The geology of Eigg

Eigg is a place where geology and landforms must impress even the most casual visitor. This booklet attempts to explain how this has come to be so. It is not comprehensive, but picks out some of the more exciting episodes in Eigg's long history, and the contributions of some of the more remarkable investigators of it. It assumes an interest in the natural world, but little prior knowledge of geology. Terms that may be unfamiliar are defined in the glossary. Please use it during your visit, and tell us of any deficiencies or suggested improvements.

Geology and landscape

It is often hard for those who are not geologists to separate the origin and history of the present landscape from the much longer history revealed by the rocks of which our mountains and lowlands are composed. Except in the case of active or recently active volcanoes, of which there are none in Britain, the present landscape owes its origin to the action of erosion on rocks of varying hardness, variably disposed within the Earth's crust and cropping out at its surface. In Scotland, the familiar erosional action of rivers and the sea was supplemented, quite recently in geological terms, by the powerful erosional force of mountain glaciers and ice sheets, whose effects are clearly visible in the present landscape. The ups and downs of sea level associated with the formation and melting of glaciers also had dramatic effects on coastal landforms. So our mountains and coastlines are, to a geologist, quite young features of the last few thousand years. But the rocks themselves were laid down as sediments on the sea floor, or expelled as magmas from volcanoes, tens, hundreds or even thousands of millions of years ago, and allow us to reconstruct a succession of lost landscapes far different from the present one.

Eigg as an island

At the height of the last glacial period, about 20 000 years ago, Eigg was covered by an ice sheet extending westwards from the mountains of mainland Scotland. Sea level was much lower than now because so much water was locked up in land ice worldwide. As the ice melted, the island we know was revealed, and its form modified by continuing oscillations of sea level, landslips around the coastal cliffs, and erosional forces acting on the mountains. The pitchstone rock of the Sgurr proved resistant to glaciation, and so forms the abrupt ridge that dominates views of the island today. It is carved from volcanic rock, but the peak of the Sgurr is not a volcano.

The basaltic cliffs behind Cleadale are also volcanic. They are crumbling. You can hear them doing so on a still day, and so their form is constantly changing.

The sandstones forming the cliffs of Laig Bay were once sediments. They are being eroded by the sea, contributing new sand to the Singing Sands (Camas Sgiotaig) and Laig Bay. These processes are recent, and ongoing. For most of geological time, Eigg had no separate existence, but the rocks of which it is formed, and their relationship to those of the surrounding area, tell us much about the history of Scotland over hundreds of millions of years.

Eigg in the Hebrides

If you stand on top of the Sgurr on a clear day, you can see much of the framework of north-west Scotland spread out before you. Far to the west, the low line of the Outer Isles is visible. These are composed of the oldest rocks in Scotland, which formed part of a mountain chain over 2000 million years ago. Those mountains are long since destroyed, and what remains is their roots. To the east, the Highlands are mountains still, although mere stumps compared to their stature of 400 million years ago. In between, in the islands of the Inner Hebrides that dot the Minch, some equally ancient rocks are found, such as in north Rum, Tiree and Coll, but most of the rocks are much younger.

There are two main types of these younger rocks: sedimentary rocks, mainly of Jurassic age (about 200–140 million years old), and igneous rocks, which are younger still (about 60 million years old). The sedimentary rocks are mainly soft and have been extensively eroded since they were deposited, so they occupy the low ground on the islands, and much of the area covered by the sea. The volcanic igneous rocks are much harder, forming the Sgurr itself, Beinn Bhuidhe, and most of the plateau areas of west Skye, Mull, Canna and Muck.

Hardest of all are the intrusive igneous rocks, originally cooled from magma to hard crystalline rocks well beneath the Earth's surface, but now forming the magnificent mountains of Rum, and the Cuillin in Skye. Therefore, on a broad scale, the Minch and the Inner Hebridean islands are made of relatively young rocks situated between two areas of much older rocks, representing the sites of two former mountain chains of very different ages. On a more-local scale, on Eigg, are Jurassic sedimentary rocks and Palaeogene lavas. Rum is made of much older sedimentary rocks and Palaeogene intrusions that were formed much deeper in the Earth's crust than the lavas of Eigg, which were formed at the surface of the Earth. There is a major fault— a zone along which movement has taken place— between Eigg and Rum. This is known as the Camasunary Fault after the locality where it is seen onshore on Skye. The effect of the movement was upwards on the Rum side of the fault, thus raising the older rocks of Rum to the same level as the younger rocks of Eigg.

The geological make-up of Eigg

The island of Eigg displays a great variety of geology, but its make-up is quite simple. The rocks are neither folded nor faulted to any major extent, so the oldest rocks occur at sea level and the youngest, the Sgurr pitchstone, forms the highest ground.

There is a gentle tilt to the south-west. The oldest rocks are Jurassic sedimentary rocks, seen all around the coast of the northern part of the island from Kildonnan, via the north end, to Laig, except where obscured by landslips or deposits of beach sand or pebbles. Jurassic sedimentary rocks also underlie the fields of Cleadale and Laig, showing most conspicuously in the sea cliffs between Laig Bay and the Singing Sands. These rocks were deposited in a shallow gulf of the sea, which occupied roughly the area of the present Minch. Younger sedimentary rocks, of Cretaceous age, occur as small patches near Laig and at Clach Alasdair.

Above these sedimentary rocks are basaltic lavas, emitted as comparatively gentle eruptions from volcanoes in Palaeogene times, around 60 million years ago. The lava flows, mostly only a few metres thick, extend for many kilometres, testifying to the fluidity of the magma. The lavas are responsible for the stepped topography seen on Beinn Bhuidhe and on the slopes between the Sgurr, Galmisdale and Laig. Dykes, formed by the injection of magma into vertical fissures, cut the lavas. A period of erosion interrupted the volcanic activity, during which a valley was carved between the eastern end of the Sgurr ridge and the sea at Bidein Boidheach; originally it must have extended much farther. Volcanic activity resumed, and the valley was filled with a new outpouring of volcanic rock; not lava this time but a catastrophic pyroclastic flow. This rock cooled to hard pitchstone rather than relatively crumbling basalt. Later erosion left the former valley fill standing proud as the Sgurr ridge we see today. This most famous and most topographically dramatic episode in Eigg's long history is described in more detail later.

As we move towards the present, through the glacial periods of the last few hundred thousand years with their associated rises and falls of sea level, erosion produced the great inland cliff behind Cleadale, which is still gradually retreating. The instability of the cliffs all around the sides of Beinn Bhuidhe led to the formation of massive landslips, some of which are still active, and the mantling of the lower slopes by screes. Erosion by the sea produced cliffs, caves and arches; sands were deposited to build beaches like those at Laig Bay and Kildonnan. Gradually, the present Isle of Eigg took its familiar shape..... but it will not last!

Jurassic rocks and fossils

In Jurassic times the area of the present Minch and the Inner Hebrides was occupied by a gulf of the sea, bounded by the Highlands to the east and the Outer Isles to the west. Most of the sediment that went to make up the rocks we see today was sand and mud derived from erosion of the Highlands. We do not know precisely where the shoreline was, or the course of the rivers that delivered sediment to our area. At times, so many molluscs and other shelled animals lived in the sea that their shells contributed to the accumulating sediment, which eventually hardened to limestone. The climate was much warmer than it is now, with an average temperature of about 20°C, at a latitude of about 35° north compared to the present 57° north. Temperature and rainfall varied over the 60 million years of Jurassic time. The surrounding land was well vegetated, as shown by fossil driftwood preserved in the sedimentary rocks. For part of Mid Jurassic time the water in the Minch became very shallow and partly cut off from the open sea. Shallow, brackish lagoons were formed. The climate was probably of Mediterranean type with wet winters in the hinterland and dry summers at sea level, causing the lagoons to suffer seasonal evaporation. This time corresponds to the deposition of the Jurassic sedimentary rocks most prominent on Eigg—the Great Estuarine Group. Later in the Jurassic, the seas returned, and marine creatures such as ammonites came with them.

Hugh Miller and the Eigg plesiosaur

One of the most remarkable discoveries on Eigg was made by the most remarkable man to have studied its geology. Hugh Miller was a characteristic type in Victorian Scotland — a man of diverse achievement from humble origins. As a young man he was a stonemason at Cromarty; his science and command of language were almost entirely self-taught. He first came to public fame as one of the most prominent laymen in the evangelical wing of the Church of Scotland, employing his considerable rhetorical powers on its behalf as editor of its newspaper 'The Witness'. He collected notable fossils in the course of his work and on independent forays in the Cromarty region, and eventually came to correspond with the leading scientists of the day. His most famous discoveries were of early fishes from the Old Red Sandstone. He also became familiar with the Jurassic rocks and fossils of the east coast of Scotland. His descriptions of the Old Red Sandstone fishes and his skill at popular exposition of geological themes form the basis of his present reputation.

In 1843 the evangelical wing of the Church of Scotland broke away to form the Free Church. Miller's boyhood friend, the Rev. John Swanson, Minister of the Small Isles, had joined the Free Church, thus renouncing his living on Eigg. The landowner refused him permission to reside on the island, and would not allow his former parishioners to build a new church. Swanson's response was to buy an old and leaky yacht, the Betsey, in which he cruised the islands ministering to his flock as best he could. Miller joined Swanson in 1844 and 1845, to show support for his friend and co-religionist, but no doubt he was also attracted by the opportunity to explore the geology of the Hebrides.

Miller's most memorable discovery on Eigg was of the bones of a plesiosaur, together with other reptilian and fish remains. Plesiosaurs are a group of marine reptiles already well known in the Jurassic rocks of England and Europe, but at the time unknown in Scotland. On his first visit, at the end of a long day spent exploring the west coast of Eigg, he found the reptile remains in blocks of a red-weathering (iron-rich) limestone near the north-east tip of the island. To Miller, they at once determined the age of the rocks as Jurassic, contrasting with the Old Red Sandstone and its strange fishes with which he was so familiar:

"They belonged, not to the ages of the Coccosteus *and the* Pterichthys*, but to the far later ages of the* Plesiosaurus *and the fossil crocodile"*

We now believe that the fossils belong to the Bathonian Stage of the Middle Jurassic, and are about 168 million years old.

An islander who accompanied Miller had to be convinced of the reality of the bones:

"They not a little puzzled John Stewart: he could not resist the evidence of his senses: they were bones, he said, real bones — there could be no doubt of that: there were the joints of a back-bone, with the hole where the brain- marrow had passed through: there were shank-bones and ribs, and fishes' teeth; but how, he wondered, had they got into the very heart of the hard red stone?"

Miller could not find the hard red limestone as part of the bedrock there and nor, despite much searching, could his successors. But he returned the following year, and this time located the red limestone in situ, on the east coast north of Kildonnan; a remarkable achievement in so short a visit, as the outcrop there is still not easy to find or to interpret. The limestone occurs in the lower part of a rock succession containing mudstones as well as further limestones. The rocks, now formalised as the Kildonnan Member, contain many fossils, mostly molluscs, which are very well preserved mineralogically, although fragile. The fossils have much in common with those found in estuaries today, hence the name Great Estuarine Group applied to this part of the Jurassic of the Hebrides by JW Judd later in the 19th century. In more-recent years the fossils, supplemented by geochemical analyses, have been used to show that the rocks were deposited in lagoons that were near the coast, but received much of their water from rivers. This explains the ‘estuarine’ faunas, but we now believe that the environment was one of very shallow but extensive lagoons, at times stretching at least from Muck to the north of Skye, rather than a confined river estuary.

Plesiosaur bones can still occasionally be found by searching the storm-beach on the north and east coasts for blocks of the distinctive red limestone. Fossil molluscs, especially the small mussel *Praemytilus strathairdensis*, can more easily be found at the exposure north of Kildonnan.

The Valtos Sandstone and its concretions

By far the most impressive outcrops of sedimentary rock on Eigg are the sandstone cliffs that form the broad indented headland between Laig Bay and the Singing Sands, continuing thence around the north-west corner of the island. As already mentioned, they are crumbling away, becoming the source for the sands of the present beach.

They record a great influx of sand, forming deltas built into the Jurassic lagoons that then occupied the Minch area, at a time a little more recent than that recorded by the plesiosaur-bearing strata of the east coast. This sandy episode had its counterpart in north Skye, whence came the name Valtos Sandstone Formation for these rocks. The sand had its source in hills that were roughly where the Scottish mainland now is, as deduced from larger pebbles found among the sand, and minute sand-sized grains of distinctive minerals originating from metamorphic rocks like those of the Highlands.

The most striking features of these sandstones are the vast rounded concretions that they contain. Concretions are bodies of cemented sandstone that stand proud from the more easily eroded softer sandstones around them. For a long time their origin was a complete mystery. We now know that they were formed in the long interval of time between the deposition of the Jurassic rocks and the outpouring of lava that followed 100 million years or so later. At that time the sandstones were buried beneath a few hundred metres of later sediments. The source of the calcite (calcium carbonate) that cements the sand was from small mollusc shells that were once abundant in the sands.

The shells were made of a less-stable form of calcium carbonate (aragonite) that was dissolved and reprecipitated in the form of calcite within the concretions. Such shells (the small bivalve *Neomiodon*) can still be seen in thin limestone beds interspersed with the sands. Calculations indicate that a concretion 50 cm across would have taken about 3 million years to grow, at the slow rate at which chemical changes take place in the subsurface.

We still do not know precisely why a concretion forms in one place within the sandstone rather than another. A further phase of concretionary cementation affected the Valtos Sandstone much later, when basaltic dykes were intruded into it, as described later.

Eigg and Muck as oyster beds

The deltas in which the Valtos sands weredepositedwereeventuallyflooded about 166 million years ago. Seawater returned to the shallow lagoons, which were still partly isolated from the open sea, and brackish enough to exclude most marine organisms.

The conditions were much to the liking of a species of small oyster, *Praeexogyra hebridica* (formerly *Ostrea hebridica*), which was described by the famous naturalist Edward Forbes in 1851 from examples he collected in north Skye. Miller had already recorded and described shells of the same species from Cleadale on Eigg, although he did not give it a name:

“They are small and thin, triangular, much resembling in form some specimens of the Ostrea deltoidea*, but greatly less in size. What they lack in bulk, however, they make up in number. They are massed thickly together to a depth of several feet.... Where they lie open we can still detect the triangular disc of the hinge, with the single impression of the adductor*

muscle; and the foliaceous character of the shell remains..."

This small oyster forms highly distinctive beds of limestone not only in the Hebrides but also in southern and midland England and parts of Europe. Interbedded with the oyster beds are other kinds of limestone and thin beds of mudstone and siltstone, each with subtly different fossils recording how conditions varied over time. The best locality for the oyster beds on Eigg is the lower part of Laig Gorge. The foreshore of Camas Mór on Muck is, however, much better than this locality for giving an impression of the oyster feast that would have been available to the gastronomes of the Mid Jurassic. These included fishes, but not, of course, humans.

Ammonites and belemnites, swimmers in Jurassic seas

After the formation of the oyster beds, the sea withdrew from the Hebrides almost completely, before returning towards the end of the Mid Jurassic time as it also did across England and much of northern Europe. The seaway remained open into the Late Jurassic. The evidence for the withdrawal is only scantily seen on Eigg, but mudstones deposited during the succeeding re-advance can be seen on the shore between Laig and Clach Alasdair. The rocks are soft and easily eroded, visible only as discontinuous exposures between tide marks. They contain those most characteristic fossils of the Jurassic seas, ammonites with coiled shells somewhat similar to those of today's Pearly Nautilus, and belemnites, the bullet-shaped internal skeletons borne by squid-like creatures. Both these types of swimming mollusc are now extinct. These rocks also contain fossils of bivalves, which lived on the sea floor, and which have modern equivalents. Mudstones of the same age are better developed at Staffin Bay in north Skye, hence their name the Staffin Shale Formation. They are internationally important in classifying rock strata of the Upper Jurassic because the abundant ammonites can be used to date rocks in much the same way as coins of Roman emperors can be used to date sites of human occupation.

Cretaceous rocks: Scotland at a time of Chalk

In contrast to the Jurassic, Cretaceous rocks are not well developed on Eigg or in Scotland generally. Early in Cretaceous time there was a phase of uplift of the former sea floor in western Britain, probably a distant reaction to the forces that led to the opening of the Atlantic Ocean. Thus some of the Jurassic rocks were eroded. In the later Cretaceous, much of England and northern Europe was covered by a sea a few hundred metres deep in which the Chalk was deposited, but the sea only just reached the Hebrides and the deposits are thin. Thus there is no Scottish equivalent of the rolling downland of southern England, although eroded flints in younger deposits show that there was once more Chalk in Scotland than survives now.

Locally, the later Cretaceous rocks are best seen in Laig Gorge, where a conglomerate containing pebbles of Jurassic and earlier rocks is overlain by sandstone and then by a few metres of limestone that resembles hardened Chalk; its age is Late Cretaceous, or about 90 million years. Even thinner deposits occur on the foreshore at Clach Alasdair, west of Laig, where they rest on the ammonite-bearing mudstones of the Upper Jurassic: A further small outcrop occurs high up in the cliffs of north-east Eigg, there resting on Valtos Sandstone. Interestingly, both are quite different from those at Laig Gorge, notably in containing flints, showing that the sea floor was not uniform even over short distances.

The Hebridean Igneous Province

Starting in early Palaeogene times, about 61 million years ago, volcanoes erupted, and igneous intrusions were emplaced, in the lands around the North Atlantic, including Scotland. These events formed the North Atlantic Igneous Superprovince, one of the major igneous events in Earth history: a more violent manifestation of the forces associated with the opening Atlantic than the gentle uplift of Cretaceous times. It was related to a plume of magma rising from deep within the Earth's mantle. As the North Atlantic widened, however, the formation of new ocean floor moved Scotland away from the 'hot spot' where the plume impacted on the Earth's crust. Thus in Scotland, all the igneous rocks from this episode date from 61 to 55 million years old. These ages are obtained by measuring traces of radioactive elements and their daughter products that are contained within the minerals in the rock. They are subject to revision as more and more precise dating methods are developed.

At the present day, the mantle plume is responsible for the existence of Iceland, where volcanic activity continues and gives us an idea of what the Inner Hebrides would have been like during their volcanic episode, albeit in a much colder climate than the Hebrides of Palaeogene times.

The nature of igneous rocks

Volcanic rocks, named after Vulcan and his forge, are formed from the eruption of magma onto the surface of the Earth. The sight of lavas flowing from volcanoes is familiar to most people if only from television documentaries. Another type of volcanic eruption results from the explosive release of clouds of hot and sometimes semi-molten fragments of rock suspended in gas, as seen recently on the island of Montserrat in the Caribbean. When these clouds rush across the land surface they are termed pyroclastic density currents (pyro– fiery, clastic – fragments), and they leave behind deposits, known as ignimbrites, which cover the ground and eventually cool.

Conversely, intrusive rocks result from cooling of magma underground. Intrusive rocks include dykes—vertical conduits leading magmas from the depths towards the surface along fissures and sills—planes of weakness filled with magma, parallel to the bedding of the rocks being intruded, and therefore generally nearly horizontal. The igneous rocks formed in dykes and sills are generally coarser grained than lava flows, since they cool more slowly underground, but the rate of cooling does depend on the thickness of the magma body and how close it is to the surface, and many of Eigg's dykes are fine-grained basalt.

Still deeper in the crust, plutonic rocks, named after the god of the underworld, occur as large masses that crystallised slowly and are therefore coarse-grained.

Igneous rocks are further classified on their chemical composition as basic, like basalt, which is the commonest volcanic lava, or silicic containing a higher proportion of silica. Granite is a familiar example of a silicic plutonic rock. At the other extreme for silicic rocks, pitchstone, of particular interest on Eigg, is a rock that cooled so quickly that it remains glassy rather than crystalline.

On Eigg, there are many lavas and dykes and some sills, though no plutonic rocks. But they are conspicuous in the landscape, as basic intrusions (gabbro and related rocks) form the jagged peaks of the Cuillin on Skye and the mountains of Hallival and Askival on Rum.

On Eigg itself we can examine lavas and dykes more closely, and some of the results are highlighted here. The lavas and dykes are predominantly basaltic in composition. There are a few silicic dykes and sills. The Sgurr of Eigg pitchstone is a special case, described in detail below.

The basalt lava flows: Hawaii in the Hebrides

More of the surface of Eigg is underlain by basalt than by any other rock type; in this it resembles Skye, Mull, Morvern and Antrim. Basaltic lavas are rather fluid when hot, and can flow long distances, like those erupting on Hawaii today. They can do this because the top surface of the lava crusts over, insulating the flowing incandescent lava beneath. Individual lavas may be a few metres thick, but repeated eruptions eventually build up a lava pile several hundred metres thick. Nearly 500m thickness of basalt lavas are still present on Eigg, and an unknown additional thickness has since eroded away. At the time the lavas were erupting, Eigg was not an individual island. Overlapping lava piles formed a vast series of shields and plains stretching from present-day Antrim to Skye and beyond. Because basalt lavas are fluid, they can flow on quite gentle slopes, sometimes ponding into hollows. There has been discussion as to whether the Hebridean lavas were erupted from a few large volcanoes, now represented by intrusive centres like that of the Cuillin, or whether they were erupted more widely from elongate fissures now represented by dykes. Both views may be correct in part. However most of the dykes seen on Eigg are probably younger than the lavas there and are not direct feeders to them; although they may have fed lavas since eroded away.

Lava flows

There is a distinct structure to an individual lava flow, as formed in volcanic areas today and on Eigg in the past. Its base is generally smooth because of rapid cooling, or perhaps rubbly owing to disturbance of the first layer to solidify, and may show vertical tubes where gases, mainly steam from wet soil, penetrated its base. The centre of the flow is more homogeneous, as this represents magma that flowed in later between the cooled upper and lower solidified crusts, gradually inflating the lava to a greater thickness as it continued to flow. The top of a lava is often formed of layered bubbly crusts, 5–50 cm thick. The bubbles and tubes formed where escaping gases were trapped, and many ere later filled with white minerals, forming amygdales (see below), and stand out conspicuously against the dark-grey basalt.

Even more striking are the columnar joints commonly shown in the massive centres of lava flows. Joints are cracks formed by contraction during cooling. The physics of cooling dictates that cracks form perpendicular to the cooling surface (and so are vertical in the case of a horizontal lava or sill) and that they form a polygonal pattern in plan view. Weathering may later exploit the joints and accentuate the columnar structure so produced.

Between lava eruptions, there may be long periods when plants colonise the cooled surface and soil forms; volcanic ash from distant volcanoes may also accumulate. These deposits are often referred to as boles. They are commonly bright red, partly as a result of weathering in the warm climate of early Palaeogene times, but much enhanced by baking under the succeeding hot lava. These features may be seen where basalts crop out on the shore, for instance near the Massacre and Cathedral caves, and in the near-vertical cliffs above the north and east coasts. A good example of a red inter-lava horizon is found near the Glebe Barn, at the foot of Cnoc a' Breanaich, ca. 250 m north-east of the Manse. This is probably part bole and part volcanic ash.

Trap topography

In inland areas, weathering and erosion pick out the relatively weak bases and tops of lavas, forming ledges, and the columnar centres stand vertically as minor cliffs. This produces the terraced hillsides so characteristic of basaltic terrains, known as 'trap topography' (from the Swedish word 'trapp' meaning a step or stair). It is the most widespread landform on Eigg, dominating the southern slopes of Beinn Bhuidhe, and the south and west of the island, apart from the Sgurr ridge.

Amygdales

The bubbles formed by gases trapped in solidifying lavas are often subsequently filled with white minerals, especially those belonging to the group known as zeolites. These cavities, when fully or partially filled, are known as amygdales. Zeolites are formed from rainwater that fell on the basaltic pile and percolated deep into the crust, becoming heated and dissolving salts as it did so; they are not related to individual eruptions. They commonly form beautiful crystals, much prized by collectors. Good examples can be found in fallen blocks of basalt, especially on the north coast. Different zeolites form at different temperatures and pressures depending on their depth of formation within the lava pile. Their present distribution can thus be used to infer the thickness of lava once existing above the present eroded remnants of the great Hebridean lava plateau. This amounts to several hundreds of metres, showing that the Palaeogene volcanoes were much higher than Ben Nevis is now.

Dykes

Volcanic activity is accompanied by stresses in the Earth's crust, often stretching it so that vertical fissures form when rising magmas, generally basaltic, invade it. Some of the magma escapes to the surface, but some solidifies within the fissure, forming a dyke. The margins of the intrusion cool faster than the centre, becoming finer grained or even glassy. The rocks alongside the dyke are heated and often hardened, becoming more resistant to weathering. Sometimes more than one pulse of magma enters the same fissure. Because stresses affect large regions of the crust, dykes are generally more or less parallel to each other, forming a dyke-swarm; those in the Hebrides mostly trend between north-west and north-north-west. However, local influences mean that parallelism is not exact, and dykes are commonly found to intersect.

These features of dykes are particularly well displayed in the foreshore between Laig Bay and the Singing Sands, where basalt dykes cut the Valtos Sandstone.

The term dyke originates from instances where vertical basalt dykes have been intruded into soft sedimentary rocks or lavas, and erosion leaves them standing proud like walls separating fields — as dykes on the foreshore below Galmisdale, for example.

However, north of Laig Bay, the reverse is often the case: the most resistant rocks are the baked sandstones at the dyke margins; the sandstones away from dykes are of intermediate resistance, and the most-eroded rocks are the basalt dykes themselves. Thus one sees parallel double walls with a trough between. The dykes are less than 2m across and many are less than a metre, testifying to the fluidity of the basalt magma. The hardened sandstone margins are made up of tiny concretions of calcite, individually rounded but commonly coalescent. The reason for this striking example of differential erosion is probably that the thin dykes are fine grained and commonly closely fractured; also that basalt is more susceptible to chemical weathering than is quartz-rich sandstone, especially where the latter is cemented.

The Laig Bay dykes intrude Jurassic sandstones and their age relative to the basalt lavas is not obvious; some could have been feeders. Many dykes are seen to cut the lavas on Eigg, so they must be younger than the lavas they intrude. Good examples can be seen in the cliffs behind Cleadale. Most dykes pre-date the Sgurr pitchstone, as can be proved where they are truncated beneath its base, as seen at The Nose.

Sills

Sills are formed where magma inserts itself along a plane of weakness parallel to the bedding of the rocks being intruded, rather than across bedding as with a dyke; sills are therefore most commonly nearly horizontal. There are fewer sills than dykes on Eigg, but some of them are thicker; they are also more varied in composition. There are many thin basalt sills within the Jurassic sedimentary rocks on the north coast and at Laig Bay.

One of the most impressive sills forms the cliffs of Sgor Sgaileach and the nearby islet of Eilean Thuilm at the north-east corner of the island. This sill is of silicic, fine-grained igneous rock (quartz porphyry). It is columnar, and weathers red, something that initially confused Hugh Miller when he found red limestone blocks, similar in colour to the sill, adjacent to it.

The story of The Sgurr

Ever since the retreat of the ice, the Sgurr of Eigg has been prominent topographically, seen as a precipitous column from the harbour to the east and as a long undulating ridge from the sea to the south. In the nineteenth century, it also played a prominent part in discussions of Scottish geology, especially in the persuasive writings of Sir Archibald Geikie. Then in 1906 the Cambridge petrologist Alfred Harker, fresh from triumphs in interpreting the igneous rocks of Skye, challenged Geikie's theory of its origin. Another giant of Scottish geology, E B Bailey (later Sir Edward and, like Geikie, director of the Geological Survey) consequently visited the island to see for himself. One cannot do better than quote the introduction to Bailey's paper of 1914, to explain what the argument was about:

"The Sgurr of Eigg first attained to geological prominence in 1865, when Sir Archibald Geikie in his delightful account of the Scenery of Scotland offered a novel and entirely captivating theory to account for its origin. According to Geikie, as all well know, the precipitous ridge of pitchstone, which culminates at its eastern extremity in the Sgurr, is the inverse of an ancient valley sunk by a winding river in the basaltic plateau of the west. Before the development of the river channel, so the theory runs, the sources which had supplied the basalt lava of the plateau had already become extinct; but volcanic activity was not entirely banished from the region, and presently a great outpouring of acid lava, entering the valley, flowed for miles along its course, gradually choking it, perhaps even to the brim. The resulting pitchstone has stood the test of time much more securely than the surrounding basalts, for while these latter have wasted to a level generally lower than that of the old valley floor, the pitchstone itself still remains in large measure unaffected, and thus furnishes a somewhat battered cast of the erstwhile hollow.

The artistic appeal of Sir Archibald Geikie's conception has been admitted on every hand; but very properly its credentials have been subjected to a dispassionate and searching enquiry. In 1906, Dr Harker, after mapping the district for the Geological Survey, published an alternative version of the pitchstone ridge. We are now asked to abandon the cherished notion of a lava moulded upon the uneven contours of a river valley, and to accept instead that of an intrusive sill irregular and transgressive in its own right."

Although Bailey supported Geikie in the main points at issue, Harker argued back, and the rest of the geological world, perhaps scared by the clash of the titans, seems to have lost interest. The Sgurr never regained its former textbook popularity. It is only in recent decades that Geikie's ideas have again become generally accepted.

Now, in a further twist to the tale, a new theory, published in 2013 by David Brown and Brian Bell of Glasgow University, makes the Sgurr pitchstone a testament to perhaps the most catastrophic volcanic eruption to afflict Scotland for at least the last 250 million years. But before expounding this, it is worth briefly reviewing the early 20th century controversy, because it was historically important and makes an interesting study of changing geological theories and attitudes.

Some history

Even before Geikie's papers gave it wider fame, the Sgurr was well known, because its pitchstone is an unusual and attractive rock type, because the 'Eigg Pine' (see below) was found there, and because it had been graphically described by many writers, including Hugh Miller. The early writers were vague about its origin, although Miller at least probably regarded it as a lava flow.

Geikie's main line of evidence for his interpretation was that the Sgurr pitchstone is underlain by conglomerate — sedimentary rock composed of rounded boulders, indicating water action. Together, the conglomerate and the pitchstone filled a steep- sided hollow, as shown particularly clearly at Bidein Boidheach, where the western end of the Sgurr ridge is truncated by the present cliff (Figure 21).

At the east end, beneath the Sgurr itself, conglomerates are also found but only half of the former valley is preserved, the southern part having been removed by subsequent erosion. At this locality, the base of the pitchstone is broken-up and decomposed, and fossil wood is found. A subsidiary point made by Geikie was that the south face of the Sgurr ridge has a strikingly banded appearance, caused by an alternation between glassy pitchstone and more-crystalline layers (then called felsite). Geikie regarded these layers as successive lava flows (Figure 22).

To understand Geikie's especial enthusiasm about his theory one must realise that in the 1860s the erosional origin of valleys, so obvious to us today, was by no means universally accepted. It had been urged much earlier by Geikie's heroes, Hutton and Playfair, but catastrophic explanations, which regarded valleys as fault-troughs, were still current:

Hugh Miller had been a supporter of such ideas. With the story of the Sgurr, Geikie could demonstrate the initial formation of a valley, the deposition of conglomerates within it, the outpouring of a lava, and then — to clinch the argument — the final stage in which the former valley fill became the highest point in the region. As he put it in 1871, the Sgurr *"will remain as striking a memorial of denudation as it is a landmark amid the scenery of our wild western shores".*

Harker believed that the felsite layers were intruded into the pitchstone after it had solidified, so there was no direct evidence of successive lava flows. He also concluded that the pitchstone itself is a sill, not a lava. His theory involved a series of coincidences that Bailey and later authors explored and it is now discarded. The exposures involving fragmented pitchstone beneath the Sgurr, seen at the Recess and described in Excursion 4, are particularly hard to explain as an intrusive contact.

The modern view: how the Sgurr formed

The sequence of events as we now understand them is as follows (see (Figure 23)). The main change to Geikie's original concept that has taken place follows from the discovery that the pitchstone contains distinctive shards derived from pumice (volcanic glass full of bubbles), showing that the eruption was driven by expanding gas and that the deposits formed from a hot pyroclastic flow, rather than a lava1.

First, basalt lavas were erupted between 61 and 60 million years ago, forming a broad plateau probably substantially above sea level, and dykes were intruded into them. Volcanic activity ceased. Winding valleys, draining from east to west, were eroded in the basalts. Mapping has shown that there was a coherent series of former valleys, not only beneath the Sgurr ridge but throughout the area later occupied by pitchstone, and that those valleys show relics of ‘trap topography’.

Coarse conglomerates containing water-rounded pebbles and boulders accumulated in the bottom of the valleys, largely by mass-flow down the valley sides. The boulders were mostly derived from the surrounding basalts but some from different rock types, including Torridonian sandstone, from farther away.

Eruptive activity resumed 58.7 million years ago. The pyroclastic material consolidated to form pitchstone, while still hot. The pitchstone cooled evenly on the valley sides, leading to the formation of columnar joints at right angles to the cooling surfaces provided by contact with the basalt slopes. Near the top of the flow, where the cooling pitchstone was acted upon by irregularly percolating water, complex cooling formed joints in spectacular fans, still to be seen at several places along the Sgurr ridge.

Volcanism finally ceased, and a long period of erosion ensued. The basalts quite rapidly wasted away, but the pitchstone was more resistant, so that the filling of the former valley system became the highest ground, the pitchstone standing proud above the basalt plateau. Glacial erosion provided the finishing touches.

More on the new interpretation

Why is the pitchstone an ignimbrite?

We have already recorded that the Sgurr pitchstone is now regarded as an ignimbrite, deposited from a pyroclastic flow. It had traditionally been regarded as a lava because

1 Footnote: At the time the Geological Survey memoir was published (1997), it was evident that the basal part of the pitchstone had originated as a pyroclastic flow. Later work by Brown and Bell has shown that this applies to the whole thickness of the pitchstone. it appears to be a homogeneous glass, apart from containing crystals formed before it erupted. It is notoriously difficult to distinguish between silicic lavas and ignimbrites, because the latter, although transported as fragments, can become glassy as the hot fragments accumulate and compact rapidly.

Brown and Bell have discovered that relics of an original fragmental texture can be found throughout the pitchstone’s thickness, not just at its base. The basal breccia to the pitchstone, seen at the Recess, is regarded as a peperite, a rock formed when magma or lava interacts with wet sediment on the valley floor, mixing and fragmenting as it does so. Peperites are characteristic of ignimbrites, as opposed to the more blocky breccias found beneath some silicic lavas. Another difference between ignimbrites and lavas is that silicic lavas are viscous; they do not normally travel far or fast from their source. There is no known nearby source for the pitchstone. Pyroclastic flows can travel far, and at terrifying speed, making them the most-dangerous forms of eruption in inhabited areas today. Brown and Bell also maintained that the layering seen in the pitchstone resulted from successive, but closely spaced, pulses of pyroclastic activity, rather than recording a later intrusive episode as many had claimed.

How far did the pyroclastic flows extend?

The islet of Oigh Sgeir, 30 km north-west of Eigg, is composed of a rock identical to the Sgurr pitchstone. It has often been proposed that it might lie in a prolongation of the lava-filled valley system seen on Eigg. But this is difficult to reconcile with the viscous and slow-moving nature of silicic lavas. It is much easier to explain as a pyroclastic flow, which need not have arrived via Eigg.

Where was the ultimate source?

Rum, sometimes proposed on grounds of proximity, can be ruled out, now that dating has been improved: the igneous rocks there are too old (and pebbles probably derived from them occur in the conglomerates beneath the Sgurr).

Igneous rocks of appropriate age are well known in the Red Hills of Skye, and are accompanied by several volcanic vents. Their geochemical composition shows that they are a possible source. So the proposal is that vast catastrophic eruptions from one of the vents sent pyroclastic flows across the area as far as Eigg, and probably far beyond. Several flows arrived in rapid succession, producing the layered ignimbrite pitchstone we see on the Sgurr. Such ignimbrites must once have been widespread throughout the region affected, not just within valleys as was proposed in the original theory. They have been eroded away except where ponded in palaeovalleys like those on Eigg, where perhaps they also most thoroughly vitrified to simulate lavas. Thus the valley fills subsequently proved resistant to erosion, producing the inverted topography that so impressed Geikie 150 years ago.

What remains to be discovered?

A troubling question is the source of the boulders in the conglomerate. Most are of local basalt, but others include large, subangular blocks of Torridonian sandstone, a rock well known in the north-west Highlands and also, much closer at hand, on Rum. However, the pre-pitchstone valleys drained westwards, which makes it difficult to accept Rum as the source, and the size and sub-angularity of some of the boulders makes long-distance transport problematic. Might the blocks have been transported by the pyroclastic currents? Pyroclastic density currents elsewhere (western USA, Tenerife) are known to have carried large blocks of rock tens of kilometres from source. Work remains to be done on this.

Another problem is to determine more precisely the source vent for the pyroclastic eruption among the known vents on Skye, or maybe it was from a source now under the sea.

Conclusion

The Sgurr pitchstone records the latest and most dramatic eruption in the Palaeogene volcanic history of Scotland. It deserves a new burst of fame for anybody interested in Scotland’s past.

The Eigg Pine

Hugh Miller ended one of the chapters in ‘The Cruise of the Betsey’ with a striking sentence: *“The gigantic Sgurr of Eigg rests on the remains of a prostrate forest.”* He was referring to the then already-famous occurrence of the Eigg Pine.

Fossil wood from beneath the Sgurr cliffs was first described by John MacCulloch in 1814. Pieces of it became some of the first samples to be studied using the new technique of cutting a slice of the wood and grinding it down until it became transparent — essentially the same technique as is used to prepare the thin sections of rock samples that strain the eyes and test the patience of geology students to the present day. This enabled the internal structure of the wood to be observed, which revealed that it belongs to the pine family. It also revealed growth rings, which could be compared to those of modern pines to reconstruct conditions of growth. The Eigg pine wood was described by Witham in 1831 and became the subject of additional accounts in the next few years. (It now seems that the credit for the sectioning method and subsequent description belongs to James Nicol, and that Witham stole the fame).

So, on his visit in 1844, Miller was naturally anxious to see the source of the wood and collect samples for himself. His ascent towards the Sgurr ridge with his companions was uneventful, until an encounter just as they reached the critical locality provoked one of his most entertaining asides:

“Just at this interesting stage, however, our explorations bade fair to be interrupted. Our man who carried the pick- axe had lingered behind us for a few hundred yards, in earnest conversation with an islander; and he now came up, breathless and in hot haste, to say that the islander, a Roman Catholic tacksman in the neighbourhood, had peremptorily warned him that the Sgurr of Eigg was the property of Dr M’Pherson of Aberdeen, not ours, and that the Doctor would be very angry with any man that meddled with it. .... I was tickled with the idea of a fossil preserve, which coupled itself in my mind, by a trick of the associative faculty, with the idea of a great fossil act for the British empire, framed on the principles of the game-laws: and, just wondering what sort of disreputable vagabonds geological poachers would become under its deteriorating influence, I laid hold of the pickaxe, and broke into the stonefast floor. And thence I succeeded in abstracting — feloniously, I dare say, though the crime has not yet got into the statute book — some six or eight pieces of

the Pinites Eiggensis, amounting in all to about half a cubic foot of very ancient wood— value unknown. I trust, should the case come to a serious bearing, the members of the London Geological Society will generously subscribe half-a-crown a-piece to assist me in feeing counsel. There are more interests than mine at stake in the affair. If I be cast and committed— I, who have poached over only a few miserable districts in Scotland— pray, what will become of some of them — the Lyells, Bucklands, Murchisons and Sedgwicks— who have poached over whole continents?"

It was a joke to Miller, but 'fossil poaching' has become a serious issue, especially in the USA, and the law, inevitably, has become involved.

Miller's collection is now in the National Museum of Scotland. Further collections were made in the nineteenth century and by the Geological Survey in the early years of the last century. It seems that the large pieces found in these later collections might have come from one large pine trunk and its associated branches. No large pieces have been collected in recent years. Smaller fragments of wood can still be found at the classic locality and also elsewhere along the base of the Sgurr ridge. Some of these are in the condition of charcoal, contrasting with the silicified wood found by MacCulloch and later workers. Wood occurs in both the conglomerate underlying the Sgurr pitchstone and in the decomposed base of the pitchstone itself, the part certainly representing a pumice deposit.

In the light of our present understanding of the Sgurr, the wood belonged to vegetation present in the area shortly before the eruptions that heralded the arrival of the pitchstone in the ancient valley; its age is Palaeogene, 58.75 million years2. Trees were growing in or around the valley before eruption of the hot gas cloud that heralded the arrival of the pyroclastic flow, thus explaining the wood found within the base of the pitchstone. The charcoal could have resulted from wildfires started by lightning, but some of it might also result from volcanic activity.

The flora awaits a comprehensive botanical evaluation. The large pieces of wood belong to the Eigg Pine, but there are also woods akin to the modern monkey-puzzle, and wood belonging to the Rosaceae family of flowering plants, probably related to *Eucryphia*, a beautiful flowering tree seen in Scottish woodland gardens, including that

2 Footnote: There has been confusion over the date for two reasons— firstly the volcanic rocks were believed to be Mid Jurassic in Miller's day ["oolitic" in the then-current terminology], and secondly Harker suggested that the wood might have been derived from the genuinely Jurassic rocks beneath the volcanic section, in order to conform to his now-discredited theory of the origin of the Sgurr. at Eigg Lodge, today. Better-known floras from elsewhere in the Hebrides confirm that the climate then was much warmer than that of Scotland today.

Miller's prostrate forest may be an exaggeration, but he also wrote perceptively about the storehouse of climatic information that resides in the growth rings of fossil wood. He combined description of the Eigg Pine with other wood from east Scotland that we know is much older (really Jurassic!), but the message is clear.

"In one of my specimens, and one only, the rings are of great breadth. ...... This one specimen furnishes curious evidence that the often-remarked but little understood law, which gives our better and worse seasons in alternate groupes, various in number and uncertain in their times of recurrence, obtained as early as the age of the Oolite [Jurassic]. The rings follow each other in groupes of lesser and larger breadth....... An arrangement of nature—first observed, as we learn from Bacon, by the inhabitants of the low countries, and which has since formed the basis of meteoric tables and of predictions, and elaborate cycles of the weather—bound together the twelvemonths of the Oolitic period in alternate bundles of better and worse: vegetation throve vigorously during the summers of one group, and languished in those of another in a state of partial development."

Just such studies now enable palaeobotanists to elucidate the past climates of the Arctic and Antarctic, where in past geological times large forest trees grew prolifically, despite the length of the polar night.

After the volcanoes: erosion

During the period of volcanic activity, Eigg was an anonymous part of a vast basaltic plateau that covered much of north-west Scotland and the north of Ireland, although already with the unusual feature of a pitchstone-filled valley. After volcanic activity finally ceased, the basalts and other rock types were weathered under a warm climate, and rivers dissected the plateau. Parts of it subsided, becoming the sites of large lakes somewhat like Antrim's Lough Neagh today, in which freshwater sediments accumulated about 26 million years ago. The nearest of these was west of Canna. We do not know precisely when the outlines of the present islands began to appear, because the record of earlier events has been largely obliterated by intense glacial erosion within the last million years, indeed much of it within the last 100000 years. However, major faults, like the one between Eigg and Rum, probably moved during post-volcanic pre-glacial times, and even when not active, the shattered rock along them would have been readily eroded. Thus valleys were formed, eventually to be flooded when the sea returned to the area. So when the Ice Age began, the Hebridean area would have had substantial relief, but not necessarily bearing much resemblance to the present shape of the islands, and none at all to the shape of individual mountains.

During the Ice Age

After the long period of relatively gentle erosion by rivers, erosion intensified dramatically when the first of a succession of glacial periods affected Scotland. Rounded mountains were given jagged arêtes and glaciers carried huge boulders over vast distances. We do not know exactly when glaciers reached our region, because the erosion caused by one ice sheet tends to obliterate the landforms and deposits created by preceding ones. We do know that major glaciation of the North Atlantic region was under way by 2.4 million years ago, accompanied by a marked fall in sea level, and that glaciers waxed and waned, and sea level fell and rose, repeatedly thereafter. At times of low sea level, Eigg, if it existed as such, would have been joined to neighbouring islands. Only the record of the last glacial period, ending about 13 000 years ago, survives in decipherable form. Its waning stages, and a brief re-advance of local glaciers about 11 000 years ago, shaped the present outline of Eigg, and indeed of the rest of Scotland. Since the melting of the ice, the landscape continues to evolve, but at a much slower rate — at least until the ice returns, as it will a few thousand years after our species has finished its current experiment with the Earth's atmosphere. So there is no final answer to the question "when did Eigg become an island", and the concept of finality itself is out of place in geology. However, we can examine the local evidence for glacial and related activity.

Glacial till and glacial erratics

The most widespread deposits in glaciated regions are tills, consisting of material brought by glaciers from the mountains to the lowlands, where the moving ice slowed and eventually melted. [Till was formerly known as 'boulder clay' but since the coarse fragments are not necessarily as large as boulders and since the matrix is not always as fine as clay-grade, the modern term 'till' is preferred.] The nature of the 'boulders' enables the source of the glaciers to be determined. Tills themselves are not generally conspicuous on Eigg, but pebbles and boulders derived from them ('erratic boulders') are frequently found, especially on beaches. Metamorphic rocks from the Highlands are common, especially, but not only, on the east coast, showing that the whole island was once covered by ice. More-locally derived coarse glacial debris, moraine, forms two prominent ridges above Blàr Mór in the north-west of Eigg. This material is closely associated with the area of landslips described below. Probably, glacial erosion and land-slipping proceeded concurrently.

Where glacial till is thick, masses of ice can be included within it. When these melt, many years later, depressions form on the surface, and these fill with water, forming a kettle-hole lake. An attractive example is to be seen beneath the basalt cliff east of Laig Farm.

Raised beaches

Raised beaches are another famous feature of glacial Scotland. They testify to times when relative sea level was higher than it is now. The matter is not simple. At times during the last few hundred thousand years, sea level worldwide was higher than at present, because there was less ice in the world, but for most of the time there was more ice and sea level was lower. These conditions alternated many times. The most widespread raised beach in the Inner Hebrides is the youngest, dating from just a few thousand years ago. Sea level was rising: so why is the beach raised? The answer is that Scotland was rising too. The Highlands had been depressed by the weight of ice upon them, but when the ice melted they rebounded. The amount of the rebound was greater than that of sea-level rise, so storm-beaches, similar to those forming today, are found at heights above sea level of 5m or more, for instance behind Laig Bay and near Eilean Thuilm on Eigg. There are no such raised beaches on the Outer Isles, because they were never covered by thick ice and so did not rebound. The rate and extent of post-glacial rebound provide one of the ways in which geophysicists calculate the viscosity of the Earth's mantle.

Landslides

Perhaps the most striking landforms on Eigg, apart from the Sgurr, are the basalt cliffs of the north of the island and the landslides that surround them. Cliffs retreat by a combination of processes. Rock fragments fall and accumulate at the foot of the cliff, forming screes. Masses of rock and soil slide down hillsides as mudslides. On a larger scale, whole segments of cliffs rotate and subside, forming landslides. This happens especially where hard, dense, permeable rocks, such as basalts, rest upon soft, easily eroded and impermeable rocks such as mudstones, as in the north of Eigg. Most of the visible landslides formed shortly after the last deglaciation. Cliffs were left unsupported as the ice melted, and the climate was wet and cold. Whole sections of the cliff face subsided, rotating as they did so, so that the rocks within the subsided block dip back towards the cliff face, as also does the land surface. Small lochans are often trapped behind the slipped blocks.

The best example on Eigg is at the former shieling on the east coast, whose setting is so beautifully described by Hugh Miller. He arrived at sunset, one day in 1844:

"Rarely have I seen a more interesting spot, or one that, from its utter loneliness, so impressed the imagination........A slim pillar of smoke ascends from the roof in the calm, faint and blue within the shadow of the precipice, but caught in the sunlight in its ascent, and blushed, ere it melted into the ether, a ruddy brown. A streamlet came pouring down from above in a long white thread, that maintained its continuity unbroken for at least two- thirds of the way; and then, untwisting into a shower of detached drops, that pattered loud and vehemently in a rocky recess, it gathered itself up into a lively little stream, and, sweeping past the shieling, expanded in front into a circular pond, at which a few milch cows were leisurely slaking their thirst. The whole grassy talus, with a strip, mayhap a hundred yards wide, of deep green sea, lay within the shadow of the tall rampart; but the red light fell, for many a mile beyond, on the glassy surface; and the distant Cuchullin Hills, so dark at other times, had all their prominent slopes and jutting precipes tipped with bronze; while here and there a mist streak, converted into bright flame, stretched along their peaks, or rested on their sides. An island girl of eighteen, more than merely good-looking, though much embrowned by the sun, had come to the door...."

The cliff behind the shieling, over which the streamlet tumbles, is of basalt, part of the narrow plateau of Beinn Bhuidhe. The green fields where the cattle grazed are fertile because they are on gravels accumulated in a former lochan, now drained by erosion of its one-time barrier by the stream that sweeps past the shieling. The barrier itself is formed by the landslip; in the walls of the little gorge made by the stream one can see Jurassic sandstone tilted steeply towards the cliff, with mudstones beneath it. Above the sandstone are level-bedded gravels of the former lake. The building is ruinous and deserted.

Figures

(Figure 1) Basalt cliffs behind Cleadale.

(Figure 2) Camas Sgiotaig (the Singing Sands) viewed from the cliff to the south (Excursion 1).

(Figure 3) Eigg in the Hebrides. By permission IPR/25-11c— British Geological Survey.

(Figure 4) Rum from the Sgurr ridge (Excursion 4).

(Figure 5) The geology of Eigg. Note that basalt dykes and sills are not shown. By permission IPR/25-11c — British Geological Survey.

(Figure 6) Plesiosaur skeleton.

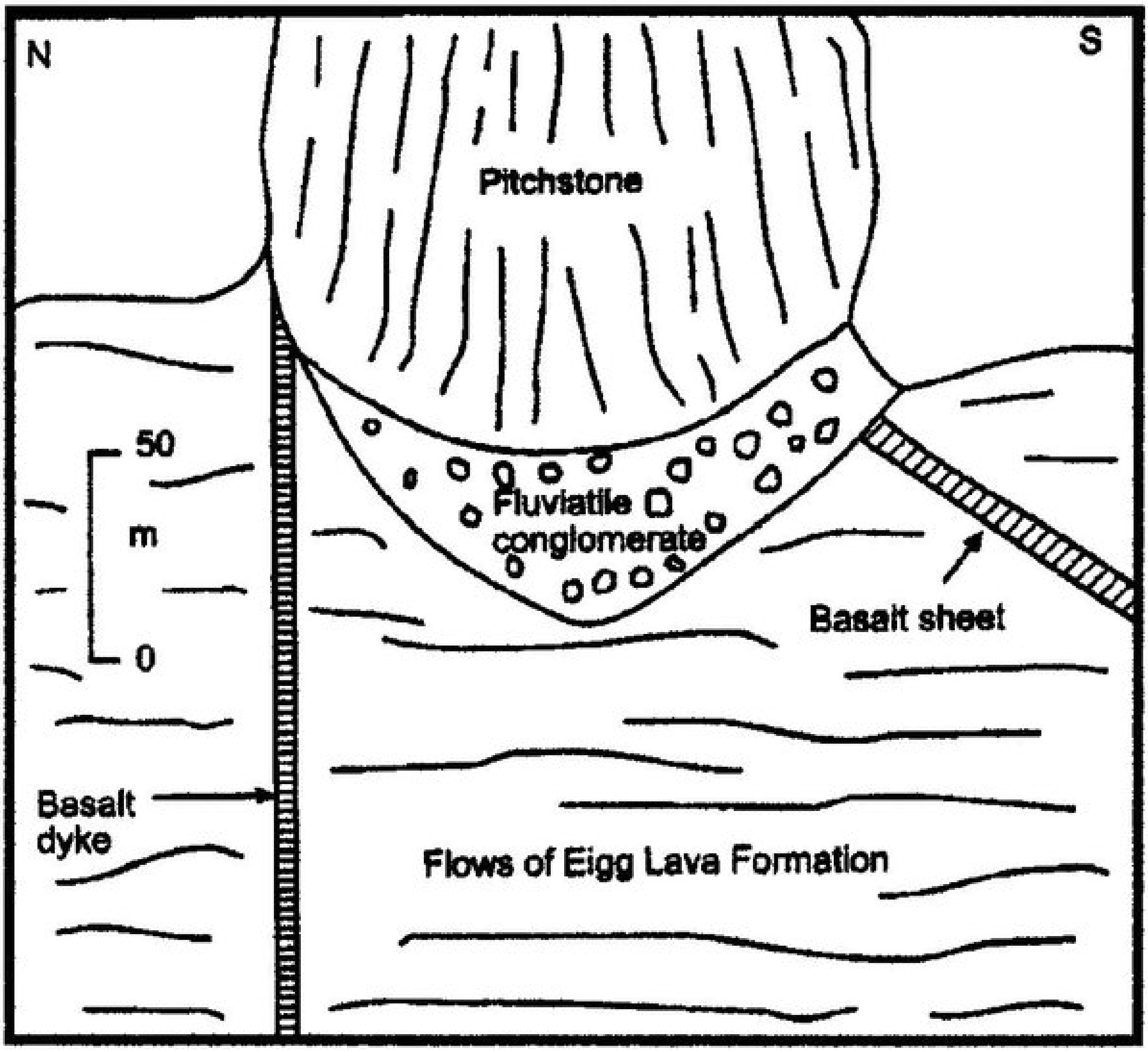

Figure 21 Sketch of cliffs at Bidein Boideach, showing conglomerate underneath the pitchstone. By permission IPR/25-11C – British Geological Survey.

Figure 22 The south face of the Sgurr ridge, showing layering and the columnar nature of the pitchstone.

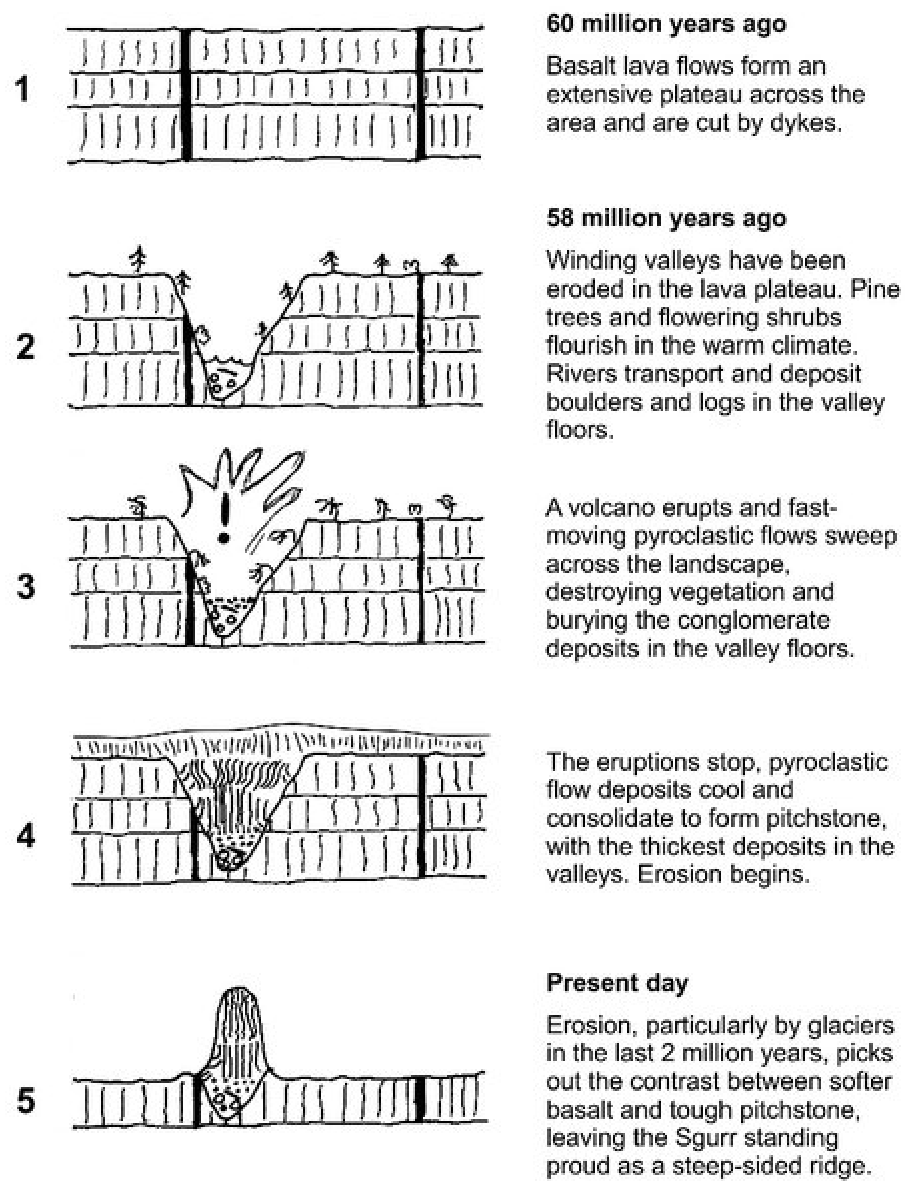

Figure 23 Sketch showing the different stages in the formation of the Sgurr.

Figure 1 Basalt cliffs behind Cleadale.

Figure 2 Camas Sgiotaig (the Singing Sands) viewed from the cliff to the south (Excursion 1).

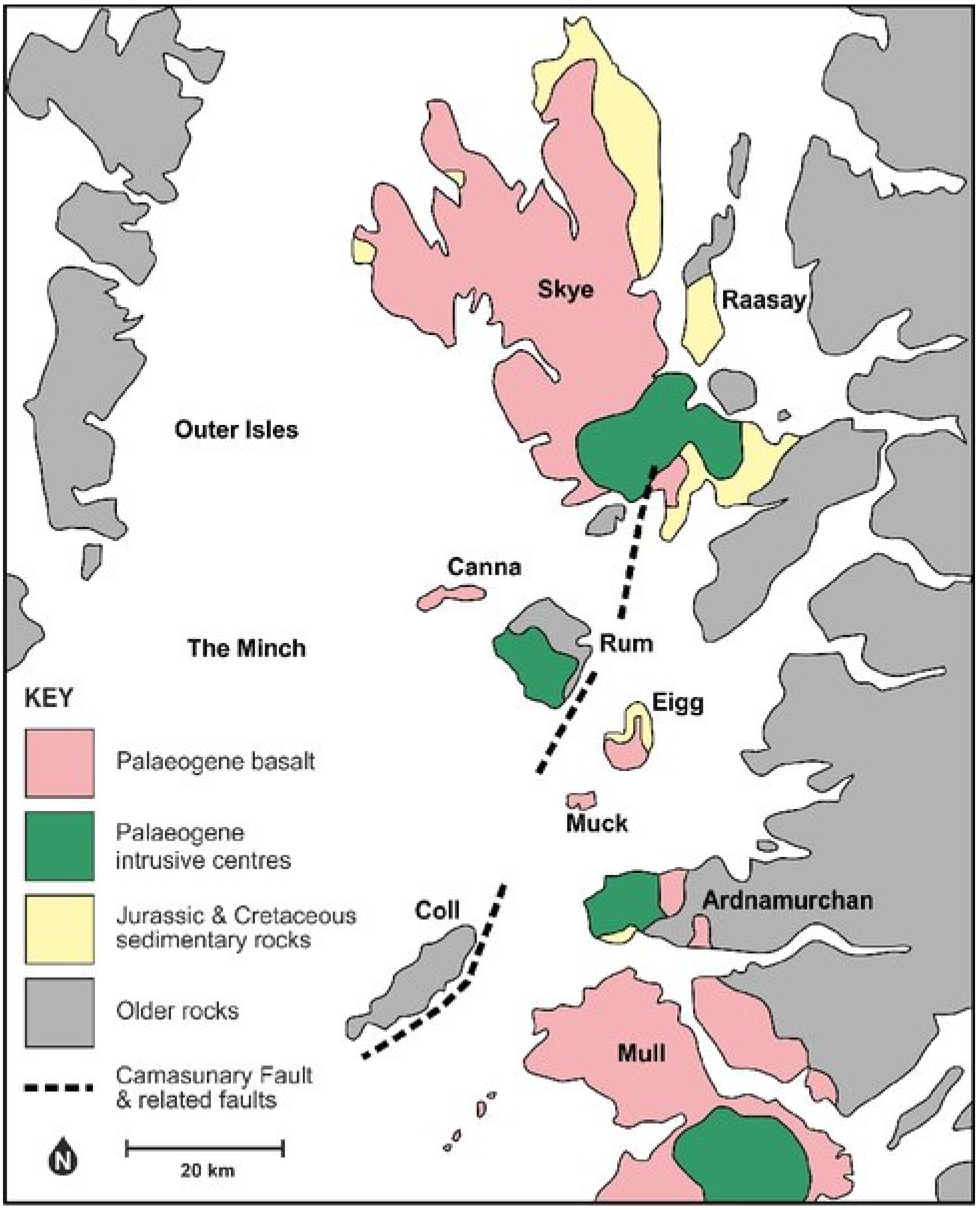

Figure 3 Eigg in the Hebrides. By permission IPR/25-11c— British Geological Survey.

Figure 4 Rum from the Sgurr ridge (Excursion 4).

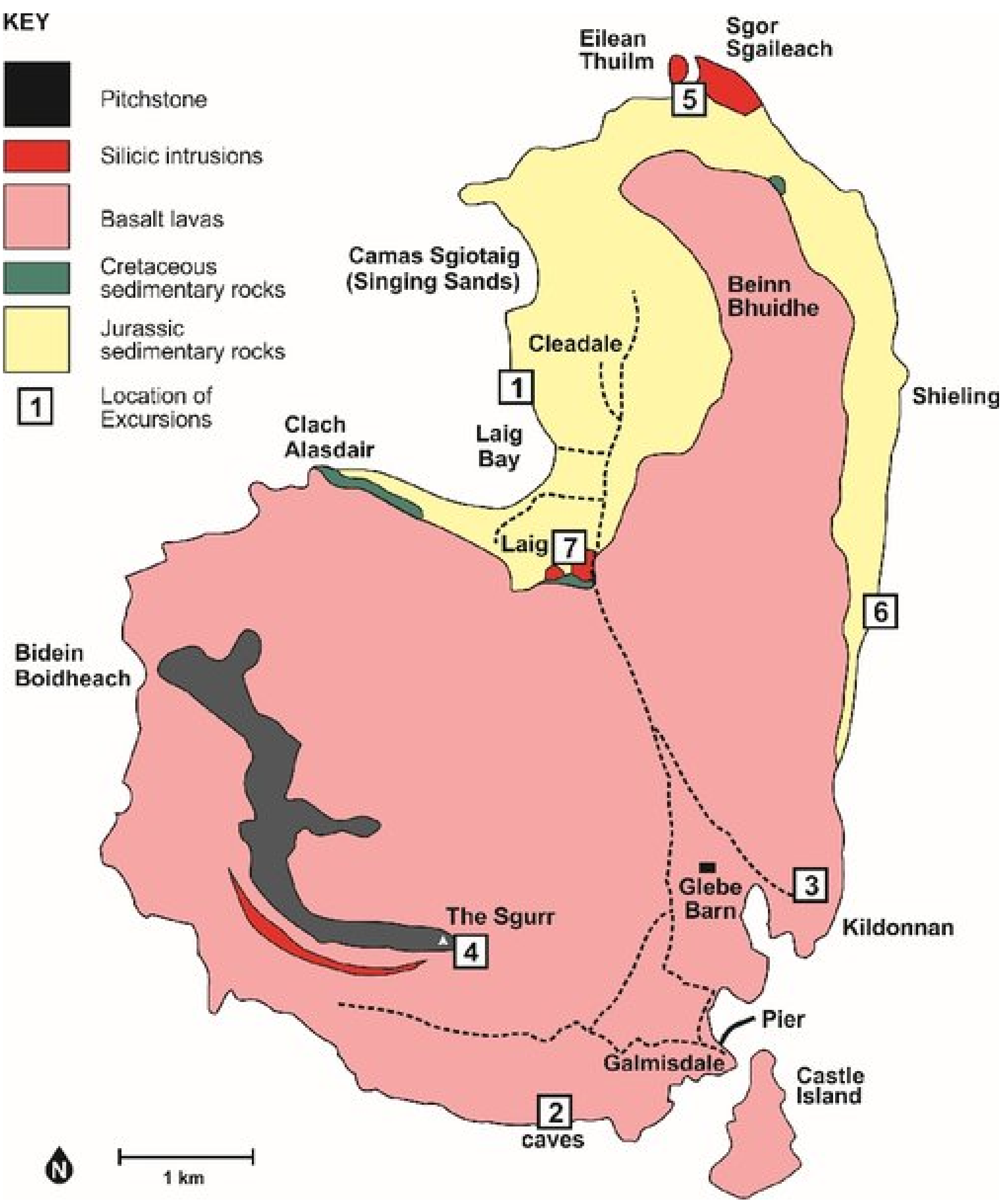

Figure 5 The geology of Eigg. Note that basalt dykes and sills are not shown. By permission IPR/25-11c — British Geological Survey.

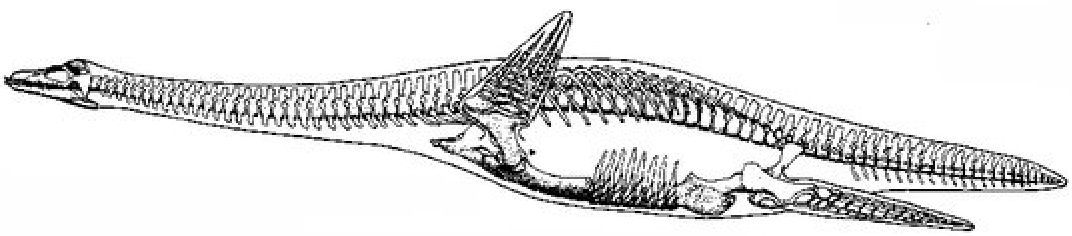

Figure 6 Plesiosaur skeleton.

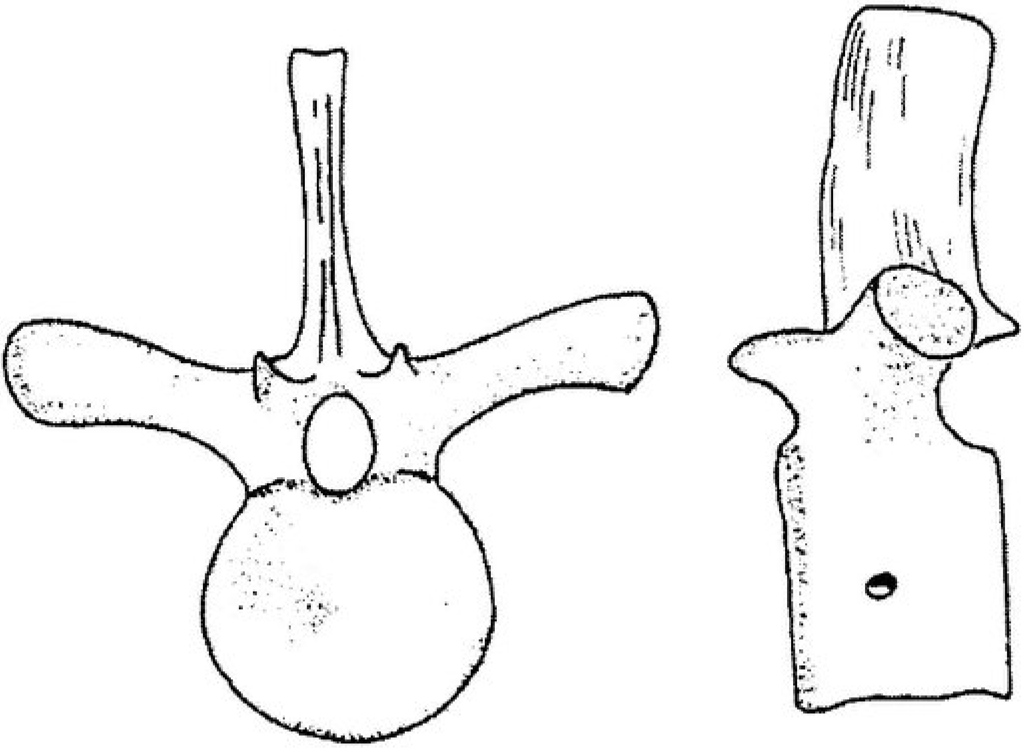

Figure 7 Plesiosaur vertebrae.

Figure 8 Praemytilus strathairdensis scale x2.5 (Excursion 6).

Figure 9 Concretion in the Jurassic sandstone, Laig Bay (Excursion 1).

Figure 10 Praeexogyra hebridica (Excursion 7).

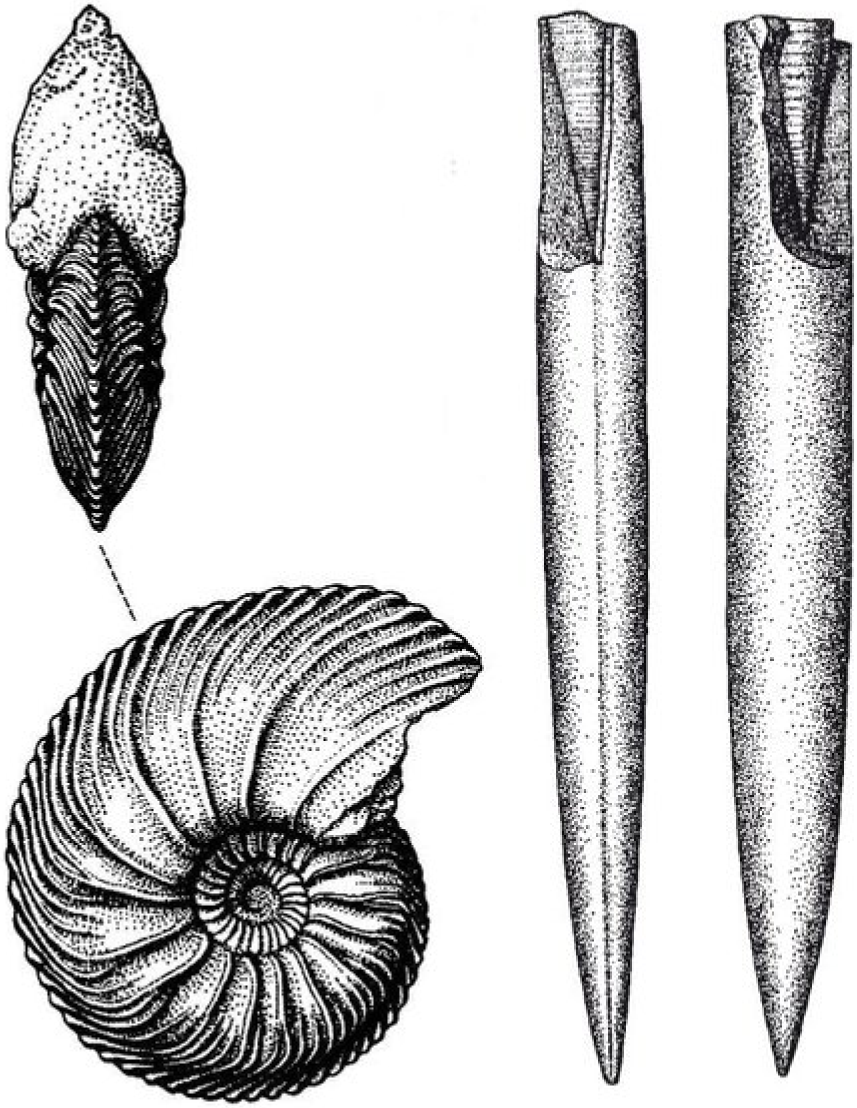

Figure 11 Examples of Jurassic ammonite (Cardioceras) and belemnite.

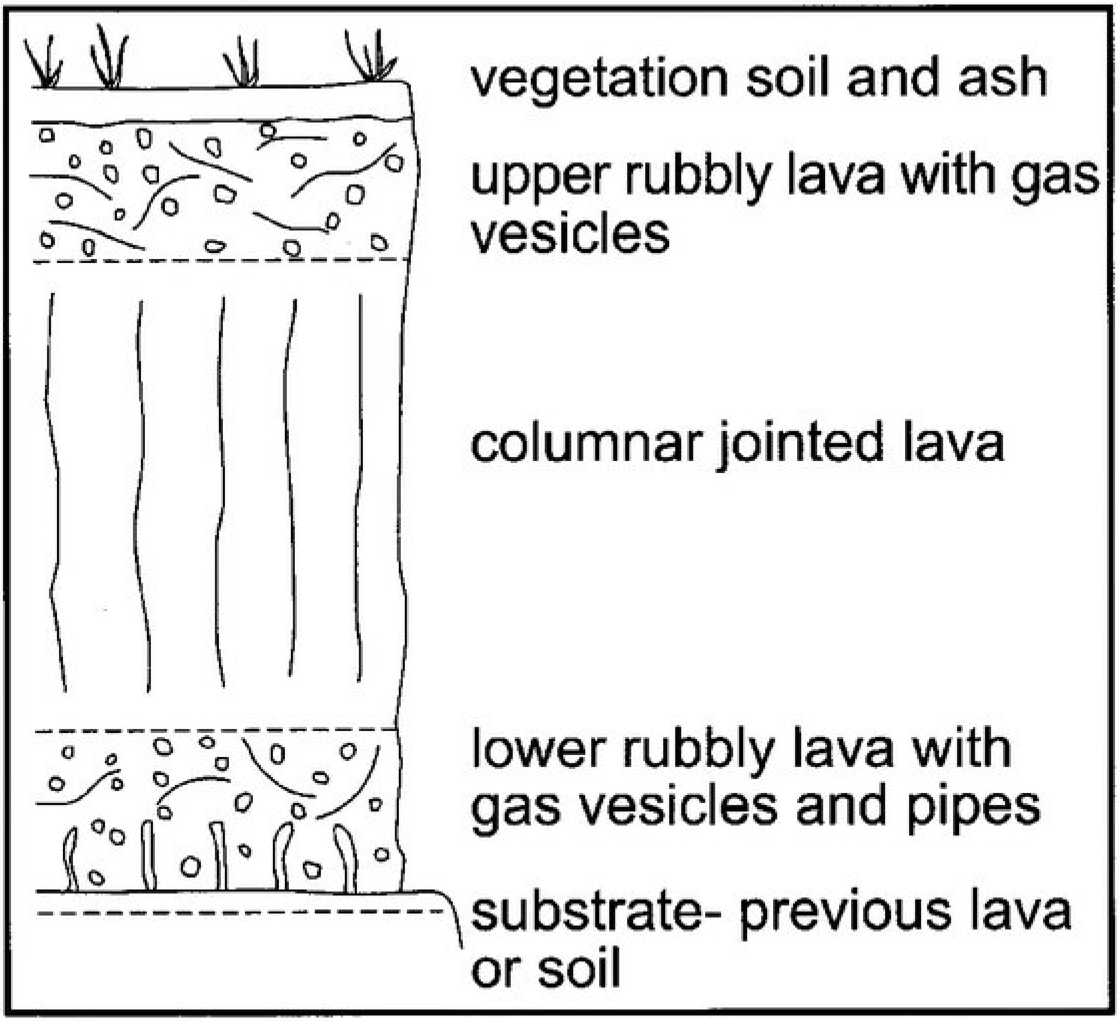

Figure 12 Typical structure of a lava flow.

Figure 13 Columnar joints in a basalt lava flow.

Figure 14 Red bole developed between lava flows owing to intense weathering of the top section of the lower flow.

Figure 15 Sketch of Eigg showing trap topography.

Figure 16 Dykes intruding Jurassic sedimentary rocks between Laig Bay and Camas Sgiotaig.

Figure 17 Dyke intruding basalt lava flows, Galmisdale (Excursion 2).

Figure 18 Dyke intruding sandstone, near Camas Sgiotaig (Excursion 1).

Figure 19 The Sgor Sgaileach silicic sill forms the northern tip of Eigg (Excursion 5).

Figure 20 The Sgurr from the east, showing the junction between the pitchstone of the Sgurr and the brown- weathering basalts below.

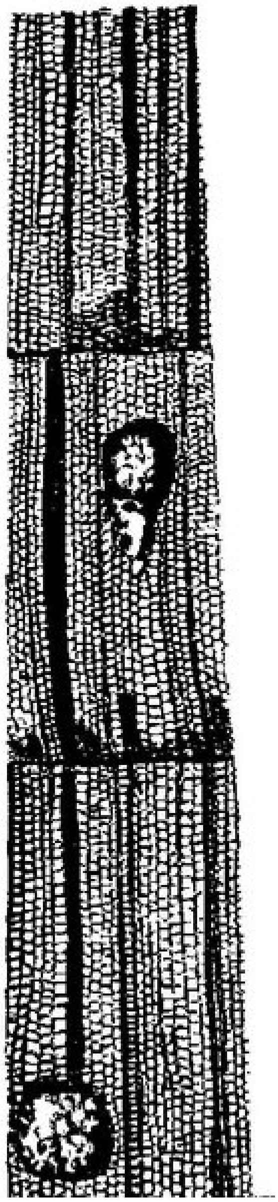

Figure 24 Thin section of Pinites eiggensis.

Figure 25 Kettle hole lochan near Laig farm (Excursion 1).

Figure 26 Raised beach behind Laig Bay, with Cleadale and Bealach Thuilm.

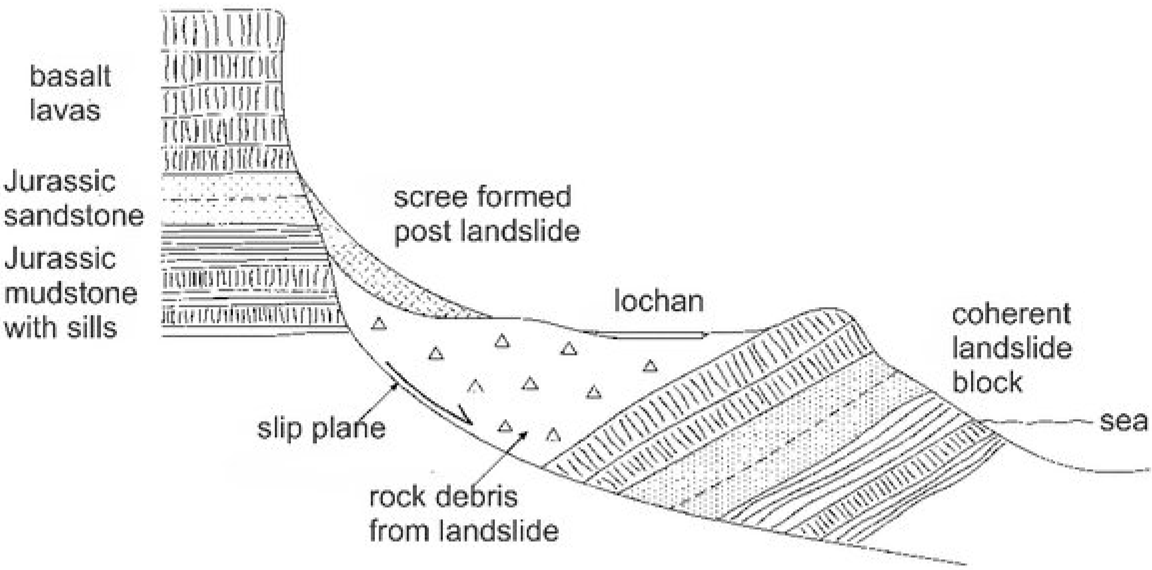

Figure 27 Diagram of a landslide.

Figure 28 Remains of the shieling, east coast of Eigg (Excursion 6).