



Source 1.19 A water-filled caldera forming the Blue Lake, Mt Gambier, South Australia

produced a shield area of around 50 000 km², with the most recent eruptions having taken place about 5 000 years ago at Mt Schank and Mt Gambier (the location of the water-filled crater of Blue Lake) in South Australia. These 2 explosive eruptions in South Australia were the culmination of volcanic activity that had begun in the Tertiary period (commencing about 65 million years ago). In India, the Deccan Traps were formed about 60 to 68 million years ago by multiple layers of **extruded** shield and flood basalts, which exceed depths of 2 000 m. Due to erosion and plate movements, the flood basalt province now covers only about 500 000 km²; it was even more extensive in the geological past. Lava flows sometimes produce unusual features, like the Undara Lava Tubes in north Queensland. Here lava flowed down valleys, solidified at the surface and allowed molten lava to move out

extruded pushed out through a vent or fissure

beneath the solidified surface. Once lava ceased flowing, the large underground gaps remained, creating the tubes that now form a bat habitat and attract many tourists.

Fissure vents are those where magma and gases escape through often lengthy fractures in the Earth's surface. Many of these fractures are associated with existing volcanoes, either because the magma is forcing the ground to fracture or because plate movements have ruptured the surface. In the 2 months before the 1991 eruption of Pinatubo in the Philippines, a 1.5 km long fissure was marked by steam, some ash emission and explosion craters. The fissure extended to the volcano's summit when the major eruption occurred in June of that year. Numerous fissures appear in Iceland, which is an above-sea-level part of the Mid-Atlantic Ridge, along the zone of seafloor spreading. Fissure vents in Iceland are thus probably created by divergent plate movements.

ACTIVITY 1.10

- 1 Find images showing examples of 3 different types of volcanoes.
- 2 Indicate where the volcanoes are located and when they erupted last.
- 3 Discuss the impacts on human populations of the volcano types investigated.

Plate tectonics and landforms at different scales

Plate tectonics and volcanism help us to understand landform differences at the continental scale, but the results of these forces are also visible at regional and local scales. At a regional scale, basalt flows from volcanoes may extend over a subcontinent, as in India; a graben may be inundated by the ocean, as in Spencer Gulf in South Australia; or a series of volcanic islands may appear, as with the Hawaiian Islands. At the smaller local scale,

swampy ground and changed river directions can result from fault movements; anticlines and synclines can be recognised in railway cuttings or other exposures; and volcanic craters of varying sizes can develop. Even smaller landform features are associated with each of the local or regional scale landforms – for example, fractures can be identified in crests of anticlines. When considering the processes at work to create landforms, each scale tends to overlap with others, so it is useful to think of possible explanations at various scales.

1.4 Rock types and landforms

Some landforms develop mainly on one rock type, like caverns in limestone. Other landforms, such

inselberg an isolated steep-sided hill, often made of bare rock

as **inselbergs** (German for 'island mountains'), can occur on a variety of different rocks. Rocks and weathered rock (sediments) can be viewed as the raw

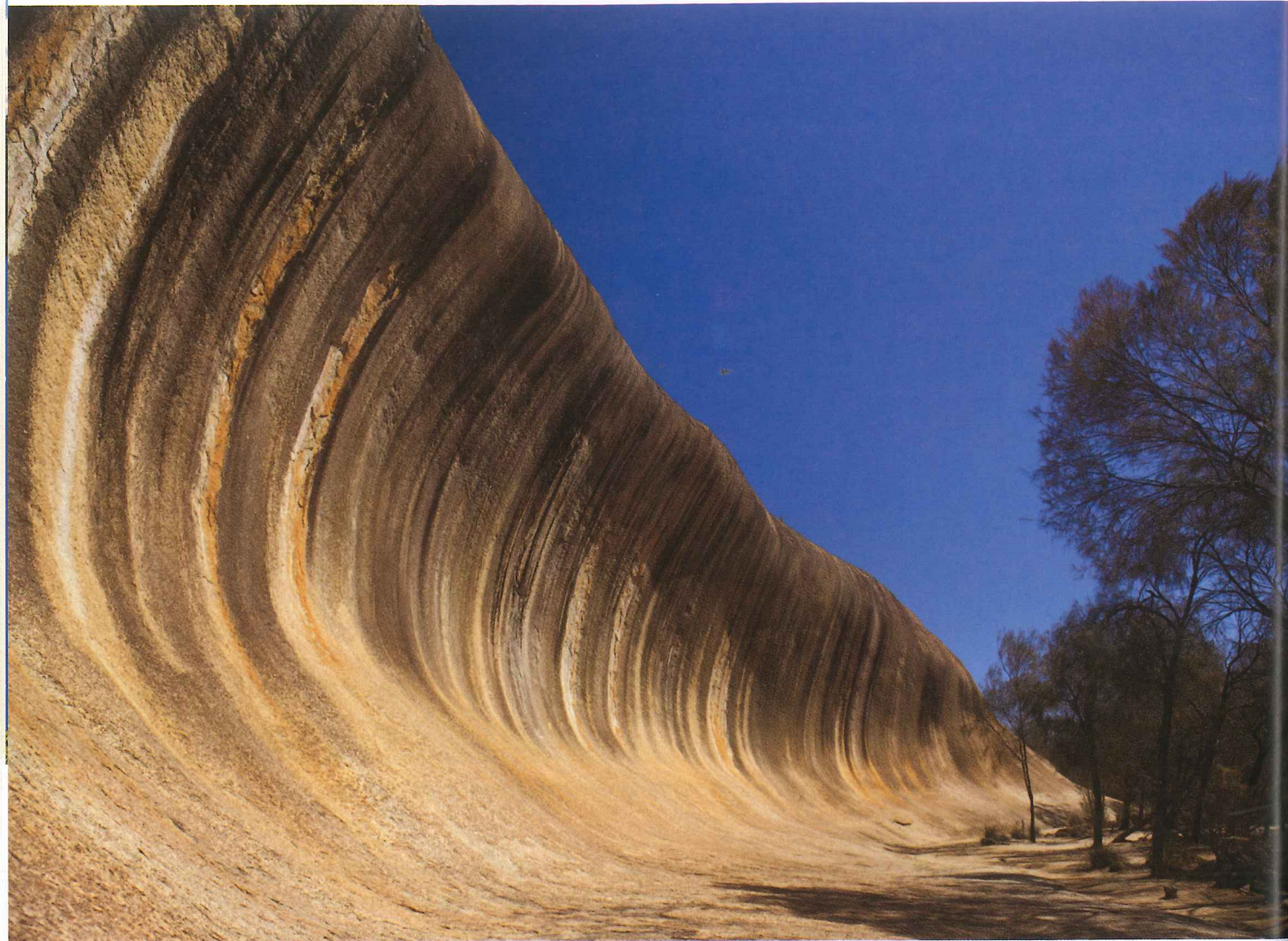
material of landscape that is fashioned into different forms by weathering and erosion. We can illustrate this by taking examples from the 3 main groups of rocks: igneous, sedimentary and metamorphic.

Igneous rocks and landforms

Igneous rocks originate from the solidification of magma. Rocks that solidify at depth are referred to as intrusive rocks, while those formed at the surface are called extrusive rocks, but various gradations exist. When magma cools slowly at depth, most crystals grow to larger than about 1 mm across, and so can be seen with the naked eye. This is the case with minerals in granite. In

contrast, extrusive rocks solidify from magma that has cooled quickly at the Earth's surface. Basalt, an extrusive rock, contains small crystals and often has vesicles.

Granite is more resistant to weathering and erosion than basalt because of the minerals it contains. When basalt outcrops in a wet climate, it eventually breaks down into a fertile soil. Granite, on the other hand, weathers more slowly into a gritty infertile soil due to the amount of quartz grains it contains. If relatively resistant granite is not strongly fractured by joints, it can form isolated high outcrops like Sugarloaf Mountain in Rio de Janeiro (Brazil), Wave Rock in Western Australia and the inselbergs on Eyre Peninsula in South Australia. These rock surfaces are relatively impermeable, and in Australia have been used as water collectors. Pits (gnammas) on the inselbergs often contain water after rain, and these natural supplies were used by Aboriginal people. Subsequently European settlers used some inselbergs as water-catchment areas for local dams.



Source 1.20 Wave Rock, a granite inselberg at Hyden, Western Australia: a low stone wall on top of the outcrop captures rainwater for a dam on the far edge of the granite.

Geographical fact

The explorer Edward John Eyre, when on the dry west coast of South Australia, noted in his diary that he found

a few drops of water trickling down a huge granite rock abutting on the sea-shore. This was the only approximation to running water which we had found since leaving Streaky Bay, and though it hardly deserved that name, yet it imparted to me as much hope, and almost as much satisfaction, as if I had found a river.

Sedimentary rocks and landforms

sandstone a rock composed mainly of sand-sized grains (diameter of 0.2–2 mm), most often quartz grains, with the matrix between these grains being made up of clay-sized particles (<0.05 mm in diameter). The rock is welded together by a cement or binder, generally siliceous (silica) or sometimes calcareous (calcite).

limestone a rock made up of calcium carbonate ('lime'), originally deposited under the ocean and formed from broken-up shells, corals, animal skeletons and other carbonate materials

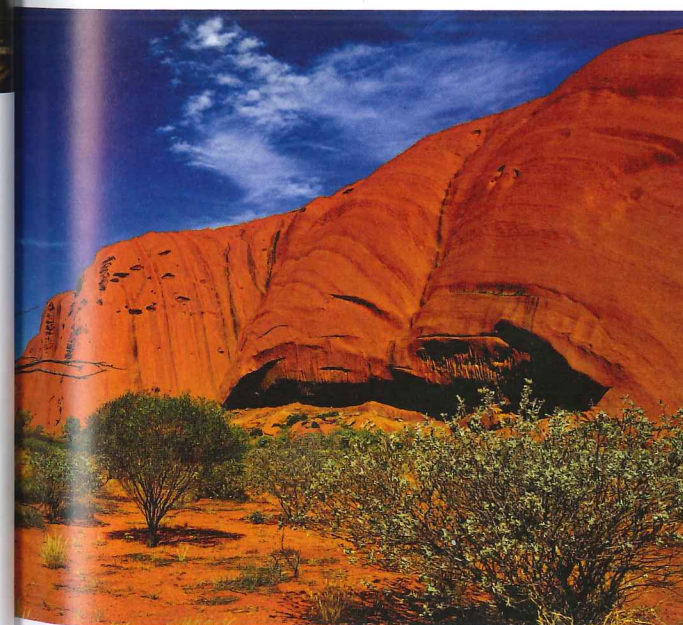
shale a rock composed of mostly clay-sized particles that have been compressed

Sedimentary rocks form from sediments deposited in layers (beds), which have later been compressed into solid rock. Many inselbergs in Australia are composed of granitic rocks, but such upstanding features in otherwise fairly flat areas can form on different rock types. Uluru, for example, is composed of a particular kind of **sandstone**, which is a sedimentary rock. Other sedimentary rocks include **limestone** and **shale**. Because all sedimentary rocks are deposited in layers, it is very easy to see whether the rock has been folded or faulted. If the beds have remained nearly flat-lying, plateaus can form, like those in the Blue Mountains in New South Wales. This area has mainly horizontally bedded sandstone, apart from the Lapstone Monocline on its eastern boundary. Most plateaus

have been dissected by streams, but the crests between the valleys will all have approximately the same height, as in the Blue Mountains.

More usually, sedimentary strata have been folded or tilted; in the case of Uluru, beds have been tilted nearly vertically to an angle of 85°. Along the east coast of the Adriatic Sea in the Mediterranean, limestone beds of the Dinaric Mountains have been folded and tilted, and dramatic mountain scenery with deep gorges has resulted from rivers cutting canyons through the mountains in order to reach the sea. Other landforms associated with limestone are also present: disappearing streams, deep solution hollows, sharp-edged rock where fractures are close together and numerous caves.

Contrasting with sandstone and limestone is shale, which is readily weathered and often produces subdued landscapes with gentle slopes and hills. These landforms appear in the Sydney Basin. Where steep slopes develop on shale, dissection has often been rapid and the climate is fairly dry so that weathering and erosion are slowed down.



Source 1.21 Edges of steeply dipping sandstone beds form corrugations on the surface of Uluru, Northern Territory.



Source 1.22 Canyon of the Morača River in the Dinaric Mountains, Montenegro. A road tunnel has been constructed through the cliff on the left.

ACTIVITY 1.11

- 1 Using the internet, find images of landforms developed on granite and on sedimentary rocks.
- 2 Indicate at least 1 landform that occurs only on igneous rocks; 1 that occurs only on sedimentary rocks; and 1 that develops on both igneous and sedimentary rocks.
- 3 Analyse whether climate seems to be the main control over which landforms develop on igneous and sedimentary rocks.

Metamorphic rocks and landforms

Metamorphic rocks are those that begin as igneous or sedimentary rocks, and have since been subjected to extreme pressure or temperature. For example, granite can be changed into **gneiss** and shale can be transformed into the much harder rock, **slate**. Because of compressive stresses during its formation, slate splits easily along planes to produce smooth leaves or plates, allowing the plates to be used as roofing tiles in older public buildings

gneiss originally a granite-type or a sedimentary rock that has been subjected to strong pressure, which also involves high temperatures, resulting in light- and dark-coloured minerals forming bands

slate shale changed into a stronger rock by heat and pressure within the Earth's surface

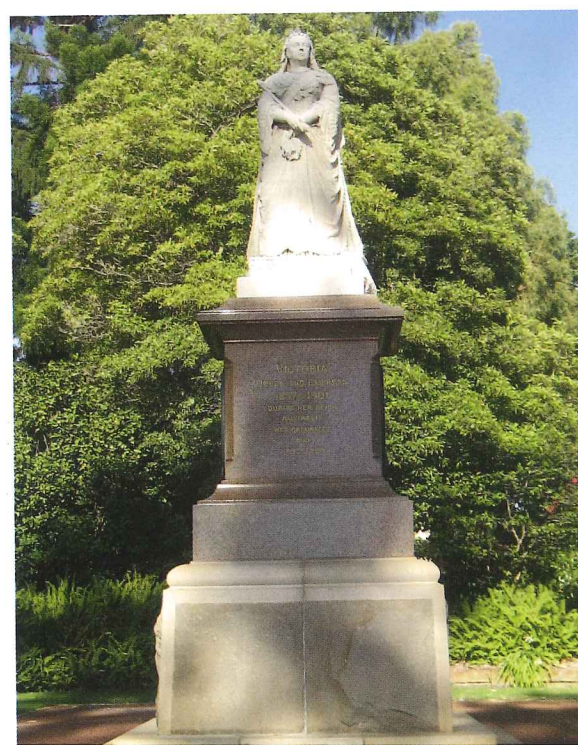
and residences. In the United States, slate is also advertised as being ideal for billiard tables, as it provides a smooth, tough surface and, properly installed, does not require high maintenance. When limestone is severely compressed, it forms **marble**, a rock that often has attractive colouring due to impurities like iron being present. Marbles in Australia are nearly all coloured, while the Carrara quarries in Italy produce white/grey marble that is exported around the world. Carrara marble has fewer impurities and is therefore more resistant

marble limestone that has been subjected to high pressure and temperature, resulting in recrystallisation of the original calcite crystals into a dense non-banded rock



Source 1.23 The Parthenon, originally constructed more than 2000 years ago on the Acropolis, Athens from Greek marble.

Source 1.24 A Carrara marble statue of Queen Victoria in Perth, Western Australia



to weathering. This is why coloured marbles are generally used for coffee tables or interior cladding in building foyers, while white marble is used for outdoor statues and monuments. In the Dinaric Mountains in Croatia, the limestone is variable in terms of the extent to which metamorphism has taken place – some areas have been subjected to extreme pressure, while others have not.

Damaging earthquakes continue to occur in this region as a result of plate movements, leading to the collapse of hotels and other buildings, and the need to completely reconstruct historic parts of towns like Budva on the coast in Montenegro. Further south, earthquakes have destabilised and damaged the much older Acropolis monuments in Athens, Greece.

Geographical fact

Carrara marble has been used in major monuments and buildings around the world, including Marble Arch, London (1833), Sheikh Zayed Grand Mosque, Abu Dhabi, United Arab Emirates (21st century), Akshardha, the Hindu complex in Delhi, India (opened 2005) and the Peace Monument, Washington, DC (1878).

NOTE THIS DOWN

Copy the graphic organiser below and summarise what you have learned about the 3 main groups of rocks.

Igneous	<ul style="list-style-type: none"> • Originate from the solidification of magma
Sedimentary	
Metamorphic	

RESEARCH 1.3

Imagine you are a guide working for a tour operator in Australia. Select an iconic Australian landform (for example, Uluru in Australia's Red Centre) and prepare a script to present to visitors. In your script, be sure to include a discussion of the processes that produced the landform and the activities that may have shaped it in the past and are still doing so in the present.