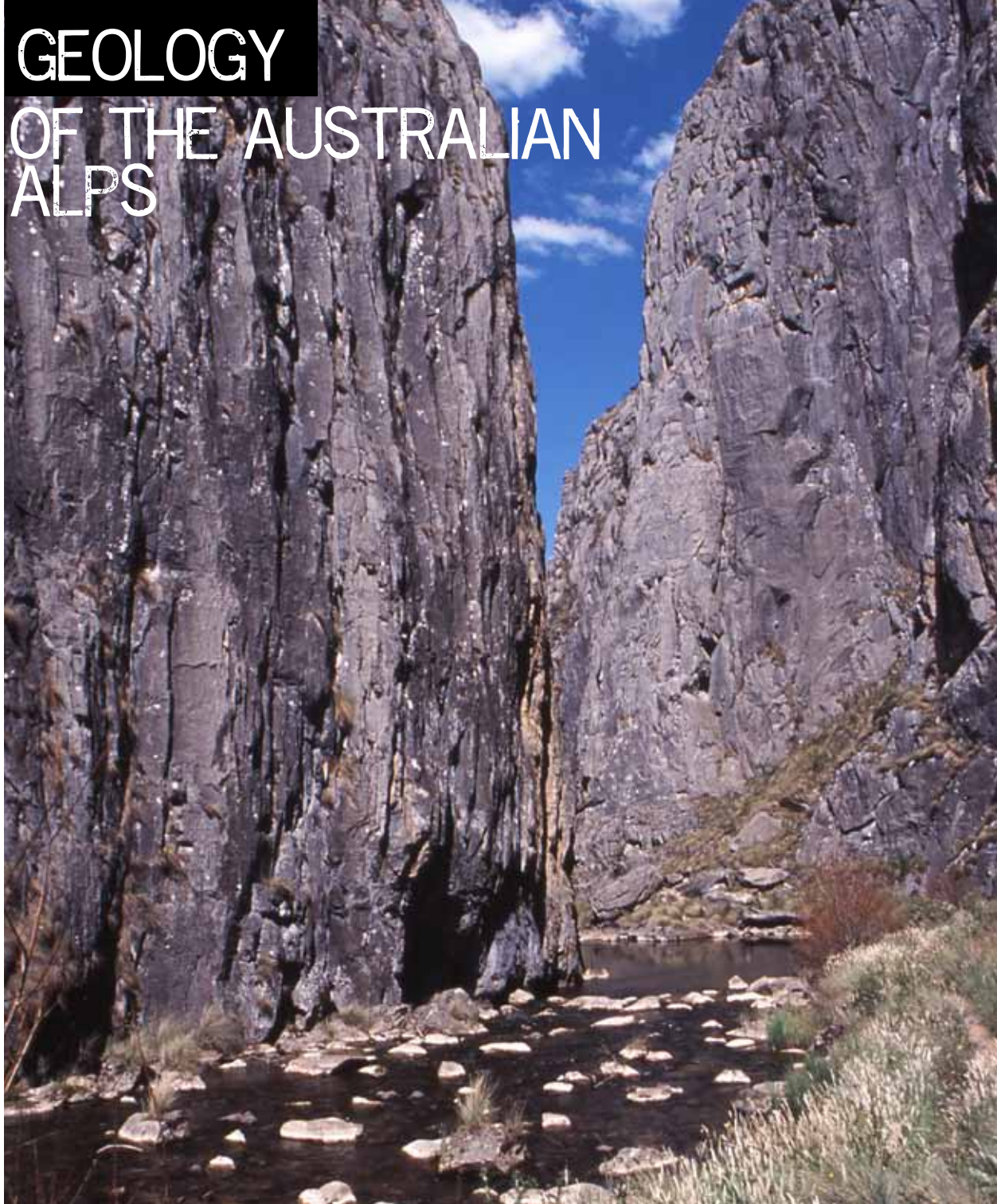


GEOLOGY OF THE AUSTRALIAN ALPS



*Gorge in limestone:
Clarke Gorge, Blue
Waterholes, Kosciuszko
National park.*

Geology is the study of the Earth, the rocks it is made of and the processes that shape its surface. Large scale geological processes formed the Alps, and rocks play an important role in producing different soil types and landforms, which in turn create distinctive ecosystems.

The Australian Alps are the highest part of a larger entity, the Eastern Highlands of Australia, which runs the length of the east coast from northern Queensland to Victoria. The origin of the Alps is the same as that of the Eastern Highlands.

Because the Australian Alps cover a large area, they display a wide range of rock types and a complex geological history spanning 520 million years. The events that formed the different rocks in the Alps, and the Alps landscapes, are described here in order from oldest to youngest. When talking geological history, we use the abbreviation Ma to mean “million years ago”.

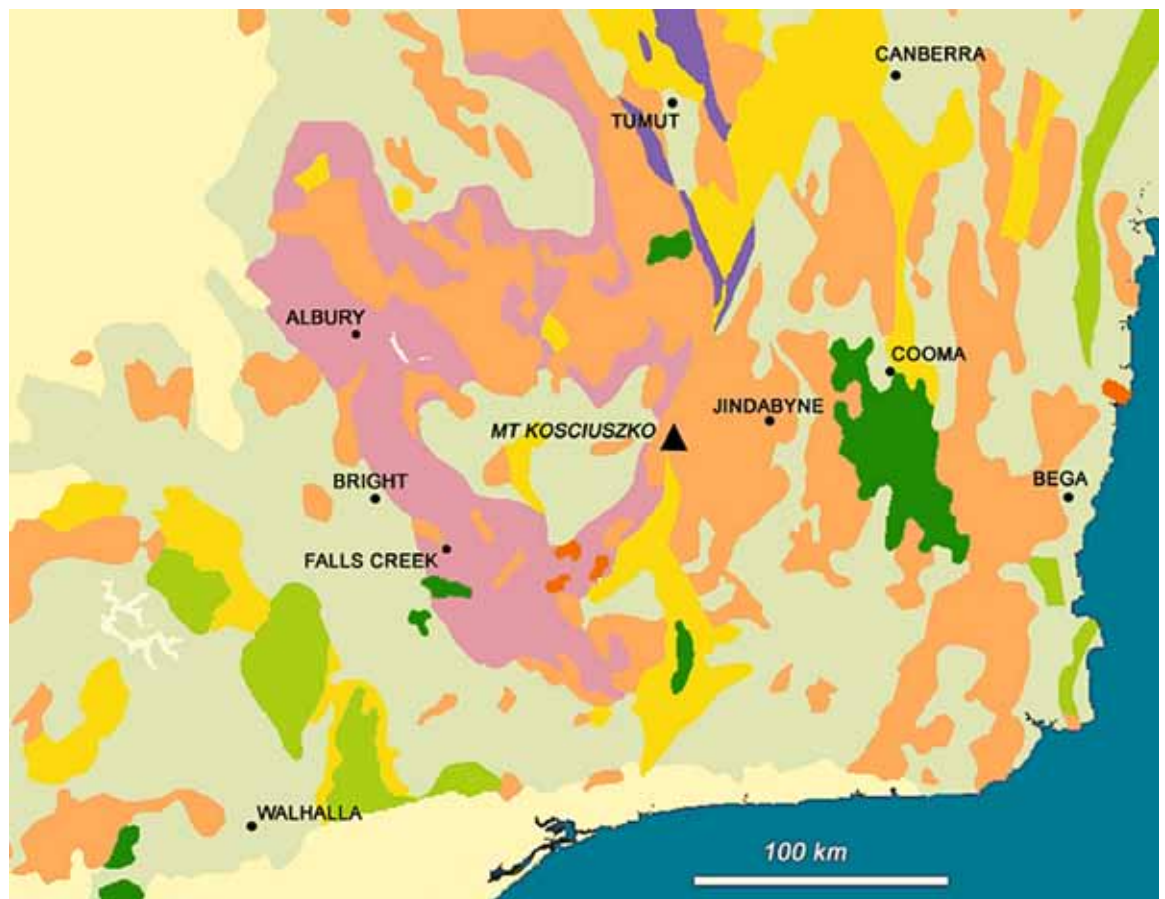
EARLY HISTORY. DEEP OCEANS AND ANCIENT MOUNTAINS





Earth's surface is continually being reshaped and modified by geological processes. Southeastern Australia has only existed as a continuous landmass for about 350 million years, and its appearance has changed radically during that time. Before 350 Ma, there were oceans and island chains where there is now dry land.

The oldest rocks in the alpine region are basalt lavas erupted onto the deep ocean floor about 520 Ma, in the Cambrian period. They occur in Victoria in the Howqua Valley and the remote Dolodrook Valley. At this time eastern Australia did not exist – the region was a deep ocean dotted with volcanic islands, similar to the western Pacific Ocean of today.

During the next 80 million years, in the Ordovician period, vast areas of the ocean floor were covered by a thick blanket of sand and mud, over time turning into the sedimentary rocks sandstone and mudstone. These rocks form much of the Australian Alps. In this time interval a large chain of volcanic islands formed in what is now New South Wales, erupting basalt and andesite lava. These rocks are seen in the Kiandra and Jagungal areas.

Geological map of the Australian Alps region.



- | | | |
|--|--|--|
|  Neogene-Holocene river and coastal sediments |  Paleogene-Neogene basalt |  Triassic-Cretaceous granite |
|  Late Devonian sandstone and mudstone |  Silurian-Devonian rhyolite and limestone |  Silurian-Devonian granite |
|  Ordovician-Silurian basalt and related rocks |  Silurian schist and gneiss |  Ordovician deep marine rocks |

From 440 to 360 Ma (the Silurian and Devonian periods) a series of mountain-building events folded the sedimentary and volcanic rocks, lifted them out of the sea to form land and moved blocks of crust tens to hundreds of kilometres along large faults. This was the result of collisions of several small tectonic plates, crumpling rocks together and thickening up the crust. In addition, some rocks were buried deep in the crust and heated, thereby becoming metamorphosed to produce rocks such as slate, schist and gneiss. Slate is common throughout the high country, with good examples at Mt Hotham and Mt Feathertop in Victoria. Schist and gneiss occur in the Victorian Alps around Mt Bogong, Falls Creek and Omeo. Some rocks were heated above 650° C, enough to melt them.

Also in the Silurian and Devonian, large bodies of granite were emplaced into the crust and huge volcanoes erupted ash and lava over the newly created land. Granite forms much of the high country, such as the Kosciuszko Plateau in NSW, the Bimberi and Clear Ranges in the ACT, and Mt Buffalo, Mt Baw Baw and Mt Wills in Victoria. Many granite bodies are resistant to erosion, and hence form plateaus and ridges with large blocks, or tors, of rock sticking up, while surrounding rocks are more susceptible to erosion and form lower country. Not all granites are resistant, however, and some are more recessive (i.e. more easily eroded) than the surrounding rocks, forming broad valleys as at Cudgewa-Thowgla and Ensay-Swifts Creek in Victoria.

The Cathedral on Mt Buffalo – large granite tors.



The volcanoes of the Silurian and Devonian periods were quite explosive, erupting towering clouds of hot volcanic ash which formed a rock known as ignimbrite. In Victoria this type of rock occurs at Lake Mountain, Mt Donna Buang and the Snowy River area, while similar rocks occur around Lake Talbingo and along the Fiery Range in New South Wales.

During the Silurian and Devonian periods the geography of southeastern Australia was complex, with small seas and large to small islands. Some islands developed coral reefs along their edges, which over time became limestone. This rock commonly has many fossils such as coral, shells and algae. Because limestone is soluble in slightly acidic groundwater, it easily dissolves to form caves and gorges, as seen at Yarrangobilly and Blue Water Holes in NSW, and Buchan in Victoria.

By about 360 Ma much of southeastern Australia was a mountain range. Note that this range had nothing to do with the present-day Australian Alps, and was part of an ancient cycle of plate tectonic movements. Wide valleys within and adjacent to the mountains were filled with river and lake sediments, forming sandstone and mudstone with a distinctive reddish colour. They can be seen in Victoria in the high plateaus stretching from Mt Cobbler to the Avon Wilderness area.

GEOLOGICALLY QUIET TIME

After the last episode of folding, about 340 Ma, southeastern Australia entered a 200 million year period where not much happened, geologically speaking. Australia was part of the supercontinent of Gondwana, lying in the interior of the landmass. The mountain ranges were slowly worn down to a low-lying plain and very few rocks of this period are preserved in the alpine region.

Around 300-250 Ma the Earth entered a global ice age, and at this time Australia was close to the south pole. Ice sheets covered much of southern Australia, and glacial deposits are preserved outside the alpine region in Victoria and New South Wales. Any such deposits within the Australian Alps have been since eroded away.

LATEST PERIOD. FORMATION OF THE AUSTRALIAN ALPS

There is still debate about when the Australian Alps came into existence, with some geologists arguing that they arose only a few million years ago, while the majority argue that the Alps arose around 100-60 Ma, based on evidence collected over the last 30 years. This account takes the majority view.

About 130 Ma stirrings in the deep mantle began to break up eastern Gondwana. Australia began the long process of breaking away from Antarctica and Zealandia (a now largely submerged continent stretching from New Zealand to New Caledonia). The process began with magma moving upwards into the lithosphere, causing it to heat and expand upward, forming a dome-shaped plateau running along what is now the east coast of Australia. By 100 Ma the plateau was possibly over 2000 m high in its highest area, the site of today's Australian Alps. Gondwana split apart along this line of magma upwelling, and a rift valley formed along the centre of the plateau, with an east-west trending branch where Tasmania moved southward away from Victoria. The rift valley, similar to today's East African Rift Valley, was formed by stretching of the crust leading to the valley floor dropping along a series of faults.

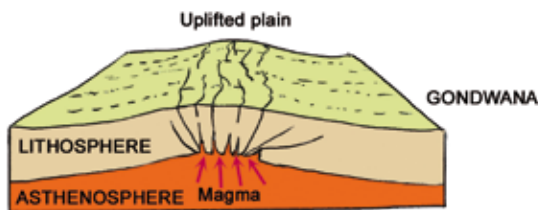
Zealandia moved eastwards, with the Tasman Sea filling in the gap, while Tasmania only moved a short distance southwards, forming the shallow Bass Strait. The Australian Alps were left behind as a remnant of the original plateau, with a steep seaward side and a gentle slope toward the inland. By 65 Ma the Tasman Sea and Bass Strait were in their current configuration and the Australian Alps were probably not much higher than they are today. Since then erosion has carved deep valleys into the plateau and rounded off the landforms. In New South Wales most of the alpine area is one large tableland, while in Victoria erosion has proceeded further, producing many smaller plateaus separated by rugged valleys.

Over the last 50 Ma basalt lava has been erupted episodically over much of the alpine region. The lava came out of small volcanoes and flowed across the landscape and down valleys. Many of the high plains in Victoria are covered by basalt, such as the Bogong, Dargo and Nunniong High Plains. In New South Wales the Monaro Plain is a large area of basalt lava flows. Because basalt lava is quite fluid, it quickly fills in the low-lying areas to form the flat landscapes of these high plains.

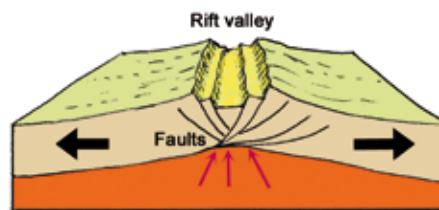
Although the Alps were mostly in place by about 90 Ma, there have been several minor uplift episodes since then in various parts of the Alps. These events have in many cases altered the course of rivers by tilting and faulting, in some cases reversing their flow and sending them in new directions.

Formation of the Australian Alps.

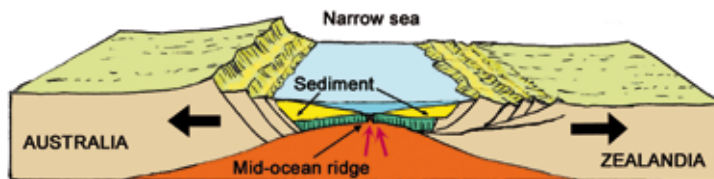
130 million years ago



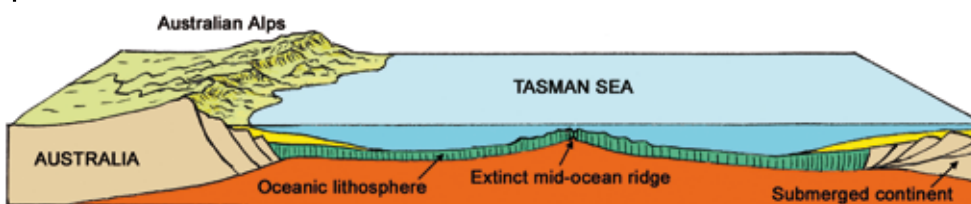
100 million years ago



80 million years ago



present



THE PLEISTOCENE ICE AGE

Most of the last 2 million years have been a time of global ice age, with ice caps forming on high ranges around the world, as well as at the poles. This cold period is known to geologists as the Pleistocene epoch. Because the Australian Alps are only of modest height, the highest point being Mt Kosciuszko at 2228 m, glaciers were formed only on the very highest parts (above 2000 m) in the vicinity of Mt Kosciuszko. Several tarns and cirques remain: these result from glaciers scooping out hollows in the ground. Examples of tarns, which filled the bottom of cirques after the ice melted about 12,000 years ago, are Club Lake, Blue Lake and Hedley Tarn. Some of the small valleys near Mt Kosciuszko have the U-shaped cross section typical of valleys carved by glaciers.

Much of the Australian Alps outside the small glaciated area was still affected by cold conditions during the Pleistocene, indicated by periglacial features such as block streams, terracing and frost-shattered boulders. These features all require ice to be present in rocks and soil for much of the time.

Are the Australian Alps geologically unique?

The shape of the Australian Alps is quite different to that of the more famous mountain ranges such as the European Alps or the Himalayas. Those mountains contain many sharp peaks and deep glacial valleys. In contrast, the skyline of the Australian Alps is rather flat and rounded. It is often said that this is because the Australian Alps are much older than the European Alps and Himalayas, and erosion over time has worn them down. However this is only a small part of the answer.

There are two main reasons the Australian Alps are flat and smooth. Firstly, they originated by a different plate tectonic process, continental splitting, rather than continental collision which formed the European Alps and the Himalayas. Uplift in continental collisions is much faster and often of greater magnitude than the slow process of uplift during continental splitting. Secondly, the Australian Alps were never high enough to have large ice sheets and glaciers, and it is the erosion by ice that produces the sharp and jagged peaks of the Himalayas and European Alps.

Does this then make the Australian Alps geologically unique? The answer is no, as around the world there are many mountain ranges formed in the same way as the Australian Alps (and the Eastern Highlands in general), such as the Drakensburg in South Africa, the Western Ghats in India and the mountains of Norway. And to see how our Alps' Eastern Highlands may have looked at about 70 Ma, we can study the mountains on each side of the Red Sea. Even though quite young, the Red Sea mountains have a similar topography to the Australian Alps, with large plateaus dropping steeply to the sea. However, erosion has not had time to round off their shapes.

Geological period	Time range	Events
Holocene	10,000 years ago to present	The ice cap melted and southeastern Australia became warmer and wetter. Erosion continued, but has recently been modified by the building of dams, clearing of forests and overgrazing.
Pleistocene	2.6 Ma to 10,000 years ago	A global ice age affected the earth. Cold, dry conditions prevailed in Australia, and a small ice cap formed around Mt Kosciuszko.
Neogene	23–2.6 Ma	Several episodes of uplift along faults raised parts of the Alps even higher. Some basalt lava was erupted in several localities. Australia moved quickly northwards into warmer and wetter climate zones, and erosion continued to shape the Alps.
Paleogene	65–23 Ma	The Alps were in place as a high plateau along the southeast coast of Australia. Australia began moving away from Antarctica into more northerly latitudes. Eruption of basalt lava occurred in many parts of Alps. Erosion of the Alps continued to deepen valleys and isolate plateaus.
Cretaceous	130–65 Ma	Australia started to separate from Gondwana, firstly India moved westwards from Australia, then a large plateau arose along what is now the east coast of Australia – the beginnings of the Australian Alps. By 100 Ma the plateau was riven by a rift valley that ran along the east coast of New South Wales and the south coast of Victoria. Antarctica and Tasmania moved southwards slightly while Zealandia move quickly eastwards, forming the Tasman Sea by 60 Ma.
Carboniferous, Permian, Triassic, Jurassic and early Cretaceous	340–130 Ma	A long period of erosion and weathering slowly wore down the early mountain ranges to a low plain covering most of eastern Australia. By now Australia was part of the supercontinent of Gondwana. Between 300 Ma and 250 Ma glaciers covered much of southern Australia during the Permian ice age.
Late Devonian to Early Carboniferous	360–340 Ma	A final period of folding and mountain building occurred, with sand and mud deposited in rivers and lakes in broad valleys between the mountain ranges.
Silurian to Middle Devonian	440–360 Ma	Several episodes of folding and mountain building, caused by tectonic plates colliding with each other, created islands and then more continuous land masses. In the shallow seas next to the islands coral reefs grew and later turned into limestone. Generation of magma deep in the crust led to granite bodies being intruded into the crust and explosive volcanoes on the surface. Some rocks were buried deeply and metamorphosed into schist and gneiss.
Ordovician	490–440 Ma	Much of the area was still in the deep ocean. Several kilometres of sand and mud were deposited on the ocean floor. In New South Wales a chain of volcanoes formed a series of small islands in the ocean.
Mid to late Cambrian	520–490 Ma	The area now occupied by the Australian Alps was a deep ocean, with basalt lava erupting onto the ocean floor and also forming scattered volcanic islands.

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Poster of Australia through time:

https://www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=71079

GLOSSARY

andesite: a black or dark green volcanic rock with intermediate amounts of silicon.

basalt: a black volcanic rock with low silicon and high magnesium and iron.

block stream: a "river" or field of rocks that have moved downhill as a mass, held together by ice forming between the blocks.

cirque: a bowl-shaped depression formed at the head of a glacier by the scraping action of the ice.

crust: the uppermost layer of Earth. Crust forming the continents is 30 to 70 km thick; crust forming the ocean floor is 5 to 7 km thick.

gneiss: a layered metamorphic rock formed at high temperatures (> 600° C).

Gondwana: the supercontinent consisting of Australia, Antarctica, New Zealand, India, Africa and South America. It was assembled over the period 500 Ma to 200 Ma, and began to break up into fragments about 180 Ma. Australia was one of the last fragments to separate.

granite: a common igneous rock formed at depth in the crust, consisting of interlocking crystals of quartz and feldspar and minor dark coloured minerals. Commonly forms large rounded tors.

ignimbrite: a volcanic rock of high silicon content formed by hot ash accumulating around a volcano during an explosive eruption; generally whitish with small crystals of quartz and/or feldspar.

lava: magma that has erupted onto the Earth's surface.

limestone: a sedimentary rock composed of calcium carbonate, formed by the accumulation of animal shells, coral and other biological matter.

lithosphere: the outer rigid layer of Earth, consisting of the crust and the uppermost mantle.

magma: molten rock, often containing solid crystals. When magma solidifies, it forms an igneous rock.

metamorphism: changes in the mineral make-up and structure of a rock due to the application of heat and/or pressure. Temperature increases with depth in the Earth, so rocks buried deeply get hot as well as being put under immense pressure from the weight of the overlying rocks.

periglacial: pertaining to areas that were not covered by glaciers, but underwent geomorphic processes related to the freezing of water.

plate tectonics: the formation of large structures on the Earth, such as continents, oceans and mountain ranges, by the movement of large rigid blocks (plates) of lithosphere over the Earth's surface at rates of a few cm per year. Plates may move toward or away from each other, or slide past each other, each type of movement creating different structures.

rift valley: a large valley bounded by faults and formed by stretching apart of the continental crust; often the first stage in the development of a new ocean.

mantle: the largest part of the Earth, immediately below the crust and extending down to 2900 km depth; composed of dense minerals rich in magnesium and iron.

schist: a metamorphic rock containing a large proportion of aligned mica minerals which give it a sparkling sheen.

sedimentary rock: rock formed by the accumulation of sediment, such as sand grains, clay particles, pebbles, chemical precipitates, or by the accumulation of biologically produced material.

slate: a fine-grained metamorphic rock formed at relatively low temperature (250° - 450° C), and characterised by an alignment of microscopic platy minerals which cause the rock split along parallel planes known as cleavage planes.

tarn: a small lake filling the bottom of a cirque; also known as a cirque lake.

tectonic plates: parts of the lithosphere that move relative to each other; typically thousands of kilometres across.

terracing: steps formed on hill sides by mass movement of ice- and water-saturated soil down-slope