°, **ridges** of the harder rocks usually form, with steep slopes on either side (Figure 1.16).

Where large faults cut across the landscape, with different rocks on either side, then erosion tends to remove one type of rock at a faster rate than the other and a steep slope develops between the two rock types (Figure 1.17). This is called a **fault scarp** and, since such large faults are usually straight, fault scarps tend to cut straight across the country.

If the main rock underlying an area is granite, a tough erosion-resistant rock, it usually forms undulating upland areas with poor soils. Sometimes the granite is so resistant that it is exposed on the hilltops as rounded domes of jointed rock called **tors** (figure 1.18).

These features mean that you can stand on a hill top and look across at the shapes of the hills to see how the geology is lying. You can do the same in coastal areas, where the tough rocks form headlands and the weaker rocks form the bays between them (Figure 1.19). So a series of alternating tough and weaker rocks at the coast can form a series of headlands and bays. You can find out which of the rocks in your local area are likely to form hills and headlands, and which will form valleys and bays by doing the 'Rock, rattle and roll' test on the http://www.earthlearningidea.com website.

Try looking at the view from your window. Any hills or upland areas you can see are made of tougher rocks, while weaker rocks form any valleys or lowlands. Can you tell from the shapes of the hills what the underlying geology is like? You might be able to tell from the shape of any valleys you can see how they were formed as well.

Figure 2.15: A cuesta of gently dipping tough rocks with weaker rocks on either side. The rocks dip in the direction of the shallow slope

Figure 2.16: A ridge of steeply dipping rocks, with weaker rocks on either side.

Figure 2.17: A large fault has shattered and weakened the rock here, and it was later eroded into a valley by a glacier. A long narrow lake now fills the valley. The rocks on the right hand side of this view were tougher than those on the left, producing higher land and a steeper fault scarp slope.

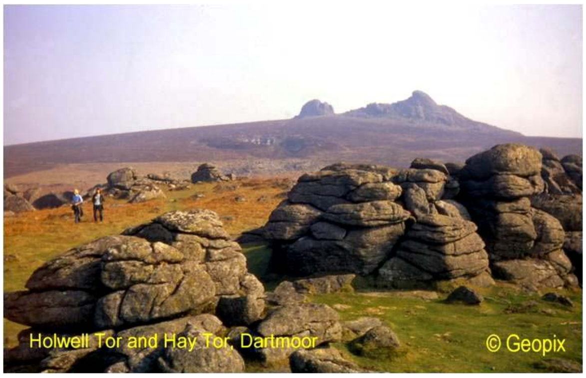


Figure 2.18: An upland granite area with a jointed granite tor exposed on top of the hill.

Figure 2.19: This photo was taken from a headland of tough rocks, across a bay cut by erosion into weaker rocks, towards the tough rocks of another headland in the distance.

## 2.4 Modification of the landscape by human activity is often influenced by the underlying geology

Your view from a hill may have been changed by human activity, particularly if the underlying rocks are valuable or contain valuable minerals. You may be able to see active **quarrying** or **mining** activity in the distance (as in Figures 1.20, 1.21 and 1.22), or signs that quarrying or mining once took place there (Figure 1.23).

In the past, when the quarrying or mining activity stopped, the area was usually abandoned leaving tell-tale signs, like rock faces in unexpected places, hollows in the land surface or heaps of mining debris, abandoned buildings or other signs of activity. Things are very different today, since mining and quarrying companies have contracts that require them to leave the site in good condition when they leave (Figure 1.24). This may mean filling old quarries with waste material and planting vegetation to cover them, landscaping old tips of mining debris, removing old buildings and mining or quarrying gear, or allowing old pits to flood. These old mining areas are called 'brownfield sites' because of their industrial past, since if they are to be used for new buildings, remediation has to be carried out to remove any pollution and deal with dangers such as subsidence from old mine workings. 'Brownfield sites' contrast with 'greenfield sites' where no such remediation is necessary. Sometimes old mine or quarry workings are made into country parks, nature reserves or golf courses for people to enjoy. Some of the most visited areas near industrial cities are reclaimed mining and quarrying areas of the past.

Figure 2.20: A quarry in the distance.

Figure 2.21: A working quarry.

Figure 2.22: A working mine.

Figure 2.23: An abandoned mine.

Figure 2.24: A restored quarry. The old quarry has been filled, the surface landscaped and vegetation has been planted.

Figure 2.25: Dinosaur tracks conserved in an old quarry.

## 2.5 Important rock exposures should be conserved

Old quarries and mining areas can be excellent for wildlife, since they often have a wide range of environments, from rocky ledges where birds can nest, to marshy areas for wetland creatures. However, some are worth preserving because of their geological interest. For example, it is important to preserve dinosaur tracks (Figure 1.25) and trails or fossil forests, but it may be equally important to preserve small fossil sites, or areas where rock-forming environments can be seen particularly easily. In the UK, sites of particular scientific interest, that can be both biological or geological, are identified as '**Sites of Special Scientific Interest**'. SSSIs cannot be used for development unless special permission is granted. Other sites that don't have national importance, but are still valuable for scientific or educational purposes are designated in the UK as '**Regionally Important Geological and Geomorphological Sites**' (RIGS). Really large and important areas can be designated as World Heritage Sites, such as the 'Jurassic Coast' along the coastline of Southern England, whilst many regions across the world are being given

Figure 2.26: A castle on a volcanic plug in the Bohemian Paradise Geopark.


Figure 2.27: Hazardous material in an old metal-mining area

**Geopark** status by UNESCO (the United National Educational, Scientific and Cultural Organisation) because of their geological importance and interest; Figure 1.26 shows an example.

Old mining and quarrying areas that have been conserved have been risk-assessed for health and safety and, providing visitors are sensible, the risks are small. However, the same cannot be said for other abandoned and working sites, which can be very dangerous areas (Figure 1.27). Working sites usually have good fencing with warning signs, but abandoned sites may have no warnings. There are particular dangers from unstable rock faces, old mine shafts or entrances that may not have been capped properly, old dams full of mud from mine workings, and quarries flooded with water that is often very deep and cold.

The Geological Fieldwork Code, published by the Geologists' Association, provides the following guidance for people visiting field sites in the UK, whether they are natural exposures or rock faces in old mining or quarrying areas. Similar guidance should be followed when visiting any geological sites across the world.

**GEOLOGICAL FIELDWORK CODE**

- Obey the Country Code and observe local bye-laws. Remember to shut gates and leave no litter.
- Always seek permission before entering onto private land.
- Don't interfere with machinery.
- Don't litter fields or roads with rock fragments that could cause injury to livestock or be a hazard to vehicles or pedestrians.
- Avoid undue disturbance to wildlife. Plants and animals may inadvertently be displaced or destroyed by careless actions.

- On coastal sections, whenever possible consult the coastguard service about tides or local hazards such as unstable cliffs.
- When working in mountains or remote areas, follow the advice given in the booklet "Safety on Mountains" issued by the British Mountaineering Council, and in particular inform someone of your intended route.
- When exploring underground, be sure you have the proper equipment and the necessary experience. Never go alone. Report to someone your departure, location, estimated time below ground and then your actual return.
- Don't take risks on insecure cliffs or rock faces. Take care not to dislodge rock: others may be below.
- Be considerate. Don't leave an exposure unsightly or dangerous for those who come after you.