

THE COMPLETE SCOTLAND

GEOLOGY AND SCENERY

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A STUDY of the map of Scotland shows that topographically the country is divided into three distinct regions, the Scottish Highlands, the Southern Uplands, and the broad Midland Valley which lies between. Towards an understanding of the origin of these features and of the scenery to which they give rise a brief account of the geological history of the country may be helpful. The Highland area is, for the most part, occupied by metamorphic rocks, rocks primarily of igneous or sedimentary origin which have been so subjected to pressure and heat, so folded, fractured, sheared and crushed, that it is impossible in many cases to tell what they were originally. They have been thoroughly reconstructed; the granite, sandstone or clay has become the gneiss, quartzite or schist respectively. Three divisions are recognized, the Lewisian Gneiss of the North-west Highlands and the Outer Isles, the Moine Series of the Central Highlands, and the Dalradian Series of the Eastern Highlands.

The oldest rocks in Scotland, the foundation on which the later superstructure has been erected, are the Lewisian, sometimes spoken of as the Fundamental Complex. The series includes gneisses and schists, the metamorphosed representatives of ancient granite rocks, or of fragments of the cover into which they were intruded. Since their formation they have been subjected to earth pressures time and again; they have been repeatedly invaded by igneous rocks, and the result is a tough, grey, durable gneiss, the "Old Boy" of Scottish geologists.

The scenery to which this ancient rock gives rise is likewise characteristic. It nowhere rises into a hill of any considerable height, but presents a monotonous landscape of grey rock, now rising through the heather in rounded hummocky knolls, now sinking into hollows occupied by lochans. Without doubt this smoothness of contour as well as the freshness of the exposed rock is a legacy of the Ice Age, but for its monotonous uniformity another explanation must be supplied.

In striking contrast to the grey gneiss on which they rest, the red hills of Torridonian Sandstone rise above, and seem to dominate the Lewisian plain. They are mere remnants of erosion, but they tell how the present Lewisian fragments formed part of a more extensive land, of how this was carved by erosion into mountain and valley, and worn down to an irregular plain. Submergence followed and the old land surface was buried under at least 10,000 feet of strata, the Torridonian Series. These were in turn elevated, and have been largely stripped off, and with their removal this primeval landscape is once more exposed to view.

The Torridonian strata are mainly red sandstones, and they still lie in practically horizontal beds. The pyramidal hills into which they have been carved add a needed touch of form and colour to the gneissic landscape. Some like An Stac and Suilven are crumbling rapidly in ruins, others like Coul More or Slioch are more resistant, but in every case their form and

architecture make them striking features of the landscape. They rise tier on tier of massive sandstones, carved by erosion into mural precipices, receding along joint-planes into gullies and chimneys, or projecting into craggy bastions.

With the Torridonian uplift, the movements which affected this ancient land were not yet at an end. Capping many of the Torridon hills and sometimes resting directly on the gneiss is a white quartzite which yields readily under weathering, littering the hill-tops with screes of angular fragments. From a distance these screes gleam in the sunshine, and seem to envelop the summits in a mantle of snow. This quartzite is the lowest member of the Cambrian formation. The Torridonian sandstones had been upheaved, and partially stripped off, when the area was once more submerged beneath the waters of the Cambrian sea, and a series of sandstones, shales, and limestones deposited, of which in spite of subsequent elevation and erosion, 2,000 feet still remain. Three successive land surfaces are thus evident in the north-west, the surfaces of Lewisian and Torridonian times and that of the present. Such mountains as Ben Arkle, Ben Eighe, Quinaig, Ben More Assynt and Liathach are especially notable in this respect.

One more chapter of geological change in the north-west has yet to be added. The normal upward succession is Lewisian, Torridonian, Cambrian. Sometimes however Torridonian, Moinean, or even Lewisian may be found resting on Cambrian, the youngest member of the succession. This apparent inversion presented a problem which long baffled solution until it was shown conclusively to be due to a series of gigantic overthrusts whereby great sheets of strata had been torn from their native beds, and pushed bodily westwards for a distance of at least ten miles, over-riding and surmounting the unmoved strata to the west. Such overthrusts where folded strata snap under powerful pressures are to be found in all mountain ranges, notably in the Alps, and their early recognition in the North-west Highlands makes this classic ground. The best localities for examples of these thrusts are the cliff of the Knockan, and the Stack of Glencoul (Moines on Cambrian), Ben Liath Mhor (Torridonian on Cambrian), and Loch Glencoul (Lewisian on Cambrian).

The Origin of the Highlands.

The traveller who climbs the winding path that leads to the summit of Ben Nevis is well rewarded for his labour in the magnificent panorama that lies spread around him. Ranging into the distance ridge follows ridge and peak succeeds peak, with "many a darksome glen and gleaming loch," the wide sweep of the Highlands, "a tumbled sea of hills." But if he should be so unfortunate as to make the climb when the valleys are filled with mist, with the dark hill-tops peeping through their filmy shroud, then is he doubly rewarded, for the origin of the Highland hills is made clear. All these peaks are seen to rise to the same general level, so that if the straths and glens were infilled, the surface would be that of an elevated plain, highest in the west, and sloping gently towards the east. Out of this plain has been carved the varied form of hill and strath and glen; the Highlands are the remnants of a dissected plateau.

In this landscape the most arresting physical feature is the hollow of Glen More - the Great Glen - with its chain of lakes; a great cleft which runs from the Linnhe Loch north-eastwards to the Moray Firth and which provides the route of the Caledonian Canal. It lies along a

line of fault, the extent of which is still unknown; of great antiquity, movement along it has not yet ceased, and earthquake shocks occasionally occur. By it the Highlands are cut in two and a marked effect is produced upon the drainage system. Prior to its initiation the rivers flowed eastwards in response to the slope of the ground, as consequent streams. West of the Great Glen they still do so without any regard to the underlying geological structure, the main lines of which run N.E.- S.W. They must therefore have begun to dig their valleys before the present structural folds were impressed upon the rocks, or at least before they were exposed at the surface, and the trend of their valleys shows the remarkable persistence of a river when it has once entrenched itself. East of the glen the faulting has diverted the drainage so that the rivers flow north-east, more in accordance with the underlying structure.

Ben Nevis.

Turning now to his immediate surroundings, let the traveller observe the mountain on which he stands. The summit of Ben Nevis is composed of volcanic rocks, lava-flows erupted as long ago as Old Red Sandstone times, and they rest on schists, a fragment of the old land surface over which they flowed. It is to be noted that the lavas are ringed round on every side by granite. The explanation of this structure reveals an interesting phenomenon in the mechanics of igneous intrusion. The molten rock may burst its way to the surface, and give rise to a volcano; or it may simply uparch the overlying cover, and, occupying the cavity, cool quietly in situ. In this instance, however, the pressure exerted by the uprising liquid has rent the overlying roof, and a sinking block has forced the molten rock up along its margins to form the granite rings. Erosion has once more exposed the sunken roof, and the tough lavas, more durable than the granite, now tower above it and give rise to the mural precipices which form the northern aspect of the mountain.

The above phenomenon is termed a "cauldron subsidence," and a second example may be cited, that of the Glencoe region. Glencoe has a sinister reputation in Scottish history, and to the wayfarer it may present itself in sinister garb, its darksome corries and gloomy recesses veiled in mist. To the lover of scenery in its wilder aspects Glencoe makes a strong appeal. The glen itself is a relic of the time when the rivers flowed east before the formation of the Great Glen Fault, but widened and deepened by glacier action. Above it tower grand mountains, Aonach Eagach on the one hand, on the other the "Three Sisters of Glencoe," and Buchaille Etive Mhor, the "Herdsman of Etive." These hills are built up of lava flows contemporaneous with those of Ben Nevis. They rest on and are almost entirely surrounded by schists. They have been preserved through a cauldron subsidence, the sinking of an elliptical block 9 miles long by 5 wide. The lavas which once surrounded the cauldron, and a portion of the softer schists underlying them, have been planed away, and the resurrected fragment carved into its present form.

The Cairngorms.

Turning eastwards from Ben Nevis, the eye dwells on the Cairngorm massif. The best

viewpoint for this group of mountains is from the north or north-west; from the south they fail to impress. From Aviemore their structure is apparent - an extensive plateau with a slight eastward slope, cleft in two by the through pass of the Larig Ghru, and dissected by valleys into the six Cairngorms. Farther to the south-east rises the mass of dark Lochnagar.

The plateau origin of these mountains is shown by their uniformity of height (all in the neighbourhood of 4,000 feet), and by their level summits, littered with granite debris. For the Cairngorms are of granite, one of several masses in the Eastern Highlands now exposed through the removal of the thick cover into which they were injected. They show the varied forms of mountain scenery to which granite from its jointing and composition lends itself, but in these northern regions it is the evidence of glacial erosion that impresses most. Braeriach and Lochnagar possess magnificent corrie basins; there are glacial lakes, moraine-dammed like Loch Callater, or resting in over-deepened valleys like Loch Avon or Loch Muick, while the scree-littered hill-sides bear evidence to the shattering action of frost.

The Southern Uplands.

The scenery of the Southern Uplands is of a different order. To one fresh from the rugged grandeur of the Highlands, they bring a sense of quiet restfulness and peace. Their dearth of lakes, their treelessness, the smoothness of their grassy slopes, broken here and there by scour or ravine, their level summits, are in strong contrast to the Highlands; only in the west do the granite hills of Galloway recall some of the features of Highland scenery, and these are the parts least visited. It is at certain seasons of the year when they are ablaze with colour that they present their most attractive aspect. To this must be added the charm of romance, enshrined as they are in song and story.

The Midland Valley.

The Midland Valley of Scotland is a wide tract of country faulted down against the Highlands on the one side and the Southern Uplands on the other. The somewhat abrupt front of the Southern Uplands forms one fault scarp, another rises north of the valley of the Forth in the steep face of the Ochils, while to the north the fertile vale of Strathmore ends sharply against the Highland Boundary Fault. As occasional earthquake shocks show, this fault is still in progress of adjustment. The faulted territory consists of strata ranging in age from Silurian to Permian; it contains the seams of coal which have made this the industrial belt of Scotland. Composed mainly of softer sediments giving rise to a low gently-rolling plain, such scenic features as it possesses are all due to the presence of igneous rocks. The Pentland Hills are mainly Old Red lavas ridged up and denuded till their core of Silurian rocks has been exposed; so also is the long line of the Ochils and Sidlaws, cut through by the valley of the Tay. Such relict volcanoes as Arthur's Seat, the Binn Hill, Largo Law and North Berwick Law, to name but a few, bring vividly before the mind a time when the valley of the Forth was girdled with fire, pouring forth the lavas that went to form King Alexander's Crag, Inchkeith, the hills of Stirlingshire and the Lothians, or injecting the sills and dykes that now rise as prominent crags above the

surrounding plain. Such features are eloquent of the power of vulcanism in creating scenery and of long-continued erosion in modifying it.

The Western Isles.

Passing now to the Western Isles we see vulcanicity once more active in landscape formation. Unhappily fragments only of its work remain, but they include the finest scenic fragments to be found in Scotland. No one can know Scotland who has not explored Arran or the Coolins, or wandered over what were once lava wastes in Mull, Staffa, or Skye. These lavas, the "Plateau Basalts," were erupted in Tertiary times during the latest period of vulcanism to which these islands have been subjected. Sheet after sheet of molten rock issued forth, flowing far and wide, burying and preserving beneath it fragments of Mesozoic strata, elsewhere destroyed. In some cases sufficient time elapsed between successive flows for the formation of a soil and the growth of vegetation, the remains of which, preserved beneath a subsequent flow, have helped to fix its age. Most of that ancient land has disappeared through subsidence or erosion, but in what remains the scenic features due to the basalts are well displayed. In the west of Skye they rise tier on tier, to form cliffs upwards of 1,000 feet high, sometimes forming a level capping to a hill (Macleod's Tables), or cleft by erosion into isolated spires and pinnacles (Old Man of Storr, Macleod's Maidens). The regular jointing assumed by the central part of each flow during cooling is everywhere apparent, but is best seen in the caves and cliffs of Staffa.

As to the origin of the plateau basalts there are two theories. According to Judd they were emitted from central volcanoes. Sir Archibald Geikie, from his knowledge of the plateau basalts of the western United States, referred them to fissure eruptions, the quiet upwelling of lava from lengthy fissures formed in the earth's crust, and in the multitude of dykes ("dyke swarms"), which cut the region, he saw the sources of these lavas. Both theories are possible, but the tendency is to return to Judd's original conception, and to regard the "ring complexes" of Arran, Mull, Rum, Ardnamurchan, and Skye as the basal wrecks of volcanoes from which the lavas flowed.

For geology and scenery combined, Arran has long-been noted. Within its small compass are compressed representatives of all the geological formations in Scotland from the Dalradian to the Cretaceous. Through these the granite mass of the north was intruded, rising above, and dominating the landscape. The island has been riddled with dykes and injected with sills of various igneous rocks, dolerites, porphyries, and the pitchstones for which Arran is famous. Out of this complexity of rocks erosion has carved a varied series of scenic features, of granite peak and ridge, of mountain corrie and glen, of rock scarp and waterfall.

Arran possesses two examples of "ring complexes," the granite intrusion of Goatfell, and the so-called "vent" lying to the south of it. Such structures may be summed up as consisting of one or more injections of molten rock, presumably round the margin of a sinking block (cauldron subsidence), since their outcrops when exposed at the surface are ring-shaped or arcuate. Such intrusions necessarily imply strains and tensions in the surrounding country rock, and they are accompanied by a vast number of sheets and dykes intruded along lines of weak-

ness thus developed. They may even have reached the surface, and appeared as lava flows, but owing to subsequent erosion such evidence has almost everywhere been destroyed. The Arran intrusion consists of an outer ring surrounding a central core, but in the examples exhaustively examined, those of Mull and Ardnamurchan, a shifting of the focus of intrusion has been noted, with a wide variation in the nature of the rocks successively intruded.

Skye.

In Skye the structure of its chief scenic feature, the Coolins, suggests a "ring complex" but this has yet to be proved. The region is unique in the attractions it offers to the mountaineer, the geologist, the artist, or the mere lover of nature. In an area 6 miles across are contained no fewer than fifteen peaks exceeding 8,000 feet in height, with numerous lesser hills, none of which deserves the epithet bestowed by Ruskin of "inferior." So varied is their scenery according to the geological structure and so variable from day to day and from season to season that the hills of Skye have become the Mecca of all true mountain-lovers. The two types of hills, the gabbroic and the granitic, the Black Coolins and the Red Hills, stand out in strong contrast. Marsco and Glamaig, of granite, are conical in shape with smooth outlines and scree-covered slopes; the sweeping arc of the Coolins presents a serried array of peak and pinnacle, of ridge and gully, of corrie and rock-basin, of bare, black rock and scree-covered slope. The contrast is intensified by light and shade from hour to hour. In the soft light of a summer's evening the Red Hills lie bathed in the warm rays of the sinking sun while the Coolins stand out grim and forbidding, their corries shadowed in darkness, their deep lochans like pools of ink. In winter they seem even more forbidding, their craggy summits seen for a moment through the swirling mists; yet in winter they attain their greatest beauty, their blackness veiled, their scars hidden beneath a soft canopy of snow.

The final chapter in this brief review of the origin of Scottish scenery opens with the Ice Age. During that period when north-western Europe was buried under ice, the high grounds of Scotland nourished their individual icefields from which ice moved outwards in all directions, until by the union of neighbouring streams it was directed along certain defined channels, reaching as far south as the Thames valley and moving westwards into the Atlantic as an unbroken wall of ice. Since the highest hills are glaciated almost to their summits, the total thickness of this sheet (taking the depths of the valleys and fiords into account), cannot have been far short of 5,000 feet. The passage of this huge rasp produced great changes in the landscape, the extent of which may be gauged if we form a mental picture of Scotland in pre-glacial times. The solid rock was capped with weathered debris probably to a considerable depth, the ruggedness of the uplands was intensified by crag and tor and scree-covered slope, the smoothness of the valleys accentuated by down-wash from the hills. Lakes, ever evanescent features of the landscape, were absent, their sites occupied by alluvial flats or marshes. Contrast with this the present topography of Scotland. The smooth, flowing outlines of the hills; the rounded, hummocky knolls (*roches moutonnées*), still bearing on their polished surfaces the scratches and grooves made by the ice; the over-deepened U-shaped valleys, the multitude of lakes, some resting in rock-basins scooped out by the passing glacier, others still

dammed behind morainic ramparts, yet others resting black and sullen, in deep hollows beneath corrie walls; the huge erratics, often carried many miles; the sheets and mounds of boulder-clay; these among other features everywhere meet the observant eye, and bear witness to the transforming power of ice. For ice is the instrument that rounds off the work, rather than the chisel that creates it. Its finer touches are fast being removed, and the land is returning to its pre-glacial condition.

Since the disappearance of the ice, the unstable character of the earth's crust has been emphasized in certain Scottish areas. Up the eastern and western coasts there are "raised beaches" which indicate successive uplifts of the land to a height of 100 feet or more. These may be represented by a rock shelf, a shingly slope, or a rock cliff hollowed by the waves when the land stood at a lower level. In the Orkneys and Shetlands, and in the Outer Isles, there is as strong evidence for subsidence. Narrow valleys floored with peat are being invaded by the sea, sounds are widening, and even buildings are disappearing. While uplift may in part be due to crustal rebound on the removal of its load of ice, there is evidence of a warping movement, involving Scotland and Scandinavia in up-heaval, while the intervening area is being depressed.