THE CREST OF SUILVEN FROM THE EASTERN PEAK.

By G. Straton Ferrier, R.S.W.,
after sketch by H. M. Cadell.

THE GEOLOGY AND SCENERY

OF

SUTHERLAND

BY

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Scotland, stern mother, for struggle and toil,
Thou trainest thy children on hard, rocky soil,
And thy stiff-purposed heroes go conquering forth,
With the strength that is bred by the blasts of the north.
—BLACKIE.

SECOND EDITION, REVISED AND ENLARGED

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PREFACE.

THE very kind reception which was given to the first edition of this little book has encouraged the Author to venture on again coming before the public with a new edition of it in his hand. During the ten years which have elapsed since it appeared, many new discoveries have been made in the classic geological area of the North-West Highlands. In consequence of these, a good deal of revision has become necessary, and, apart from the fact that the first edition has been for several years out of print, the booklet had ceased to give correct information on some of the subjects within its scope. It was originally published by the Sutherland Association, as the first of a series of booklets on subjects interesting to natives of the county, and has been followed by several others, to the great credit of the Association, whose laudable objects deserve the highest praise.

In response to the wish of friends, I have prepared a new edition on a somewhat wider basis, in the hope that it may appeal to a more extensive circle of readers, and may even induce visitors to go north and see for themselves the beauties of that remote part of Great Britain. With this in view, two maps have been appended and numerous illustrations added, as well as sundry diagrams of a more purely geological kind. I have endeavoured to treat a somewhat complex subject in a simple way, and shall feel abundantly rewarded if the labour of love which has been bestowed on the following pages, shall be the means of throwing a little new interest into the journey of any reader bent on visiting Sutherland for the first time. Some of the chapters are necessarily more technical than others, and may with advantage be "skipped" by the reader who finds them too dry. The chapter on the scenery of Sutherland has already appeared in the pages of the *Scottish Geographical Magazine*, for August 1895, as a separate article; but apart from this, nothing of a popular kind has, so far as I am aware, been written on the geology of Sutherland since the first edition of this book appeared.

For the diagrams of the experimental illustrations of mountain structures I am indebted to the Royal Society of Edinburgh, to whom the blocks belong, and I have likewise to thank Mr G. Straton Ferrier, R.S.W., and Mr R. Lunn of the Geological Survey, for assistance with the illustrations of the scenery. The geological map lays no claim to originality on the author's part, and only a small portion of the area it covers was mapped by him when on the staff of H.M. Geological Survey. In the map I have mainly to acknowledge the excellent work of my late colleagues, and the recent information it contains has been obtained from the Geological Survey by Messrs Bartholomew & Co., who have already published it in the admirable "Royal Scottish Geographical Society's Atlas of Scotland" recently issued by them. The horizontal and vertical sections attached to the map are the work of the author, who is therefore alone responsible for them.

Speed forth little book, and may you, like your predecessor, meet with many a good friend, and prove yourself a pleasant and useful companion to the traveller in the rocky wilds of Sutherland!

GRANGE, BO'NESS, N.B.,
1st January 1896.

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"The northern realms of ancient Caledon,
Where the proud Queen of Wilderness hath placed
By lake and cataract her lonely throne,"

have long been extolled by the poet, the painter, and the sportsman; but of late years their praises have also been sung by those who love to study, in the rocky pages, the lore of the long-forgotten past. The remote wilds of Sutherland, hemmed in by rugged cliffs and buffeted by the fierce Atlantic billows, have, within this generation, acquired an interest in the eyes of the geologist to which few other parts of the British Isles can lay claim in like degree. The strange and varied forms of the mountain masses, with their peculiar hues and scenic effects, cannot but appeal to the imagination even of the uninitiated traveller in these regions, and awaken in his mind a desire to know something more about their history and structure. It will therefore now be our endeavour to describe briefly, and in plain language, some of the main points of geological and scenic interest in Sutherland, and to give an outline of the prehistoric annals of this desolate corner of North-Western Europe.

Before coming to close quarters, however, it may be well to survey from afar the field we propose to wander through, so as to catch, as from the top of Pisgah, a glimpse in perspective of the distant summits we intend to scale.

We shall begin at the base, and here we find a wide and rugged expanse of the most ancient rocks known to the geologist, stretching southwards from Eriboll and Cape Wrath through the parishes of Eddrachilles and Assynt to the Coigach mountains and Loch Broom. The old, or Archæan gneiss—for such is the name of this formation—lies below all the stratified rocks of the earth's crust, and forms the solid foundation on which they have been laid down. In most countries it is still deeply buried under these deposits, but in the west of Sutherland the gneiss has at some former period been upheaved, and the beds which covered it have been washed away into the sea, leaving it again exposed to the light of day. This process of denudation or laying bare has, however, been only partial, and at many places pieces of the overlying strata are found spreading over its rugged edges in great flat cakes.

The gneiss is a crystalline rock resembling granite in some respects, but the formation that covers it is very different in character, being made up of water-worn grains and fragments, arranged in regular strata, which was originally laid down as sand and gravel in the bottom of the sea. These stratified sandstones and fine gritty conglomerates have a prevailing deep red or chocolate colour, strikingly contrasted with the grey and streaky aspect of the gneiss. They rise into imposing mountains towards the south-west of Sutherland, and from their great development in the Torridon country, the red rocks have been named the Torridon sandstones, the formation to which they belong having recently been described appropriately as the Torridonian. The Torridonian rocks were formerly supposed to belong to the Cambrian, or oldest known British stratified system. Recent discoveries of fossils of true Cambrian age in the rocks which cover the red sandstones, show, however, that the Torridonian formation is much older than was formerly thought to be the case. It is, in fact, the oldest bedded formation known in Britain, and here on the west of Sutherland we thus find fragments of the two most ancient geological systems hitherto discovered on the surface of the earth.

The white Cambrian quartzites, and the overlying fossiliferous shales and limestones which creep up over the edges of the red rocks, and are often seen capping the summits of the older and more sombre mountain masses, are also of great geological interest. The fossils they contain have shown us their relative age, and thrown an important light on the geological history of this region, and, indeed, on that of the Scottish Highlands generally. The kenspeckled character of the white glistening quartzites, dull grey limestones, and brown crumbly shales, enable them to be easily recognised at a distance, and thus permit many of the complex mountain structures of Sutherland to be deciphered at a glance.

As we cross these ancient formations, and cast our eye eastwards in the direction say of Ben Hope and Clibreck, the vision sweeps over a wide track of crystalline schists, occupying nearly all the eastern half of Sutherland. These "Eastern Schists," as they have been called, were produced during a remarkable series of earth movements which took place about the beginning of the Silurian period. Some of the curious structures produced by these movements have been explained by a simple series of experiments carried out by the author, and of these old earth-creeps and their experimental imitations we shall hear more afterwards. But whatever interest the Eastern Schists may have in the eyes of the geologist, the general reader will probably be far more interested in the fact that they have been found to contain a little gold at several places in the county. Between the Eastern Schists and the Old Red Sandstone, which once nearly covered them, there is a wide gap in the geological record, and between the Old Red rocks and the Jurassic strata at Golspie and Brora a still longer chapter in our history is here awanting.

The work of the old glaciers of Sutherland, and the long-continued operations of erosion and denudation, by which the land surface has been carved and moulded into its present picturesque form, finishes our tale, and brings the unwritten to the verge of the historic past.

Much has been written, especially of late years, on the rocks of Sutherland, and a great controversy raged for long among the brethren of the hammer as to the age and history of some of these formations.

The following pages are not intended primarily for scientific readers fond of dry details and long names, but are meant, as far as possible, for use among visitors to these parts, and general readers who may not perhaps have fathomed all the mysterious depths of philosophy or natural science. The student who wishes a deeper draught from the Pierian spring than the following pages can supply, may drink copiously from the following among other fountains:—

SCENERY OF SUTHERLAND.—Sir Arch. Geikie, "Scenery of Scotland," second edition; Prof. Heddle, *Mineralogical Magazine*, vol. iv.

PALÆOZOIC ROCKS.—Macculloch, "Western Islands of Scotland," 1819, vol. ii.; Murchison, Nicol, and A. Geikie in *Quarterly Journal of the Geological Society*, many papers from 1856 to 1861; Geikie, Peach, and Horne in *Nature*, vol. xxxi., 1884, p. 29; "Old Red Sandstone of Western Europe," by A. Geikie, *Trans. Roy. Soc. Edin.*, vol. xxviii.; Heddle, *Min. Mag.*, vols. iv. and v.

HIGHLAND CONTROVERSY.—C. Lapworth, *Geological Mag.*, 1883 and 1885; *Nature*, 1884, p. 29; Prof. Judd's Presidential Address at the British Association, Section C., 1885.

RECENT WORK OF THE GEOLOGICAL SURVEY.—Report by Messrs Peach, Horne, Gunn, Clough, Hinxman, and Cadell, *Quart. Jour. Geol. Soc.*, August 1888. This comprehensive paper contains a list of all the important literature up till 1888, and gives a series of typical sections in various parts of Sutherland. "The Olenellus Zone in the North-West Highlands," by Messrs Peach and Horne, *Quart. Jour. Geol. Soc.*, May 1892; "Additions to the Fauna of the Olenellus Zone," by B. N. Peach, *Quart. Jour. Geol. Soc.*, November 1894; "'Borolanite,' an Igneous Cambrian Rock," by J. Horne and J. J. H. Teall, *Trans. Roy. Soc. Edin.*, vol. xxxvii., 1893, p. 163.

EXPERIMENTAL ILLUSTRATIONS OF THRUST-PLANES.—H. M. Cadell, *Trans. Roy. Soc. Edin.*, vol. xxxv., 1888, p. 337; abstract in *Nature*, 1888, p. 488.

SECONDARY ROCKS.—J. W. Judd, *Quart. Jour. Geol. Soc.*, vol. xxix., 1873.

GOLDFIELDS.—Rev. J. M. Joass, *Quart. Jour. Geol. Soc.*, 1869, p. 314; William Cameron, *Trans. Geol. Soc. Glasgow*, vol. iv. p. 1; Ed. Greenly, F.G.S., "Notes on the Sutherland Goldfield," *Trans. Geol. Soc. Edin.*, 1895.

MAPS.

Since the first edition of this book was published, the work of the Geological Survey has extended over the whole of the western and northern parts of Sutherland, and the beautiful geological sheets already published, on the scale of 1 inch to a mile, give a detailed and exceedingly accurate account of the rocks and structures in these districts. On the north coast, Sheet 113 includes the area from Cape Wrath to Rhiconich and Loch Laxford; and

Sheet 114, immediately to the east, comprises the districts of Durness, Eriboll, and Tongue as far east as the west side of Strathnaver, and as far south as Foinaven, Ben Hope, and Ben Loyal. Sheet 107, adjoining Sheet 113 on the south, and Sheet 101 to the south of 107, include a remarkable tract of Archæan gneiss, intersected by a vast multitude of igneous dykes, faults, and thrust-planes, which are mapped with extraordinary minuteness and accuracy. Sheet 101 contains also the Torridonian rocks of Coigach, and the complex mass of thrust Cambrian strata of Assynt.

The small Geological map appended, on a scale of ten miles to the inch, is reduced with great care by Messrs Bartholomew from the Survey sheets already published, and from other reliable information; but on such a minute scale it is quite impossible to do more than give a very general idea of the distribution and structure of the different formations. This map also indicates the areas and number of the respective Ordnance and Geological Sheets comprising Sutherland and Caithness, on the scale of 1 inch per mile. Only a part of the Geological Survey sheets have as yet been published. Bartholomew's excellent orographical map, on the same scale, gives a tolerably graphic description of the physical features of this part of Scotland.

II.—Scenery and Geology.

The rocks of North-Western Caledonia are severed geologically into two main groups by a line running from the ironbound Atlantic coast,

> "where beneath the northern skies
> Chides wild Loch Eriboll his caverns hoar,"

and thence trending southwards and westwards through the rugged mountains of Assynt and Creich, into the western reaches of Ross and Inverness, and seawards

> "to that dread shore
> That sees grim Coolin rise and hears Coriskin roar."

The part of Sutherland to the west of this line, including the districts of Assynt, Eddrachilles, and a portion of Durness, forms a belt of country from ten to fourteen miles in width. A reference to the accompanying geological map will show that this region is coloured in far more variegated tints than the more extensive tract of country to the east, which means of course that here a much larger number of rock formations occupy the surface of the country. Both geology and scenery are more interesting, as the eastern region is made up almost entirely of a single formation of metamorphic schists, most dismal and monotonous in outward appearance.

These "Eastern Schists," as they have been called, have a prevailing dip or inclination to the east, and are made up of the squeezed, stewed-up, and rolled-out fragments of the underlying Cambrian and older formations, whose unaltered representatives in the western part of Sutherland will be noticed afterwards. The great earth movements which were instrumental in bringing about such remarkable metamorphism have much geological significance, but need not be further mentioned here.

Between Loch Eriboll and Strath Halladale, where the Eastern Schists predominate, we find a wide tract of dreary peat-covered country, with scarcely a tree, and, save where reclamations have been made by the late Duke of Sutherland, with hardly a green spot to relieve its awesome desolation. The Moin, between Eriboll and the Kyle of Tongue, is, as its name implies, a wind-swept tract of peat moss of this sort, covered with stiff bent grass, and without even a tuft of heather to clothe it comfortably. For a peaty wilderness of the Eastern Schists, whose silence is broken only by the cry of the grouse, or the roar of the storm blast, a better example could not be mentioned than the neighbourhood of Forsinard, at the head-waters of the Halladale and Helmsdale rivers.

In one or two cases, however, the Eastern Schists have given us exceptions in the way of scenery. Ben Hope, one of the noblest of the Sutherland mountains, amply atones for the usual scenic defects of this formation. From the south and east the appearance of this mountain is not imposing. But go to the foot of Loch Hope, and what a delightful surprise! Like a mighty pyramid, scarred down the face with deep-cut furrows, this magnificent pile is seen rising steep and bold from the shores of the loch, almost at sea-level, to a height of over 3000 feet, towering in grandeur over the wastes around, and lifting his hoary brows to the northern blasts.

The accompanying illustration is reproduced from a painting by Mr G. Straton Ferrier, R.S.W., after a sketch by the author; and in this beautiful picture, I make bold to say that I think both the geological structure and the physical character of the mountain are most truthfully depicted. I hold myself answerable for the geology of the sketch only, and have been careful to see that half way up the face the stratified appearance produced by a thick band of hornblende and actinolite schist that traverses the mountain has been correctly delineated by the artist. As a rule, artists pay but little attention either to actinolite or any other kind of schist, but in the accompanying illustrations I hope to give examples of what I consider faithful sketches of different types of mountain scenery as viewed primarily from the geological, but also in a more remote way, perhaps, from the artistic point of view as well.

Ben Hope is undoubtedly the finest example in Sutherland of a mountain of the Eastern Schists. These rocks rise into several other more or less imposing summits, such as Meall Horn, Ben Hee, Ben Leod, Ben Clibreck, and Ben Armine, all of which are more or less rounded in form and dull grey in colour. As seen from the west and north,

BEN HOPE FROM LOCH HOPE, NEAR ARNABOLL.

By G. Straton Ferrier, R.S.W.,
after sketch by H. M. Cadell.

Clibreck (or Cleith Bric, as it is more correctly spelt in Gaelic), the second highest mountain in Sutherland, towers over Loch Naver, and the surrounding tracts of peat and bent, to a height of 3154 feet, looking more like a big dog lying on the moorland, with a plaid thrown over him, than anything else that I can think of. Ben Armine, again, is nothing but a collection of rounded humps, noted for very little but their extreme ugliness and want of character in the bald and treeless landscape.

In this part of Sutherland there are, however, two other rocks of younger geological age than the schists, which have important bearings on the scenery of the region. The older of these is the syenite of Ben Loyal, at the head of the Kyle of Tongue. It is eruptive, having burst through the metamorphic rocks in large volumes, and now forms a knotty ridge with three rugged peaks, the highest of which—"The Castle"—is a little over 2500 feet in altitude. Although neither by any means the highest nor the most imposing mountain in the county, Ben Loyal has, I think, no equal for beauty in Sutherland. As seen from the eastern shore of the Kyle of Tongue, with the rough pebbly beach and rippling sea-waves in the foreground, and the wooded slopes of Cnoc-a-Mhuilinn and Castle Varich in mid-distance, the rugged peaks of Ben Loyal, bathed in blue haze or wrapped in fleecy cloud, form a picture of surpassing beauty. Professor Heddle, who, perhaps with Mr Colin Philip, the artist, knows our Scottish Bens better than any man alive, has described Ben Loyal as the Queen of Scottish Mountains. He who has visited Tongue in September or October, when the trees are decked in their full autumn tints, and the rich brown madder hue of the bent-covered moorlands blends into the distant purples and blue-greys of the mountains: he who has seen Ben Loyal under such conditions, if he has an eye for fine colour and grand outlines at all, cannot but admit that the enthusiastic professor is not far from the mark in his description of this noble mountain. The accompanying sketch is taken from the west side of the Kyle, near Melness Ferry, where the outlines of Ben Loyal are perhaps more clearly defined, although from this point of view the surroundings have not so much artistic interest as they have on the eastern shore near the sands of Tongue.

The second formation in the east of Sutherland which is scenically important, is the Old Red Sandstone. The massive conglomerates of this formation are vastly younger than either the Eastern Schists or the eruptive rocks that pierce them, and are in fact made up to a great extent of water-worn fragments of these. Isolated remnants of the Old Red conglomerates and sandstones are found scattered over the eastern part of Sutherland, in the form of what geologists call "outliers," capping the higher summits, and occasionally adding spirit to the landscape. At Tongue, the Watch Hill (or Cnoc-an-Fhreacadain) is capped with a massive bed of warm-tinted conglomerate, quite different in character from the

H. M. Cadell.

BEN LOYAL AND THE KYLE OF TONGUE.

cold grey stratified-looking schists around. Another patch of small size is found on Ben Armine, but the largest mass of the conglomerate is to be seen in the extreme eastern borders of Sutherland, rising into the pyramidal summits of Ben Griam More and Ben Griam Beg, at the head of Strath Halladale. These mountains swell up steeply from a brown tract of peaty moorland, and form conspicuous landmarks from all the dreary country to the south and west. As we cross into Caithness, the "Old Red" spreads out on all sides, and extends completely over what Heddle has aptly called the "land of flatness, flags, and fossil fishes," almost the only interesting feature in whose scenery is the magnificent line of sea-cliffs, which bring the flatness and flags to an abrupt termination.

In the south-eastern corner of Sutherland, the scenery is of a more civilised description. Much has been done to beautify it by the public-spirited Dukes of Sutherland, who have planted and cultivated the Dunrobin and Golspie coast-line for generations, covering it with bosky woods that sweep for miles along the shore of the Moray Firth, imparting to it an air of comfort and rural sweetness greatly lacking in most other parts of the county.

The line which has been described as trending southwards from Loch Eriboll, and dividing the rocks of Sutherland into two main groups, marks the course of a series of horizontal displacements of much geological importance. The outcrop of the most prominent of these "thrust-planes" gives rise to a line of feature on the steeper slopes, and is indicated in a broken line on the accompanying little geological map. The Eastern Schists were once pushed westwards for long distances over the top of the old gneiss and sedimentary strata about to be described, and it was along this "thrust-plane" that the greatest amount of sliding took place. The rocks below "the great thrust-plane" were also much thrust together and heaped up during the progress of the movements, and this packing together has greatly influenced the appearance and scenery of the rock masses in certain places.

Three great formations are found in the western part of Sutherland. The oldest of these is the Archæan or Old Gneiss, which spreads out in the form of a broad and much-worn basement, on which the younger stratified formations have been deposited. The Old Gneiss is a massive crystalline rock resembling granite in texture, but has a laminated, banded structure, and is traversed by many pink and dark dykes of basalt, granite, and other igneous rocks. It is quite devoid of bedding planes, and weathers or breaks up along joints or vertical cracks which traverse it in different directions.

The scenery of the fundamental gneiss is wild and barren in the extreme. To the visitor, who for the first time travels from Loch Stack to Rhiconich or Loch Inver across the Ceathramh Gharbh (or Rough Quarter), and casts his eye over the tumultuous sea of bald gneiss hummocks, this wide expanse of perfectly naked rock presents a most impressive spectacle.

For many square miles in the wide parishes of Eddrachilles and Loch Inver, the Old Gneiss spreads out as a rough plateau intersected with deep furrows, and covered with knolls and ridges. The hollows—true rock basins scooped out by old glaciers—are sprinkled with hundreds of charming lochans, whose sparkling waters, well stocked with trout, are dotted with mossy islets, and are often spangled with an abundant growth of beautiful white water-lilies. The ice-sheets which polished the rock, also left it strewn over with multitudes of erratics and perched boulders of all shapes and sizes. These are, perhaps, most abundant in the neighbourhood of Rhiconich and Loch Inchard.

As we go inland from the coast, the surface of the gneiss plateau is seen rising steeply into a ridge of lofty mountains trending southwards from the east of Durness to Spionnu, Cran Stackie, Foinaven, Arkle, and Ben Stack. Their dark and gnarled fronts tower boldly above the low ground like a line of grim ramparts frowning out on the Atlantic shores, and forming a fitting bulwark for this remote outpost of the European continent.

The Torridon Sandstone or Torridonian formation, known up till 1891 as the Cambrian, which covers the gneiss in many parts of Western Sutherland, gives rise to an entirely different type of scenery. In the Parph district, between Cape Wrath and Rhiconich, it sweeps over considerable areas in comparatively low flat cakes, rarely rising into conspicuous mountains. In Assynt, however, the red Torridonian strata are much thicker, and produce many noble mountain masses. These rocks consist chiefly, in Sutherland, of chocolate-coloured conglomerates resting on the rough surface of the old gneiss, with coarse and finer grits and false-bedded sandstone beds above them. They are all distinguished by their prevailing deep red or purplish hue, and this character has sometimes led geologists to class them under the Old Red Sandstone formation, before their true age was ascertained. The conglomerates and sandstones lie nearly horizontally in regular and thick beds. The rock does not crumble down uniformly under the influence of the weather, but tends to break off along straight vertical joint planes, and thus to produce huge mural precipices where exposed along the shore, or on a mountain side. Magnificent examples of these are to be seen in Assynt round the flanks of Suilven or Quinag, or in the dizzy cliffs between Cape Wrath and Durness, one of which—the Clo More, three miles from the lighthouse—rises from the waves to a height of 920 feet, and forms the highest sea-cliff on the mainland of Britain.

The island of Handa is entirely made up of Torridon Sandstone; and on the north side of the island the ledges between the beds give shelter to vast flocks of gulls, puffins, guillemots, and other sea-birds; and a visit to Handa should be included among the things to be "done" by the traveller who wants to see all the sights of Sutherland.

In the Assynt country the finest mountains are nearly all made up of Torridon Sandstone. Quinag, Canisp, Suilven, Coul More, Coul Beg, Stack Polly, and Ben More Coigach, are built up almost entirely of nearly horizontal courses of this old formation. These mountains stand like giant sentinels round the margin of a heaving sea of gneiss, or rise in buttressed pyramidal masses encircled by lofty mural precipices, and resemble at times the colossal towers of the ancients that rise amid their ruins on the plains of Babylonia.

> "Huge as the tower which builders vain
> Presumptuous piled on Shinar's plain.
> The rocky summits, split and rent,
> Form'd turret, dome, or battlement,
> Or seem'd fantastically set
> With cupola or minaret,
> Wild crests as pagod ever deck'd,
> Or mosque of Eastern architect."*

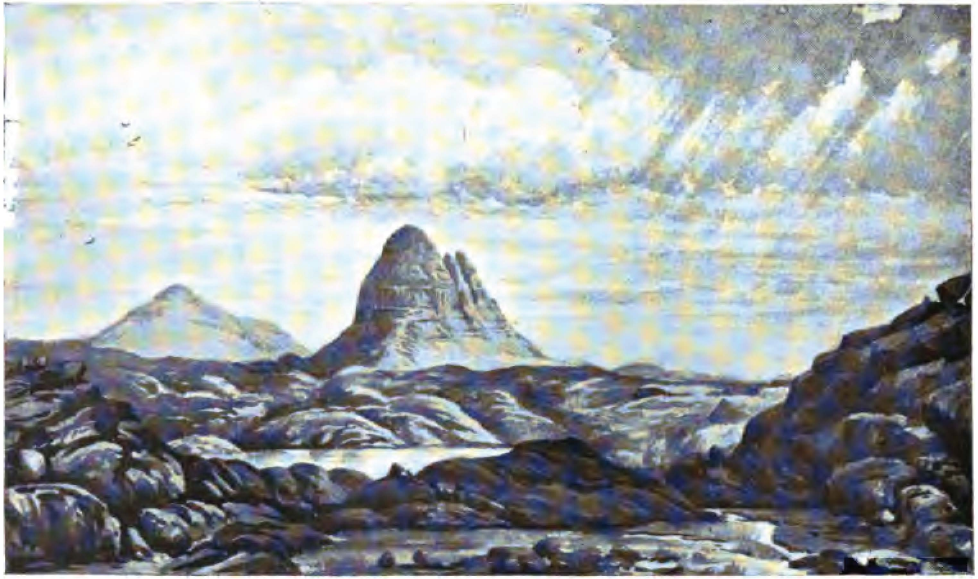
Perhaps the most notable of such summits is Suilven, known to sailors as the "Sugar Loaf," from its regular conical outline when viewed from the west. Suilven is really a long sharp ridge gashed by cross fissures, originally caused by faults or vertical planes of fracture, which cross it at right angles and produce lines of weakness which have enabled the forces of erosion to cut it up into several distinct peaks. So sharp is the crest of the ridge, that one can almost sit astride it at some places. The moun-

* "Lady of the Lake," canto i.

tain is more conspicuous for its shape than for its height, as the highest peak is barely 2400 feet in altitude. The accompanying sketches show the form of the Suilven as seen from the west, the north side, and the top of the eastern peak respectively. In the view from Inverkirkaig, four miles off, the conical shape of the "Sugar Loaf" is, I think, tolerably faithfully depicted. The hummocky gneiss platform is seen in front; and farther off to the left, the top of Canisp appears rising above the horizon seven miles off. In the drawing of the crest by Mr G. Straton Ferrier, after a sketch by the author, the characteristic form of the summit is brought out on correct geological principles. I must not in honesty omit to mention, however, that, for the sake of artistic effect, the height has here been a little exaggerated —a liberty which in this case is, I think, quite excusable, as a climb along the "knife edge" conveys the impression of quite as much grandeur as the sketch is intended to bring out (see *Frontispiece*).

The crest of Stack Polly bristles with pinnacles produced by weathering along parallel cross joints; and Ben More Coigach is, near its western extremity, quite as sharp-topped as Suilven, and slopes steeply away like the roof of a house from its central ridge.

To see these Torridonian bens in all their glory, we must wait till the sun begins to sink towards the horizon in a long, warm summer's evening. The following truthful and glowing words from Sir Archibald Geikie's delightful work, "The Scenery



H. M. Cadell.

SUILVEN FROM INVERKIRKAIG,
Showing the Summit of Canisp and the Platform of ice-worn Gneiss in front.

of Scotland,"* may well conclude this part of our subject:—

"And yet, though nearly as bare as the gneiss below them, these lofty mountains are far from presenting the same aspect of barrenness. The prevailing colour of their component strata gives them a warm red hue which, even at noon, contrasts strongly with the grey of the platform of older rock. But it is at the close of the day that the contrast is seen at its height; for then, when the sun is dipping beneath the distant Hebrides, and the shadows of night have already crept over the lower grounds, the gneiss, far as we can trace its corrugated outlines, is steeped in a cold blue tint that passes away in the distance into the haze of the evening, while the sandstone mountains, towering proudly out of the gathering twilight, catch on their giant sides the full flush of sunset. Their own warm hue is thus heightened by the mingling crimson and gold of the western sky; and their summits wreathed, perhaps, with rosy mist, glow again as if they were parts, not of the earth, but of the heaven above them."

The third and last of the great geological formations of Sutherland is the Cambrian (formerly classified as the Silurian), and here we meet with a series of strata whose distinctive colour and form produce mountains of still another character.

Resting sometimes on the Old Gneiss and sometimes on the Torridon Sandstones, the white Cambrian quartzite is easily distinguished from the more sombre rocks beneath it. The quartzite occurs in a thick bed of great regularity, which can be traced almost continuously from Loch Eriboll to Coigach, and thence

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* Second edition, p. 202.

on through the Dundonell Forest to Kinlochewe and Loch Carron. It forms on the map but a narrow strip running parallel more or less to the line of the Great Thrust. Its normal thickness in Sutherland is 500 to 600 feet, but in the thrust region it has been so packed together that it has often a much greater apparent depth. Where undisturbed, its edges are seen capping the tops of the hills in long lines of light grey escarpment, almost like the walls of some ancient fortification. On the western shores of Loch Eriboll it spreads as a thin cake over the gneiss ridge of Spionnu and Cran Stackie, forming a smooth and barren slope whose hard and close-grained surface has been splendidly polished and striated by the glaciers that once filled the valley. Perhaps the most magnificent example of the quartzite is to be found along Strath Dionard and the crests of Foinaven and Arkle, between the head of Loch Eriboll and Loch Stack, where it has been packed together and thrust into a great heap, as one might sweep up a pack of cards spread out on a table. The weird precipices round the Plat Reah, at the head of Strath Dionard, show the successive thrust-planes to perfection; and to the spectator on the road past Loch Stack a splendid view is displayed of Arkle, a mountain 2600 feet in height, the upper part of which is entirely composed of piled-up beds of white quartzite. It is here seen in magnificent cliff section, rising on the opposite side of the loch tier above tier on the back of a huge gnarled wedge of gneiss, like some colossal pile of Titanic masonry crumbling in

Photo by R. Lunn.

ARKLE FROM LOCH STACK, NEAR ARDACHULLIN LODGE.

ruins, and bestrewing its dark pedestal with the whitened products of its own decay.

The quartzite breaks up into angular blocks and sharp chippy fragments which characterise the scenery by the long screes or talus slopes they always produce, and are very trying to the boot leather of any one who seeks to climb them. This tendency to crumble often gives the summits of the quartzite mountains a rounded form. The rock is almost entirely made up of pure quartz or silica, and where it predominates the ground remains perfectly barren and devoid of soil and vegetation. The crests of the quartzite peaks, with their long white screes, resemble, to my mind, in many cases, the smooth bald head of some venerable patriarch, whose fringe of snowy locks descends in streams far down on his rounded back and shoulders.

From an artistic point of view the quartzite has but little to recommend it, and however interesting it may be to the geologist, it presents neither the rich warm colouring nor the structural features which give so much scenic interest to the Torridonian rocks of Sutherland.

The quartzite was originally covered with a comparatively thin bed of brown shale, which has recently become celebrated as being the home of *Olenellus* and other interesting fossils of Cambrian age. Wherever the *Olenellus* shale crops out, a bright green streak of vegetation is found flourishing on the good soil into which it crumbles. These oases in the grey deserts of the quartzite occur at intervals all along the line of the Cambrian outcrops, and the fresh vegetation that clothes them enables the shales to be recognised at a glance, and affords better grazing for the sheep and deer than is found on any other rock in the region.

The highest and thickest member of the Cambrian formation in Sutherland is the great fossiliferous limestone of Durness and Assynt. The Durness limestone is over 1500 feet thick, but it never rises into prominent mountains, and has consequently but little scenic importance in Sutherland. It is most conspicuous in the vicinity of Inchnadamff in Assynt, where it has been packed together like the quartzite, and forms the prominent plateau of Stronchrubie surrounded by steep and noble cliffs. The limestone beds are grey in colour, and wherever they predominate, their decay produces good and comparatively fertile land, which can be cultivated with some chances of success. Unfortunately for the farmer, the limestone districts are of very limited extent, and beyond the blue patches shown on the map at Eriboll, Durness, and Assynt, there are no other places where the rock covers any considerable area of ground in Sutherland.

To turn from the mountains to some of the other physical features of Sutherland, we may look briefly at its lakes and valleys. The orographical map shows the general lie of the land. The watershed corresponds roughly in direction with the great displacement, and lies a little to the east of it. The long sloping plateau of the Eastern Schists is traversed by the valleys of the Oykell, the Shin, and the Helmsdale rivers, which drain into the North Sea, and by the Naver and the Halladale, which find their way into the North Atlantic. Most of these straths are comparatively tame for the greater part of their course. Loch Shin, which runs for some sixteen miles along the principal depression, is a bare and most uninteresting sheet of water lying in the bottom of what has been compared to a huge gutter, with neither tree nor crag to relieve its dull monotony. Loch Naver is a great improvement on Loch Shin, stretching as it does from the foot of Ben Clibreck to the head of "bonnie Strathnaver." The beauty of this strath in particular never impressed me very much, it must be confessed, and the person who first gave it this name must have been best acquainted with ugly places, and rather hard up for information about the rest of the county.

He who wants to find beautiful valleys and fiords should visit the Kyle of Tongue, Strath Hope, Strath Beg at the head of Loch Eriboll, or the glens of Loch More, Loch Kylesku, and Loch Assynt. But if deep gloom and awesome desolation are preferred, commend me to the remote and weird recesses of Strath Dionard at the back of Foinaven.

> "Where rocks were rudely heap'd, and rent
> As by a spirit turbulent;
> Where sights were rough, and sounds were wild,
> And everything unreconciled;
> In some complaining, dim retreat,
> For fear and melancholy meet."

The most beautiful journey in Sutherland is, I think, the drive from Inchnadamff to Scourie, along the charming and verdant shores of Loch Assynt. The old castles of Ardvreck and the ruined walls of Calda House here add to the scene an element of life and human interest, which is sadly lacking in much of the scenery of Sutherland. The fragrant birken slopes and grassy banks below the grand precipices of Spidean Coinich, help also to relieve the overpowering sense of rockiness, which, although abundantly fitted to inspire awe and admiration, also conveys a sense of fear, depression, and lifeless desolation, instead of the happiness and love that should mingle as a component element in every truly pleasing landscape.

III.—The Old Gneiss.

The upper part of the earth's crust consists mainly of stratified formations, formed by the deposition of sediment on the bed of the ocean, and these have, for the sake of convenience, been arranged according to their ages under separate groups. The most ancient of these groups contains the Permian or New Red Sandstone, the Coal-Measures, Old Red Sandstone, Silurian, Cambrian, and Pre-Cambrian formations, the last of which is the oldest. They all contain fossils of a type long extinct, and have hence been named the *Palæozoic*, or old-life formations.

But what lies below? The old geological books say granite, but granite, although often found in huge mountain masses which swell up from below the stratified formations like islets from beneath the ocean, is on closer inspection found to be in reality younger than they, and to send out veins and offshoots into them.

Wherever their foundations have been laid bare, the Palæozoic rocks are seen to rest, not on granite but on *gneiss*, a crystalline rock, whose origin has puzzled many generations of geologists. The word is of German origin, and as the rock occurs only in the remote parts of Scotland, it may be unfamiliar in appearance, as well as in name, to many readers. Gneiss, like slate, is one of the so-called metamorphic or changed rocks. It has been produced by the combined forces of heat, pressure, and chemical action, working on rock masses, deep below the surface of the ground. The original rock has generally been squeezed and altered by these agencies to such a degree that its former character has been quite obliterated; but here and there, perhaps, there may be a few lumps of the parent rock scattered like kernels in the gneiss, which have been too durable for perfect "digestion" during the process of metamorphism, and are thus left to give us a glimpse of what the gneiss may have been made out of.

Gneiss has two peculiarities. It is, in the first place, a perfectly crystalline rock like granite, without any water-worn grains or pebbles. It has in the second place a banded or stratified appearance, due to the arrangement of its mineral constituents in laminæ or leaves. These bands are made up of a few common minerals with a sprinkling of rarer sorts through them. The principal minerals are quartz, felspar, mica, and hornblende. The quartz is the hardest, most durable, and most abundant of the four, and is nearly always white in colour. The felspar is either white or pink, and it is this mineral which imparts to the well-known granites of Aberdeen and Peterhead their white and red tints respectively. Mica, a mineral easily recognisable by the flat form of its crystals, which can be split by a knife into very thin flexible and transparent leaves of great toughness and durability, is sometimes black and sometimes brownish or nearly white in colour. The hornblende, which is dark green or black in hue, occurs as needles or bundles of glossy prisms, which, like the felspar, split up when broken along "cleavage planes" traversing the crystals in definite directions.

It will thus be clear that if one of the bands in the gneiss contains a preponderance of quartz or felspar, it will be light in tint, whereas if black mica or hornblende are most abundant the colour will be dark. A hand specimen of gneiss resembles a closed book with chapters of varying lengths, each chapter consisting of pages of a different tint. The pages are not always smooth and flat, but are far oftener bent, torn, and crumpled by the long-continued ill-usage to which they have been subjected. The following photograph of a block of contorted metamorphic rock from Ballater gives an idea of the appearance of a lump of crumpled gneiss after exposure to the weather.

A BLOCK OF CONTORTED METAMORPHIC ROCK.

6

Gneiss is a kind of metamorphic rock common to formations of many ages, whose rocks may have been subjected to a process of squeezing and stewing at various times. The banded or foliated character, as has been said, is common to all varieties of gneiss, but the old gneiss of the North-West Highlands has some peculiarities of its own, which must not be omitted here. It has had its character much changed by various igneous intrusions, and repeated squeezings and foldings, which have affected it at various times after its original construction.

Among the invaders of the old gneiss, the pegmatites, or coarse granitic veins, are perhaps most conspicuous. They are particularly abundant on the Ceathramh Gharbh, Foinaven, the Cran Stackie ridge, and in the sea-cliffs at Cape Wrath, and are so numerous that sometimes they make up about half of the whole rock. The pink or flesh-coloured orthoclase-felspar crystals, which enter very largely into their composition, are sometimes as large as a man's head, and their prevalent light tint easily distinguishes them from the more sombre gneiss that surrounds them. The pegmatite veins vary in breadth from an inch to 100 feet, and are sometimes several hundred yards in length. They can be seen from afar interlacing on the cliffs like gnarled ivy stems, or wriggling like huge pink snakes across the grey gneiss hummocks. At Cape Wrath and the headlands to the south the pegmatites can often be descried rising from the ocean depths like the fleshy tentacles of a monstrous octopus, petrified ages ago while clutching the dark precipices in its clammy grasp.

Where the pegmatites predominate, the surrounding gneiss is often almost entirely made up of black hornblende rock. In this matrix there are knots or kernels of beautiful radiating actinolite crystals, veins of serpentine, talc, epidote, and crystals of magnetite or occasional pockets of hematite, which, with numerous rarer species, make the old gneiss a happy hunting-ground for the mineralogist.

The other invaders of the old gneiss are mainly a remarkable plexus of dykes of light-coloured granite and dark basalt rocks. The former are plentiful between Loch Laxford and Ben Stack, and the latter farther south between Loch Laxford and Loch Inver, where they cross the country in a multitude of roughly parallel lines. Their general trend is from E.S.E. to W.N.W., and they often weather out so as to produce long dark lines of hollow, by which their course can be easily traced for distances of sometimes ten or twelve miles. The rocks of these dykes are known geologically as dolerites, basalts, peridotites, and palæopicrites, and it is clear that they have been injected along cracks after the earth movements and metamorphisms which produced the gneiss were nearly all finished.

Nearly, but not quite, however. After these invaders had ravaged the place, the old earth-creeps began again, and the rock began to split up and slip internally along certain planes. Wherever one of these thrust-planes or lines of sliding happened to cross a dyke obliquely, the dark basalt was compressed and drawn out or rolled flat like dough, while at the same time its mineralogical composition became completely changed. The dykes thus moved were altered into hornblende-, actinolite-, talc-, or chlorite-schists, the gradual passage from the massive basalt rock into the silky-looking schist being often clearly traceable.

The question of the origin of the old gneiss has, as I have said, vexed geologists for many a year. It was once supposed to have been deposited on the floor of a boiling ocean when the earth was still young and ardent on the surface. The "boiler theory" has, however, long ago exploded, and the banded structure is now known to have no connection with primeval stratification in water. From the most recent investigations, the parent rock would appear to have been originally igneous in character. Recent lavas have been found to possess a banded structure like that in some parts of the old gneiss, produced before the final consolidation of the molten rock and while the individual mineral ingredients could segregate out from the original magma.

Scientific men are fond of using long names, and particularly ugly ones, whenever they have the chance. In speaking of this ancient rock, I have described it as the Old Gneiss, which it is *par excellence*. Various other names have been given it, such as Laurentian (from the St Lawrence basin, where it predominates), Hebridean (from the Hebrides), and Fundamental, from its position at the base. Of late, however, the term Archæan has been in general favour among the fraternity of the hammer. As this book is intended mainly for plain people like you and me, remembering also that brevity is the soul of wit, we may do worse than stick to the concise and expressive Saxon name. Cheese and wine are excellent things in their way, and *old* cheese and *old* wine are regarded as particularly good by the connoisseur; but were they to be described as *archæan* their flavour would, I am sure, be at once destroyed.

IV.—Destruction and Reproduction.

In deciphering the history of the rocky crust beneath us, we must take into account certain fundamental principles if we are to avoid forming false conclusions. Let us, then, pause for a little and reflect.

As soon as the solid land emerges from the ocean in which it has been gradually formed, the atmospheric forces begin to attack its surface. While rain and frost carry on their work of disintegration, and the rivers remove the loosened grains and sweep them as mud into the sea, the angry billows at the same time work havoc along the coast-line, and begin to saw their way steadily inwards. What we now call shale, sandstone, and conglomerate was originally mud, sand, and gravel, washed in this way from some ancient land and swept down by rivers to be spread in layers over the ocean floor.

This process of gradual demolition constantly going on around us is named *denudation;* and as geology is based on the great principle of uniformity throughout the past of all the processes at present in operation, we assume that denudation has gone on uninterruptedly since the beginning of the world as we now know it.

If not counteracted by upheaval, the combined attacks of the elements will, in the course of ages, wear the land down to the level of the waves, and there will be produced a broad platform of rock, whose surface is called by geologists a *plane of marine denudation.* If this platform were now to become submerged, the old rocks would speedily be buried beneath sediment; and between the old formations and the new deposit there would evidently be here a great gap in the geological record, as there would be no representative of the formations which were being laid down in the sea, while the old land surface was still high and dry. We should, in fact, have a history with the middle chapters awanting, and to find the missing pages we must needs search elsewhere. Such a breach in the continuity of the rocks at any place is called an *unconformability,* several good examples of which will soon come under our notice. Vast as is the interval of time represented by the stratified formations, there may be still greater periods unrepresented by any formation, and only indicated by an unconformability between them.

Now it is certain that the old gneiss must, from

has been all swept off the gneiss on the mainland, from Loch Inchard to Loch Inver. In the Assynt country it rises into the magnificent mountain pyramids of Quinag, Canisp, Suilven, Coul More, and Stack Polly, which tower in solitary majesty round the margin of a heaving sea of gneiss. Southwards, from Assynt, the sandstone sweeps continuously over Coigach and the Rhu More, and on to Loch Torridon and the western borders of Inverness.

It lies in massive beds, often nearly flat, and is as fresh and unaltered by the vicissitudes of ages as many a recent sandstone. It does not crumble down uniformly, but breaks off along straight vertical joints, and thus forms huge mural precipices where exposed on a mountain side or along the shore. Magnificent examples of these are to be seen in Assynt, or in the dizzy cliffs between Cape Wrath and Durness, one of which—the Clo More, three miles from the lighthouse—rises from the waves to a height of 920 feet, and is the highest sea-cliff in Britain.

The conglomerates and breccias, which rest immediately on the fundamental gneiss, pass up into grits, and these again graduate into fine-grained sandstones, showing the rock to have been deposited at first near a shore, and then in deeper water at a greater distance from the land.

On examining the pebbles in the conglomerates, they are seen to consist of quartz, jasper, chert, greywacke, hardened shales, siliceous limestone, slaggy porphyrite, and other finer-grained volcanic rocks. These materials are certainly not mainly derived from the old gneiss, so that another formation younger than the gneiss must have formed the ancient mainland, the waste of which produced the sediments in the Torridonian ocean that washed its shores.

The total thickness of the Torridon Sandstone in the Parph district is 1800 feet. As we go southwards, however, towards Assynt, where the formation has not been so much worn away, higher beds are met with. On the shores of Little Loch Broom, the red sandstones pass at places under a series of dark grey flags and mudstones, containing worm-casts and doubtful organic impressions. In this district the total thickness of Torridonian strata is not less than 8000 feet. A fine section of these highest beds is exposed at Caillach Head, between Loch Broom and Little Loch Broom. They are here seen along the cliffs, dipping to the east at a steep angle, and lying in juxtaposition to the old gneiss and the basal beds, against which they have been thrown down by the displacement of an enormous fault.

The Torridonian rocks of the North-West Highlands were formerly regarded by Murchison and the chief authorities as the Scottish equivalents of the Cambrian system in Wales, and, up till 1891, were always spoken of and designated as Cambrian in the descriptions and maps of the district.

In the first edition of this book, published in 1886, the author took the liberty of reserving his opinion on the question. At page 15, the following passage occurs:—"The lapse of time between the Silurian and Hebridean periods must, however, have been so enormous as to leave room for the destruction and re-deposition of several formations, and for anything that has yet been proved to the contrary, the Torridon Sandstone, although older than Siluria and younger than Hebridia, may be much older than the Cambrian rocks of Wales. It is therefore for the present safer to keep by the old term 'Torridon Sandstone,' suggested by that accurate and original observer, the late Professor Nicol of Aberdeen, till more evidence in favour of the use of the name Cambrian shall be forthcoming." Time and trouble have since proved that this caution was warranted. The discovery in 1891 of true Lower Cambrian fossils in the overlying formation has clearly proved that the red sandstones are far older than geologists used to think. They are now described as Torridonian, a name derived from the Torridon district, and applied to the pre-Cambrian rocks of the North-West Highlands. These rocks are, therefore, the most ancient sediments as yet discovered in Britain, and appear to be the equivalents of what are known as the Algonkian rocks of North America.

VI.—Cambrian Rocks.

The Cambrian formation of the North-West Highlands, which comes next in order, forms one of the most important and interesting subjects with which we have to deal. It is made up of three parts, each of which has a distinct colour, composition, and history.

Before examining these strata more minutely, the circumstances under which they were first laid down demand some attention. We have seen that the old gneiss, with its rugged mountainous surface, was lowered beneath the sea and covered unconformably by the Torridon Sandstones. The mountains were not so much denuded as to become quite planed off to sea-level before they sank. They seem to have been comparatively quickly buried under thick sediments (fig. 1), so that when subsequently upheaved, they reappeared more or less in their old rugged condition, with, however, the glens filled up by a new formation, through which the higher summits may have been at places projecting.

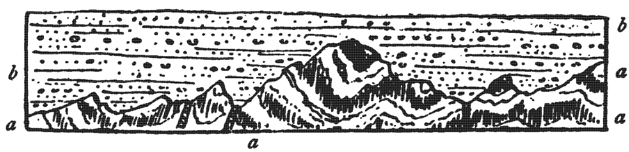

FIG. 1.—Ancient submerged Gneiss, *aaaa*, buried under Torridon Sandstone Grits and Conglomerates, *bb*.

This second upheaval of the old sea-bed again exposed it to the action of denudation, but this time the rocks apparently remained far longer above water-level; so long, in fact, that they were in the end worn down quite flat, and the surface of the land was reduced to a remarkably level plane of marine denudation, without any hills or even knolls rising above its surface. The upheaval of the red sandstones was not uniform, as they seem to have bulged up in a huge arch with the beds dipping away at each side, and the gneiss filling up the centre like a core. When the arch was planed off, the beds at the crown were first washed away so as to lay bare the gneiss below, and then the gneiss itself was worn down, with the result that the arch was reduced to a mass of ruins, with only a comparatively small part of the red strata remaining on each haunch and at the abutments.

Submergence again took place, and the Cambrian beds were laid down evenly over this flat surface, as is shown in the following diagrams (figs. 2 and 3).

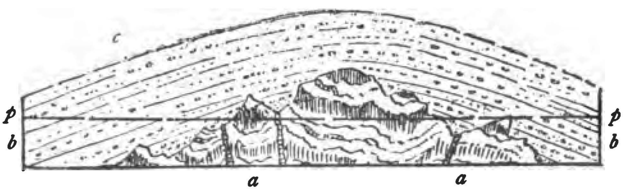

Fig. 2.—Pre-Cambrian upheaval before denudation. *pp*, Plane of subsequent denudation.

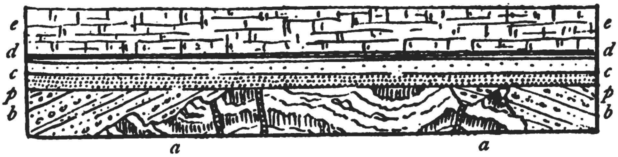

Fig. 3.—Denuded Pre-Cambrian land surface (*pp*), buried under Cambrian Quartzites (*c*), Shales (*d*), and Limestones (*e*).

And last of all, the third emergence took place when the Cambrian beds were tilted up on the west side, causing them to dip to the east, and, curiously enough, bringing back the Torridonian strata on the western side to nearly their first horizontal position.

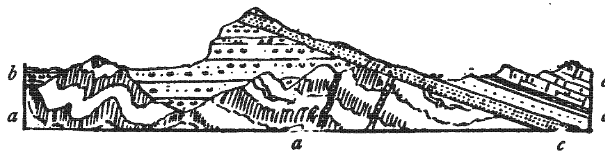

FIG. 4.—Result of latest upheaval, tilting, and denudation.

These stupendous operations, and the two unconformabilities, represent the lapse of enormous periods, from the standpoint of our feeble human measures of time, and with our limited understandings it is quite impossible to grasp the full magnitude of such vast cycles of change. In geology, as in astronomy, reason often leads when imagination fails to follow, and here we can only state the problem, without ever hoping to form anything but the faintest conception of its full significance.

The smooth floor of the Cambrian sea was first covered over very uniformly with a bed of white or pinkish sand. In time this became consolidated into quartzite, a very hard dense kind of sandstone, which accumulated as subsidence went on, until it reached a thickness of about 500 feet. The lower half is pinkish-white in colour, full of small pebbles of quartz and felspar, and is "false bedded," or traversed by planes lying obliquely to the main bedding planes, which have been produced by waves and currents washing the sand into shoals and channels on the old Cambrian sea-floor. The upper part of the quartzite is very close and fine grained. It is sometimes pure white, like loaf-sugar, or again, pinkish, or even deep red in colour, with occasional thin bands of a deep purple or bluish-grey hue. These beds are easily recognised by the presence of multitudes of cylinders of the same material, which run through them at right angles to their surfaces. These are often whiter than their matrix, and when viewed from above they give the rock a peculiar spotted appearance, while sometimes they may be seen projecting above the surface like round tackets on the sole of a hob-nailed boot. They are the old burrows of the sandworms in the Cambrian sea-bed, in which the castings have been preserved. Sometimes they are quite cylindrical, like long pencils, more than a foot in length, and varying in diameter from one-sixteenth to three-quarters of an inch. In one part of the quartzite, known as the "trumpet zone," the pipes are short and wide at the top, resembling little trumpets in shape. The upper part of the quartzite in which they abound is familiarly known as the "Pipe-rock."

The quartzite spreads as a thin cake over the gneiss mountains on the western shores of Loch Eriboll, forming the barren slopes of Spionnu, Cran Stackie, and Coniveall. It is also found on the eastern side of the loch, and forms a prominent white landmark among the wild sea-cliffs of Whiten Head. To the south it crosses the head of Strath Dionard, caps the gneiss of Foinaven, and swells out into the great precipices around the Plat Reah and the sides of Arkle. It forms a thin capping on the summit of Ben Stack, and meanders from Loch More Lodge in a narrow band southwards to Glendhu, thence onwards to the wild Assynt country, where it again swells out along the flanks of Glasven, Quinag, Ben More, Brebag, and Canisp, while small outliers crown the highest pinnacles of Coul More.

Above the pipe-rock there is a band of brown calcareous shale, with thin dolomite beds, and occasional flaggy grits, forty or fifty feet thick, and traversed by numerous dark markings, supposed by previous observers to be impressions of fucoids or seaweeds, but in reality the flattened castings of old sandworms. This shale, wherever it is found exposed to weather, decomposes into a fine yellowish clay, and as it contains a good deal of lime, forms a rich soil, and can hence be easily recognised in the distance by the bright green tint of the vegetation it supports.

The Serpulite Grit, a thin series of hard white quartzite beds, some of which contain quantities of minute trumpet-shaped fossils, named serpulites, separates the "Fucoid Shales" from the great limestone beds which form the thickest and highest division of the Cambrian series of Sutherland.

Beyond containing serpulites in their upper part, the so-called fucoid beds have not proved markedly fossiliferous in Sutherland; but in the Dundonell forest, Mr A. Macconochie, of the Geological Survey, discovered in 1891 the first important organic remains in this ancient deposit. In a thin band of dark blue shale, associated with the Serpulite Grit above the fucoid beds, he was fortunate in exhuming fragments of a crustacean, *Olenellus* by name, a member of the venerable and long extinct family of the trilobites. Further investigations by the Geological Survey revealed more specimens at other places, and Mr Horne discovered in the same beds a small brachiopod, *Acrothele subsidua*, which is known to occur in association with *Olenellus* in the far-off wilds of Utah and Nevada. To the geologist the importance of these discoveries is very great, as *Olenellus* is one of the forms of life which occur only in the lowest parts of the Cambrian formation. The fossils of the Durness limestone, of which more anon, are characteristic of both the Cambrian and overlying Lower Silurian systems, and up till 1891 the rocks containing them had been regarded as members of Murchison's Silurian system. The discovery of such a clear and characteristic fossil as *Olenellus*, however, proved that these rocks are really of Lower Cambrian age, and therefore the underlying Torridon Sandstones must belong to a much older geologic system, of which the red sandstones are but a few scattered ruins.

The limestone of Durness is the thickest in Scotland, and when in its original horizontal position must have had a depth of at least 1500 feet. It is by no means uniform in quality, but consists of many different bands, some of which contain much dolomite, and others much siliceous matter. Several of the bands are richly fossiliferous, as on the shore at Balnakiel or along the margin of Loch Chrospuil. The first fossils were found by Mr Charles W. Peach, in 1854, and more recently the fossil collectors of the Geological Survey have obtained many more species. The list comprises trilobites, annelids, heteropods, gasteropods, brachiopods, corals, sponges, foraminifera, and many cephalopods, among which are various species of nautilus, orthoceras, lituites, piloceras, and other forms of life.

This whole group of fossils bears a close resemblance to the fauna in the Potsdam and Calciferous strata of eastern North America. These formations form the borderland between the Cambrian and Silurian systems on the other side of the Atlantic, and, in lack of better evidence, it was a comparison of the respective groups of fossils that led geologists to consider the Durness limestone a true subject of Murchison's great empire of Siluria.

The soil of the limestone districts is good, and the vegetation rich and green, but, unfortunately for the farmer, the rock does not cover any very extensive tracts of country, as it is only found in quantity at Durness, Eriboll, and Inchnadamff in Assynt, as will be observed by a reference to the accompanying geological map.

Like other limestone districts, those of Sutherland abound in "swallow holes," into which the streams fall, to emerge again at lower levels, perhaps, after long subterranean wanderings. One of the most remarkable of the springs is the Fuaran Allt nan Uamh, about a mile south of Stronechrubie Farm, near Inchnadamff. A large stream here gushes up from the base of a cliff of limestone, and in dry weather forms the whole of the burn of which in winter it is but a tributary. The spring is evidently fed by the drainage of the Blar Sronchrubie—the limestone plateau to the east of the farm—which is full of swallow holes. As the water from the springs in limestone districts is hard on account of the quantity of lime it carries off in solution, many large subterranean cavities must have been eaten out during the long-continued wanderings of the streams below ground. Several limestone caverns are to be found in Sutherland, the most celebrated being the cave of Smoo, at Durness. This cavern is situated a few feet above high-tide level, and looks out to the North Atlantic from the end of a narrow inlet between steep walls of limestone. The inlet or geo is now about half a mile in length and eighty or ninety yards in breadth, and has probably been completely roofed over originally, but the roof has long ago fallen in, and the waves have cut away a considerable portion of the cliffs on either side. All that now remains is a deep dome-shaped corridor, some thirty feet high and sixty wide, which is accessible at all times, and an inner chamber, which must be explored by a boat, as it is half full of water. The inner part of the cave runs southwards, as a long dark tunnel, for some two hundred yards below the bed of the Smoo burn, which gushes down through holes in the roof, from a height of eighty feet. In times of flood the roaring subterranean waterfall, as seen by the dim light of its ghostly prison-house, presents, indeed, a grand and awesome spectacle.

Such caves have generally, at some time or other in the course of their long existence, afforded shelter to natives of the district, and an examination of the floors of limestone caverns frequently discloses interesting relics of their former inhabitants. Very little exploration of this sort has as yet been done in Sutherland; but my friend Mr Horne has kindly supplied me with the following interesting particulars of the deposits found by him and Mr Peach, who, with the Rev. Mr Short and Mr Clarence Fry, investigated the floor of one of the caves on the Allt nan Uamh in Assynt.

The most easterly of the caves on the south side of this stream, when its floor was dug up, was found to contain the following deposits:—

a. Peaty matter, from a few inches to a foot in thickness, forming the floor of the cave.

b. Lenticular layer of calcareous marl, about one foot thick, composed of the remains of various land-shells.

c. Red clay or cave earth, from one to three feet. Indications of human occupation here occur at various levels, in the form of layers of charcoal; split and calcined bones, comprising reindeer, red deer, badger, fox; bones of birds—chiefly grouse—and nests of frogs' bones.

d. Fine grey clay, with quartzite boulders, about six inches thick.

e. A layer composed of limestone fragments, yielding bones of birds, fish, and a finely preserved *canine tooth of the brown bear.*

f. A layer of gravel, composed of stones foreign to the cave, but occurring in the surrounding drift, or derived from the rocks within the basin of the Allt nan Uamh.

The collection of bones from this cave has been lately determined by Mr E. T. Newton, who has referred them to thirty-three distinct species of mammals, birds, amphibia, and fishes. The presence of remains of the Northern Lynx, Arctic Lemming, and the *Arvicola ratticeps* (all of which are now, with the brown bear, extinct in Britain), would indicate a very considerable antiquity for these deposits. It would be a most interesting undertaking to make further excavations in some of the other caves, as similar work in England and other countries has disclosed relics of great archæological importance.

VII.—Cambrian Volcanic Eruptions.

After the Cambrian limestones of Durness and Assynt had been laid down, the sleeping subterranean fires seem to have awakened to temporary activity. In the southern part of the county massive sheets of red orthoclase-porphyry are found spreading out between the red Torridon Sandstones, and running obliquely across these beds into the quartzites and limestones above them. The red porphyry is very conspicuous on the western face of Canisp, where it forms three prominent ledges. The two uppermost of these are indicated faintly on the sketch of Canisp (page 28), whose top is seen—seven miles distant from Inverkirkaig—appearing above the gneiss hummocks to the left of Suilven. The lowest of these eruptive sheets has been injected between the gneiss and the conglomerate at the base of the mountain. The fact that the porphyry for considerable distances runs parallel to the bedding planes of the stratified rocks, might lead the superficial observer to suppose it to have been a true lava-bed poured out when these rocks were laid down on the floor of the sea. Closer observation, however, soon dispels such a theory, and the fact that the rocks, both above and below the eruptive sheet, have been more or less metamorphosed by the heat of the intrusion, is of itself sufficient evidence that the porphyry paid a comparatively late visit to the district. The eruptive rocks occupy a considerable area in the southern part of Assynt. They spread eastwards from Ledbeg to a point near the road leading to Loch Ailsh—a distance of five miles—and can be traced from the peat-clad moor south-east of Loch Borolan northwards to the slopes of Sgonnan Mòr. The hilly ground north of Loch Borolan, rising in Cnoc na Sroine to a summit 1305 feet in height, is entirely made up of a granitic mass associated with the porphyry, whose southern edge forms a prominent escarpment overlooking the road from Loch Borolan to Inchnadamff. At Ledbeg, where the intruder has reached the limestone, the older rock has been metamorphosed into crystalline marble, which was once quarried here for ornamental purposes.

While examining this region, Mr Horne, of the Geological Survey, and some of the other zealous members of the staff, discovered that part of this eruptive mass possessed mineralogical characters of an entirely novel kind. Immediately to the east of Loch Borolan the geological map indicates a triangular patch of this rock about a mile and a half in length—massive in texture, greyish or pink in tint, and which effervesces freely with acid. A good section is to be seen about a mile and a half east of Aultnacallagach Inn, above the waterfall, in the burn flowing from Loch-a-Mheallain southwards into the Allt Lon Dubh. The rock is at places foliated, and is composed of the following minerals: —Orthoclase and plagioclase, felspars, melanite, pyroxene, biotite, and a substance which gelatinises with hydrochloric acid. Sphene, magnetite, apatite, and pyrites are also present in smaller quantities. A rock of this character has not as yet been found anywhere else, and being therefore new to science, requires a new name. Mr Horne, who has, with Mr Teall, examined it very minutely, decided, in 1892, to call it *Borolanite*, after Loch Borolan, whose name will henceforth acquire a celebrity such an insignificant spot in Sutherland could hardly otherwise have hoped to gain.*

These eruptive rocks cut through the highest Cambrian beds in Assynt, so that they are younger

* See paper by Messrs Horne and Teall in the *Trans. Roy. Soc. Edin.* for 1892, vol. xxxvii. p. 163, in which Borolanite and the other eruptive rocks of Assynt are minutely described.

in age than these strata. The great thrusts and earth movements about to be described, which took place in Silurian times, and smashed up the Cambrian rocks, are found to have affected the eruptive masses as well, so that the latter must have been intruded before the movements began. We therefore conclude that the eruptions cannot have taken place very much later than the time when the highest Cambrian beds were deposited, and, indeed, they may be safely considered as belonging to the same period.

VIII.—The Highland Controversy.

Before Mr Charles Peach's discovery of the Durness fossils, nothing definite was known as to the geological age of the metamorphic rocks of the Highlands, except that they were older than the Old Red Sandstone. Sir Roderick Murchison, who had been travelling over Europe exploring the earlier formations and extending the frontiers of his great Silurian system, on hearing of the discovery returned to his native Highlands, and visited Sutherland along with Mr Peach. From the character of the fossils, which were examined by Mr Salter, a palæontologist of great skill, he annexed the formations in which they were found to the empire of Siluria. The discovery in 1891 of *Olenellus* and other fossils has, however, proved, as we have seen, that the Durness limestone is really of Cambrian age, and is therefore much older than Sir Roderick supposed.

The limestone of Eriboll, which, although now separate, was originally continuous with that of Durness, lies in a basin, on the west side of which the strata are tolerably regular, but on the east have been subjected to great disturbance. They are bent about into troughs and arches, and broken and dislocated, all along the eastern side of Loch Eriboll. The country between Eriboll and Tongue is of a totally different character, being composed of the metamorphic schists and gneisses which occupy most of the eastern part of the county. Murchison found the limestone and quartzite beds passing apparently quite conformably below these schists at several places near Eriboll, and on further examination ascertained that they occupy the same relative positions all along the great line which we have spoken of as bisecting Sutherland, and extending southwards into Ross and Skye. What more natural, then, than to suppose that all the schists and other metamorphic rocks associated with them, which extend away eastwards from this line into the heart of the Highlands, are younger than the fossiliferous rocks on which they so clearly rest?

This was the view held by Murchison, and accepted by most of the leaders in geological science, and to any one, who has only seen certain sections without reckoning with every detail in the evidence, Murchison's position would seem impregnable. His companion, Professor Nicol of Aberdeen, however, could not subscribe to all Murchison's conclusions, and maintained that the ascending section from quartzites and limestones to metamorphic schists was not real but only apparent, and that the schists had not been originally formed on the top of the "Silurian" rocks, but had been pushed over them by some extraordinary movement of this part of the earth's crust.

Schists and slates, like gneiss, are not ordinary aqueous rocks, but have been produced from pre-existing rocks by the metamorphic action of heat, pressure, mechanical and chemical agencies. It is difficult to see how such rocks could have undergone the enormous alteration which metamorphism implies while on the top of other rocks which are hardly altered at all; and hitherto it had always been supposed that the crystalline metamorphic formations had been produced at great depths, under the influence of the internal heat of the earth, and were much older than any of the ordinary fossiliferous strata.

Although Nicol was firmly convinced that Murchison's interpretation of the Eriboll and Assynt sections was wrong, he was borne down by the great authority and reputation of his opponent, and his views were received with nothing but bitter opposition or neglect. In later years, after Murchison had passed away, when urged to republish his conclusions, he refused to do so, not wishing to reopen a controversy associated with such bitter memories, but expressed his full conviction that, when sufficiently accurate topographical maps were in existence, and the whole district surveyed by competent geologists, the truth of all the essential parts of his teaching would be established.

After a generation had wellnigh passed away, the accurate maps and the competent geologists appeared on the scene. During recent years the critical sections in Sutherland have been visited by many geologists, including Dr Hicks, who was the first after Nicol to question Murchison's theory. In 1882 Professor Lapworth, of Birmingham, went to Eriboll, and spent the summer in working out the structure of that very complicated district, with the aid of the recently published Ordnance Survey maps on a scale of six inches to a mile. After two summers of excessively hard mental and physical work, which nearly killed the enthusiastic knight of the hammer, he added his testimony to that of Nicol, concluding that the eastern schists may be made of materials far older than the Eriboll limestone, as they have been thrust over the latter by gigantic earth movements of later date. In the summer of 1883 a detachment of the Geological Survey, under Messrs Peach and Horne, two of the most skilled and enthusiastic comrades of the hammer that Scotland has ever seen, were sent north by the Director-General, who wished to ascertain the real facts of the case. It was the rare privilege of the author to accompany the happy band, and assist them in extracting the "secret of the Highlands." The official staff were naturally strongly prepossessed in favour of the views held by the chiefs of the Survey, all of whom followed in the footsteps of their great predecessor Murchison. After a year's work, however, Messrs Peach and Horne were compelled, by a great mass of evidence, to abandon the orthodox Murchisonian creed; and their conclusions, in the main identical with those independently reached by Professor Lapworth, were afterwards confirmed on the ground by Sir Archibald Geikie, the Director-General. So ended the Highland controversy; and the pipe of peace went freely round the philosophic circle, all parties amicably agreeing that, for aught the Sutherland sections prove to the contrary, the schistose rocks of the Highlands may have originally been much older than the period of the Durness limestones, but that their present internal structure was in great measure produced during the earth movements of a later date.

IX.—Ancient Land Agitations.

"Seems that primeval earthquake's sway
Hath rent a strange and shatter'd way
Through the rude bosom of the hill,
And that each naked precipice,
Sable ravine, and dark abyss,
Tells of the outrage still."

—*Lord of the Isles.*

The history of this ancient outrage is a long one, and hard to understand; but the old land agitations of this part of the globe were so important in their time, and have left such distinct memorials behind them, that to describe the geology of this part of Scotland without any reference to them would be like acting the play of Hamlet without "the Prince."

As we cross the quartzites and limestones from west to east, and approach the region of the schists, the Cambrian rocks show signs of ever-increasing pressure and disturbance. At a few places they undulate slightly, then the waves grow sharper and sharper, till at last, instead of bending any further, the beds of quartzite and shale have snapped across, and been pushed over one another, as we might push together a pack of cards spread on a table. But in most cases the snapping across has not been preceded by bending or folding of the rocks to any great extent, if at all. This process of heaping up of the strata, by a series of what are known in geology as "reversed faults," went on till the pile of rock, thus felted together in front of the mass advancing from the east, became too large and heavy to move any further. The pressure was only relieved by a shearing across of the upturned edges of the Cambrian rocks, over which the advancing strata glided in nearly horizontal planes. These planes or surfaces of sliding were named by the Geological Survey "Thrust-Planes," a term which is now coming into general use among geologists in different countries.

This extraordinary sliding movement did not take place along one such "thrust-plane," but along many, each as we ascend showing signs of greater displacement of the overlying rocks than its predecessor. Cambrian rocks were first pushed over one another, as at Eriboll, where the limestone has been overridden by quartzite, a circumstance which led Murchison to suppose that there was an upper quartzite of younger age than the limestone. If, as in Assynt, Torridon sandstone were present, it was thrust over the Cambrian quartzites and limestones; and, finally, Archæan gneiss was torn in great slices from its bed farther to the east, and with, perhaps, Cambrian

FIG. 5.—Head of Loch Eriboll.

rocks riding on its back, was forced westwards for long distances over everything that came in its way. Magnificent examples of these astounding phenomena are to be seen on the great cliffs at the Whiten Head, on Ben Arnaboll, and in the two great crags at the head of Loch Eriboll, shown on sketch. The base of Crag na Faoilinn, the rock nearest the loch, and of Craig Hoarl, at the top of Strathbeg two miles inland, is of quartzite beds highly inclined and packed together like cards; while the summit of each is a huge slice of massive Archæan gneiss, full of pegmatite veins, and several hundreds of feet in thickness. There is one great thrust-plane between the gneiss and quartzite, known in the Assynt district as the Ben More Thrust, since it is exhibited on the grandest scale along the sides of that mountain. Towards the top, however, the movement has been more powerful, and at last the gneiss becomes so crushed as to be no longer recognisable, and merges into a green flaggy schistose rock, made up of finely pulverised fragments of its own components, mingled with sheets of rolled-out Cambrian rocks.*

The gneiss which has been thus roughly handled, although quite recognisable when we understand the true history of its strange pilgrimage, was formerly a puzzle to all who approached it. Murchison supposed it to have been a volcanic rock injected in a molten condition among the Silurian strata; and Professor Heddle has marked it on his map as the "Igneous Rock of the Quartzite," and has also given it the special title of "Logan Rock," from Glen Logan or Laggan in Ross-shire,—a name frequently used by writers, as it involved no special theory as to its origin.

The green flaggy schists into which the "Logan Rock" merges have thus been produced under

* The horizontal section on the map is drawn through Crag na Faoilinn, and indicates these structures in a generalised way.

enormous pressure, not necessarily out of old sediments, but out of any kind of rock that came within the influence of the movement, and by a process hitherto unknown and unsuspected. Professor Lapworth invented the term "Mylonite" (from the Greek *mylon*, a mill), for milled or rolled-out rocks of this character. Large slices of gneiss and quartzite, not entirely crushed out of recognition, are disseminated through the lower parts of the mass, but the upper parts merge gradually into the crystalline schists of the eastern districts of Sutherland and the central Highlands. A large part, if not the whole, of these schists must have been manufactured since Cambrian times; but whether they have been made out of Cambrian, Torridonian, or Archæan rock cannot always now be known, since the original character of the raw material has generally been completely obliterated during the process of metamorphism. The eastern schists are, no doubt, traversed by numerous "major thrusts," and planes of less movement between them, and I have endeavoured to bring out this diagrammatically in the sections accompanying the little geological map of the district.

After the sliding and grinding, which probably took place deep below the surface, had ceased, the whole region was dislocated by "faults" or steep planes of fracture, on one side of which the rocks were elevated, or on the other depressed. One of these faults runs along the eastern side of the Durness basin, and has preserved the limestones by dropping them down, so as to make them abut against the massive gneiss ridge of Keannabin. The "Great Thrust-Plane," which brings on the Moin or Eastern Schists, and has consequently been named the "Moin Thrust," has been shifted in this way with the limestones beneath it. The thrust-plane is seen, with a little patch of green flaggy and "curly" schist above it which has escaped entire removal by denudation, at Sango Bay and on the Farrid Head at Durness. The same green schist, or mylonite, as Professor Lapworth would call it, is next found at the Whiten Head, ten miles to the east; so that were the rocks replaced in the original position they occupied before the faulting and subsequent denudation, we should have the thrust-plane and the overlying schists spreading over the whole area between Durness and Eriboll. The propelling force must have been vast indeed which could thus push one set of rocks ten miles horizontally over the top of another! In Ben More, Assynt, and many similar mountains, the effect of the thrust has been literally to tumble the mountain upside down, and to make the sober-minded and patriarchal formations turn heads over heels, and jump over one another's backs like boys playing at leap-frog.*

* The course of the Moin thrust is shown on the map in a broken line marked T, and the dotted line on the horizontal section at the top traces its course, before denudation of the surface, between Eriboll and Durness.

Since the discovery of these great displacements, geologists have been on the outlook for similar phenomena elsewhere. The result has been the discovery of thrust-planes in many countries, and in other parts of the British Isles as well. Thrusting is now regarded as quite a common geological phenomenon, and the wonder seems to be how it was that it was not found out long ago. It is, however, useful to reflect that the field for new discoveries is still wide open, and that there may yet be untapped reservoirs of knowledge at our very feet—a reflection which should bear fruit in keeping scientists humble, and showing them how little perhaps they can see of the great ocean of knowledge on whose shores they wander, and how many errors they may fall into from the imperfect vision they possess.

X.—Experimental Illustrations.

When new discoveries are made in various departments of physical science, it is usual, if possible, to try how theory squares with facts, and in such branches as electricity and chemistry, the experimental method has produced the most important results. The processes known to the geologist are, however, so complex, vast, and slow in their operation, that their illustration in the laboratory is often a matter of very great difficulty, if, indeed, it can be profitably attempted at all.

After the theory of thrusting had been established in Sutherland beyond dispute, by a great deal of hard hammering and equally hard reasoning in the field, it occurred to my colleagues of the Geological Survey and myself, that our discoveries and theorising might, perhaps, be substantiated or at least illustrated on a small scale by a few simple experiments at home. There was at least no harm in trying what could be done. If the experiments succeeded, much new light might be thrown on our work, and if they failed the result might well be attributed to the difficulty of approaching the stupendous operations of nature with the insignificant appliances at our disposal.

It was clear to begin with that the rocks had been subjected to enormous pressure from one side, and again that they had often remained so rigid under this force that they had preferred snapping to bending.

To imitate such phenomena successfully, it was therefore necessary to employ materials of such a kind that they would, when compressed horizontally, snap across and give way in definite directions rather than bend into folds like plastic bodies. Previous experimenters, such as Sir James Hall, Professor Favre, and others, had used layers of cloth, clay, etc., which were easily crumpled up when squeezed, and did not show any signs of faulting or thrusting.

The idea occurred to me, however, that plaster of Paris, interstratified or mixed with layers of damp sand, might answer the requirements of the case. After several failures, which every beginner must expect, this plan proved quite successful. The dry stucco powder was spread in thin layers between thicker beds of damp sand of different colours, and in a few minutes it had absorbed enough moisture to allow it to "set" into hardish and brittle laminæ, which snapped as a rule under strain, but in some cases permitted bending to take place. In some of the experiments, I found it possible to get good results without the stucco powder, as black foundry loam well damped and pressed together proved an excellent material with which to imitate rock strata under strain. It was found stiff enough to resist much bending, but not too rigid to prevent a certain amount of interstitial movement between the grains.

The strata were deposited, without the aid of water, however, in a rectangular trough about three feet long, one end of which could be pushed in by hand or with the help of a strong screw. The sides could be removed so as to allow the edges of the compressed strata to be examined at the end of each experiment. The accompanying diagrams are taken from photographs of the sections thus revealed.

After pushing in the beds a short distance from the right, the surface of the "rock" bulged up into a heap in front of the pressing surface, and on removing the side of the box to see what had been going on beneath, the following section was disclosed.

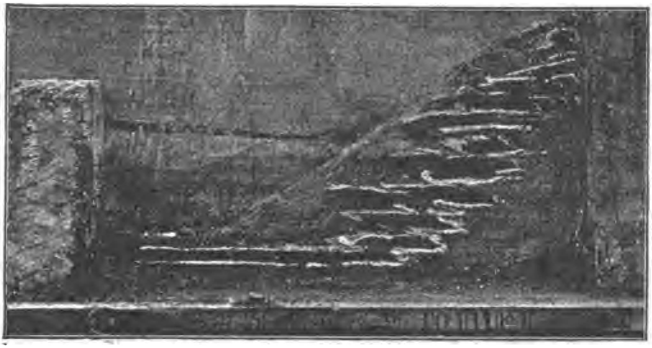

FIG. 6.—Photograph of Section.

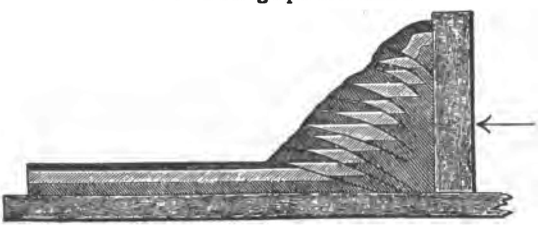

FIG. 7.—Diagram from Photograph.

Eureka! said I to myself, not loud but deep. Here was a mountain in embryo newly upheaved, before denudation had ever scratched its brow, full of neat little thrust-planes, a perfect model of some of the heaped-up quartzite bens of Sutherland, such as Arkle or Creag Dionard. This encouraged me immensely, you may be sure, and I set to work again with renewed zeal.

A new formation was deposited with a rapidity quite unknown in the cycles of geologic time, and pressure was brought to bear on it without delay. This time the operation was continued longer than before, to see what would take place. The mountain rose slowly and solemnly at first, no doubt feeling much moved inwardly as it squeezed itself upwards on the face of the pressure-board. By and by, however, it showed a decided disinclination to heap itself up in this way any further, and more and more force was needed to make it swell up vertically, and to keep the end of the box moving horizontally inwards at the same time.

In the end I agreed to let nature take its way, seeing it was useless to try to resist the natural course of events any further. The pressure was continued, without, however, now attempting to hold the lower edge of the pressing-board tight down on the

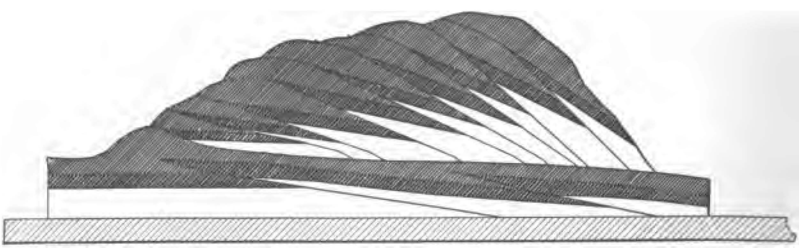

FIG. 8.

floor of the box. Hey, Presto! The whole mountain jumped up and slid forwards in a lump, thrust-planes and all, along the top of the strata below, which were also beginning to show distinct signs of thrusting.

Here was an elementary Glasven, with minor thrust-planes cut off by a major thrust, along which the whole mountain had travelled for several miles in the Palæozoic days of its youthful frolics.

In another experiment of a similar sort, it was noticed that as the push was continued, the front of the advancing mass tended to bow downwards and roll inwards, as if endeavouring to turn heads over

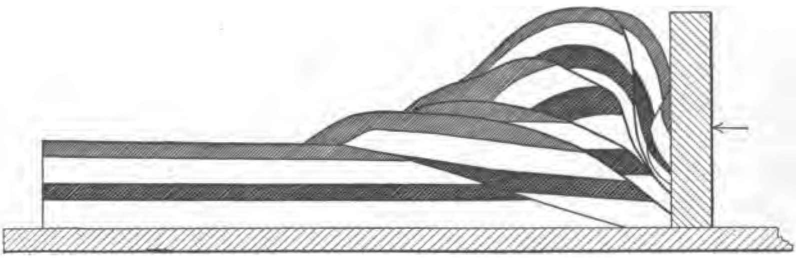

FIG. 9.

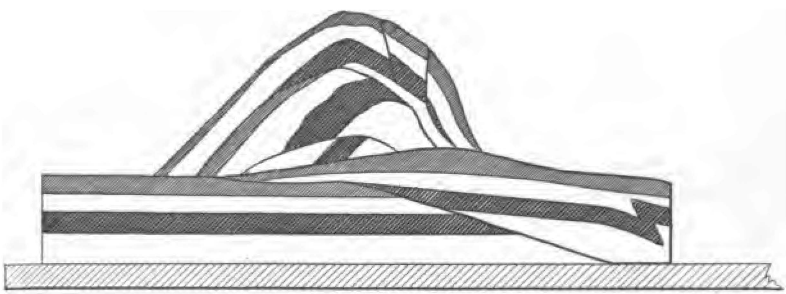

FIG. 10.

heels, which it would no doubt have done in course of time if the experiment had been continued long enough. This tendency can easily be appreciated if we press the hand, palm down, on a roughish table, and pushing it forward, notice how the points of the fingers tend to close inwards under the knuckles. The preceding figures (9 and 10) show this structure being developed at two successive stages of the same experiment.

Here again we find an elementary model of parts of Ben More, Brebag, Ben Fhuarain, and other mountains. The thrust strata have here been pushed for long distances over a major thrust-plane, and are bent down in front until they have first stood on end and then rolled in under the advancing mass.

Being now quite satisfied with the results of these experiments so far as they went, I set about to find out if possible how thrusts are related to folds, and to trace the connection of thrust-planes with other phenomena associated with the elevation of great mountain ranges.

Thrust-planes must end somewhere, and cannot conceivably run right down to the centre of the earth. They must have some deep-seated source, as they are really comparatively superficial phenomena in terrestrial dynamics. It occurred to me next to try whether a flexible and inextensible stratum underneath, which *must fold* on being pressed, would, when covered with such strata as had been used in former experiments, communicate its flexures to the surface, or if not, what would take place under light of day. For this purpose a "sole" of strong flexible waxcloth was attached to the lower edges of two blocks forming the respective ends of the pressure-box, in which the strata were formed as usual. On applying the screw from the right, the flexible substratum buckled up as was expected, ***but on the surface a thrust made its appearance***, followed in time by a second thrust in advance of it. The thrust, in fact, bent downwards and became lost in the heart of a corresponding fold beneath, and had the box been long enough we should have had a succession of thrust-planes diving down and disappearing in this way in a region of crumpled and folded but not broken rock beneath. At great depths, where the temperature is high, the rocks must begin to soften, and in such cases rock masses cannot well be expected to behave like rigid bodies. There must

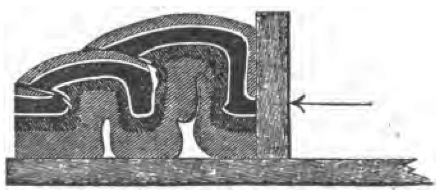

FIG. 11.

be a depth where lateral pressure produces first puckering and then flowing, as a lump of lead can be made to flow when pressed through a small hole. It would lead us too far afield to pursue this interesting subject much further now, but these and other experiments led the author to draw a few general inferences which may be mentioned here.

1. The phenomena of thrusting are superficial or

surface phenomena, produced at the edge of a great mountain chain in process of elevation.

2. Minor thrusts are first produced, then the thrust masses tend to move forward in a lump along "soles" or major thrust-planes, which truncate the minor thrust-planes abruptly.

3. These major thrusts represent a greater horizontal displacement than the minor thrusts, and may themselves be truncated by maximum thrust-planes where the horizontal movement has been much greater. In fact, the major thrusts may behave like minor thrusts with respect to the maximum thrusts, and who knows but the so-called maximum thrusts may themselves behave like minor thrusts in the presence of still vaster displacements?

4. The thrust-planes are inclined or dip towards the direction from which the pressure is applied. In the North-West Highlands this was approximately the E.S.E. Could we follow these lines downwards into the bowels of the earth, they would probably be found gradually losing themselves in the heart of large double folds. At still greater depths the folds would lose their original form and merge into a multitude of small crumplings. At last every particle of the rock having moved relatively to its neighbour, the whole mass would assume a new character. It would pass into a thoroughly crystallised and foliated metamorphic rock, the alteration having been greatly assisted by the high temperature and chemical action accompanying the terrestrial movements.

XI.—The Eastern Schists.

The rocks above the Moin thrust, in the Moin district between Loch Eriboll and the Kyle of Tongue, are very uniform in character over many square miles of country. They consist of flaggy quartzose mica-schists, dipping uniformly at gentle angles to the E.S.E. That they have a very great thickness is clear, for they rise from sea-level to the crest of Ben Hope, a mountain 3040 feet high. They are traversed by numerous major thrust-planes, which run nearly, but not quite, parallel to the planes of dip or foliation, as I have indicated on the section appended to the map. In the Moin district a well-marked band of hornblende- and garnetiferous mica-schist has been traced for several miles running through the heart of the mass. This zone or sheet of rock begins on the cliffs of the north coast, and crops out along the west side of the Kyle of Tongue, and thence round the north and west sides of Ben Hope. At places it is full of beautiful red garnets of large size, and on the face of Ben Hope it passes into a bed of actinolite schist, which forms the marked feature referred to in the chapter on the scenery of the region. To the east and south of Tongue it becomes associated with great strips of the old gneiss, one of which extends along the west side of the river Borgie, and another projects seawards in the headland of Strathy Point.*

* The outcrop of this band of rock is indicated on the accompanying map on a greatly exaggerated scale by the red streak running from Ben Hope to the Kyle of Tongue.

The hornblende schists of Ben Hope and Strathnaver have undoubtedly been originally basic igneous rocks, converted, like the dykes in the Archæan gneiss, into their present condition by powerful earth movements. Slices of unaltered diorite and gabbro are to be found here and there, passing, at the edges, into hornblende schist, and thus showing what the parent rock must have been at first. Here and there the eastern schists contain beds of partially altered quartzite and limestone. One of the latter is to be seen on the banks of Loch Shin, at Arascaig, and Shinness, and has yielded to Professor Heddle a rich variety of minerals. In approaching the limestone, the schists, usually micaceous, become hornblendic, while a bed of hornblende rock rests on the limestone. In the contact zone the following minerals, arranged in the order of their occurrence, from without inwards, were found:—Biotite, actinolite, augite, pyrite, sahlite, andesine, sphene, molybdenite, apatite, chlorite, asbestos, tremolite, steatite, talc, pyrrhotite, and malacolite. Besides these, Drs Heddle and Joass have found many other minerals in the eastern schists, including garnet, magnetite, epidote, baryte, chrysocolla, rutile, lepidomelane, haughtonite, and ilmenite. The gold of Sutherland, which appears also to be derived from this formation, will be discussed afterwards.

XII.—Later Eruptive Rocks.

During the progress of the internal agitations of the district that gave rise to the eastern schists, the subterranean fires were not inactive. Here and there granite veins were injected before the movements had entirely ceased. These granites were rolled and squeezed out like the rocks around them, and converted into foliated streaks of gneiss. But by far the greatest eruptions took place after the movements had entirely ceased.

The largest and most important of the igneous intrusions are all granitic in character. They occur principally at five places—(1) Ben Loyal and Ben Stomino, to the south of Tongue; (2) between Lairg and Rogart Station; (3) at the head of Strath Halladale; (4) on the east coast between Lothbeg and Helmsdale; and (5) at the Ord of Caithness; while smaller patches of granite are found to the north-east of Bonar Bridge and at the extreme north-eastern corner of the county.

The rock of Ben Loyal is fine-grained, and contains, as well as quartz, felspar, and black mica (the ordinary constituents of granite), a little hornblende, and—from the presence of this mineral—has been regarded as a syenite. During the Great Ice Age boulders were dispersed from Ben Loyal, and are found perched on neighbouring heights. One of these, which Professor Heddle regards as mineralogically the most wonderful and interesting stone in Scotland, is on the eastern slope of Ben Bhreck, and originally weighed about 100 tons, but has now been broken up, partly for building purposes, and partly by the Professor in the interests of science. In or near an exfiltrative granite vein traversing the boulder, and about two feet in breadth, the following fifteen minerals were found :—Babingtonite, fluor, sphene, allanite, orangite and thorite, magnetite, lepidomelane, radiated clevelandite, ilmenite, amazonstone, oligoclase (?), quartz, specular iron, bhreckite, and strontianite.

The rock forming the high ground between Lairg, Strathbrora, and Strathfleet, has more claim to the title of syenite than that of Ben Loyal, as it contains much more hornblende; but all the other eruptive masses appear to be true granites. The granite of the Ord is a coarse-grained porphyritic rock, and has been found by Dr Joass to contain veins of fluorspar, chiefly in the neighbourhood of Culgour and Loth. Another small-grained red variety is generally associated with the schists in the auriferous localities.

XIII.—Old Red Sandstone.

Long after the eastern schists had been invaded by these great eruptive masses, which never reached the surface, but cooled by slow degrees far from the light of day, the waters of the Old Red Sandstone seas began to creep up over the sinking country.

The land surface had been long exposed to denudation, and had become deeply trenched by ancient rivers and streams. So much was it worn down, that the deep-seated granite rocks were at length laid bare, and left portruding like knots on an old floor. Their débris was washed down the valleys as coarse shingle, and mixed up with the detritus of the surrounding schists. Out of the waste of that old land surface the great conglomerate of the Old Red Sandstone was constructed. The detached patches of the conglomerate at the base of the Old Red Sandstone are, like the outliers of the Torridon Sandstone, but tiny remnants of a great formation which once spread over much of Sutherland. Cnoc-an-Fhrecadain, or the Watch Hill at Tongue, and the Roan Islands are large masses of coarse conglomerate, made up of rounded pebbles, sometimes a foot in length, with nests and partings of dull red sandstone. The conglomerate, although itself unstratified, lies in thick beds very clearly defined at a distance. It can be best studied on the islands, where it forms great shelves dipping out to sea. On the north side huge masses of the conglomerate have been loosened and moved down the inclined surface of the beds below them; but the most ruinous scene is on the south-western or inland face of the large island, where, owing to the abundant joints, and the more decomposing nature of the rock, the ground seems caverned and honey-combed in all directions. "At the north end of the smaller island, in Mealchalam and the neighbouring headlands, the rock assumes its noblest forms, rising into massive buttressed sea-cliffs, a fitting termination for the Old Red Sandstone in the north-west of Scotland." *

Other outliers of the conglomerate cap the crests of Ben Armine, and form the larger portion of Ben Griam More and Ben Griam Beg; but the largest Old Red area in Sutherland extends from Ben Uarie south-westwards, by Ben Smeorale, Ben Horn, and

FIG. 12.—Base of Old Red Sandstone at Portskerry.

Ben a Bhragie, to Ben Tarvie and the Dornoch Firth. The belt of country within these limits has an average breadth of five miles, and is mainly made up of coarse conglomerates resting in violent unconformability on the old denuded schistose rocks. The river Brora has cut through the deposit, showing it to have no great thickness, and exposing the crystalline rocks below.

* A. Geikie on the "Old Red Sandstone of Western Europe," *Trans. Roy. Soc. Edin.*, vol. xxviii. p. 383.

At Portskerry, near the border of Caithness, a splendid section is exposed on the shore, in which the conglomerates and breccias at the base of the Old Red Sandstone are seen lying over an exceedingly irregular hummocky surface of the Eastern Schists. The preceding is a rough sketch of one of these cliff sections.

The only remnant of the upper part of the formation is to be found in the interesting but narrow belt of flagstones, wedged in between two faults on the shore between Helmsdale and Lothbeg. These beds resemble part of the Caithness flagstone series, and have yielded a fragment of the well-known Old Red Sandstone fish *Coccosteus*. The best place to see them is in the Gartymore Burn, north of Port Gower.

XIV.—Jurassic Rocks and Coal of Brora.*

All the formations we have been exploring belong to the Palæozoic or Ancient Life Series. The Secondary or Mesozoic series, which comes next, comprises the Trias, Jurassic formations (Lias and Oolites), and the Chalk, all of which are abundantly developed south of the Tweed, but in Scotland are only found in scattered patches among the more

* Chiefly from Professor Judd's exhaustive paper in the *Quarterly Journal of the Geological Society*, vol. xxxix., 1873.

ancient rocks. A narrow tract of these detached remnants runs along the eastern sea-board between Golspie and the Ord of Caithness. It is not continuous, but has been cut through and partly denuded away at Kintradwell, Culgour, and Helmsdale. Between Golspie and Kintradwell it reaches a maximum breadth of about two miles, but the northern end narrows down to less than half a mile, and at Green Table Point nothing is seen of the Secondary strata but a few reefs on the foreshore.

Although the area they cover is small, the variety is great, and these narrow patches contain representatives of most of the Jurassic formations.

The sandstones and cherty limestones seen on the Dunrobin Reefs and in the Golspie Burn, seem to represent the Trias, which sweeps over great tracts in Central England. But Dr Joass, who has examined the shore section at an exceptionally low tide, thinks there is enough of discordance in strike between these beds and the overlying Lias to justify our leaving their age an open question.

The shales and sandstones of the Lias, or lowest member of this Jurassic system, on which Dunrobin Castle stands, have a thickness of from 400 to 500 feet, and have been laid down at no great distance from the margin of an ancient sea. They contain very few sea-shells, but are full of plant remains, carried down by some old river, and buried amid the mud and sand falling around. The plant remains have at places been so thickly spread over the sea-floor, as to form thin layers of vegetable matter, which, in the course of ages, has become metamorphosed into coal. A boring was made in the Summerhouse Park, near Dunrobin pier, in 1770, in search of a seam whose outcrop on the shore had recently been laid bare by a great storm, but nothing of value was revealed. The sandstones are covered by beds of impure limestone, full of shells, and separated by intercalations of blue micaceous shale. They are to be seen along with the dark blue clays above them in the reefs north-east of Dunrobin Castle; and he who wishes to make the acquaintance of the ancient inhabitants of the Liassic sea, will find abundance of their relics here, among the curled ammonities, pectens, oysters, clams, and pointed belemnites, such as Hugh Miller used to gloat over on the shore at Eathie.

The dark clays are equivalents of the Middle Lias, but the Upper Lias is here awanting. The remainder of the Jurassic formations are represented by the Lower, Middle, and Upper Oolites, whose total thickness must have exceeded 2000 feet. The shales and white sandstones at the base of the Oolite, which have a thickness of over 100 feet, are seen on the reefs between Brora and Strathsteven. The sandstone has been extensively dug at the Cleat quarries, as it forms a good building stone, which hardens rapidly on exposure. Above the sandstones comes a set of variegated shales and impure fireclays, with thin, irregular seams of coal. As we continue to ascend, the shales become dark and carbonaceous, and are at places full of plant remains, crushed shells, and the scales and teeth of several kinds of fish.

It is on the top of these shales, the thickness of which is about 120 feet, that the coal-seam of Brora rests. Its existence was known at least as early as 1529, and many attempts have been made to work it to a profit, but none seem to have been very successful. A good deal of coal has, however, at various times been obtained from the seam. According to Sir Roderick Murchison, it yielded between 1814 and 1826 no less than 70,000 tons; but although a really good coal at places, its economic value is considerably diminished by the presence of a layer of iron pyrites about six inches thick, which divides it into two parts. The maximum thickness of the seam is 3½ feet. It is variable in quality, sometimes passing into a lignite, and seems in places to be wholly made up of the crushed stems of *Equisetites columnaris*. The carbonaceous shales below are highly inflammable from the bitumen they contain, and resemble the well-known oil-shales of the Lothians.

Unlike the great seams of the Coal-Measures—which are apparently the remains of forests that have flourished for countless generations on the same spot, and been finally overwhelmed by the submergence of the land—the coal of Brora is a true aqueous deposit, made up of the vegetable remains washed from some ancient forest-country and spread in layers over the sea-floor. It thus resembles the great Tertiary Brown Coal formation of Germany, formed by the accumulation of water-logged stems in large lakes. Like the Brown Coal, whose seams sometimes swell out to 50 or 100 feet in thickness, and again dwindle down to almost nil, the Brora seam cannot be expected to remain uniform over large areas, but must always be more or less variable in dimensions and quality.

FIG. 13.—Brora Coal-Pit.

The Brora Coal marks the top of the Lower Oolite. The calcareous sandstone forming the "roof-band" is the lowest member of the marine series of the Middle Oolite. It is 5 feet thick, and is surmounted by some 300 feet of shales. At places full of fossils, it is exposed inland and on the shore at Brora. The shales—the northern representatives of the Oxford Clay and Kelloway Rock—pass under a great series of sandstones, with occasionally thin coaly intercalations, and abundance of fossils in some beds. This group of strata has a thickness of over 400 feet, and is the equivalent of the Coral Rag of England. The sandstone has been largely quarried at Clynlish and Hare Hill, and has been employed in the construction of London Bridge, Dunrobin Castle, and many local erections, including the colossal statue by Chantrey on the top of Ben a Bhragie. The highest part of the Middle Oolite or Coral Rag is represented by some beds of bluish-grey limestone on the shore at Ardassie Point.

The remaining northern part of the strip from Kintradwell to the Ord, consists of the Upper Oolite or Kimmeridge Clay, which attains a thickness of perhaps 1000 feet, and has a splendid fauna and flora. At the base there are white sandstones, with marine shells, wood, etc., seen at Clynlish distillery and in the neighbourhood of Allt Chollie. Higher up the sandstone becomes conglomeratic at places, and is subdivided by beds of black, finely laminated carbonaceous shale, exposed in the cliffs and railway cuttings between Allt na Cuil and Lothbeg river, and in the artificial cut at its mouth. North of Lothbeg river these beds pass below about 50 feet of coarse sandstones and grits, which are in turn overlain by a series of hard grits, black shales, and limestones, folded in many undulations, and admirably exposed for a distance of eleven miles in reefs on the shore, but seen also in numerous inland sections between Kintradwell and Green Table Point. Besides animal remains, these beds contain a most beautiful and varied fossil flora, and great blocks of oolitic wood. The plant-bearing rocks are over 500 feet in thickness, and pass upwards into soft light-coloured sandstone, very ferruginous at the top. This sandstone has a visible thickness of 100 feet, and is seen just north of the Allt a Ghruan between the boat harbour of Navidale and Green Table Point.

To the north of Garty blocks of foreign origin are seen embedded in the grits and limestones. These included fragments become so large and numerous as to form at the Ord regular thick zones, designated by Murchison the "Brecciated beds" of the Ord, from the angular form of their contents. Among the blocks are long pieces of Caithness flagstone, in which Hugh Miller found remains of well-known fishes and fucoids.

We cannot do better than conclude this chapter on the Helmsdale oolites in the eloquent words of our great countryman:—"Macaulay anticipates a time when the traveller from some distant land shall take his stand on a broken arch of London Bridge, to survey the ruins of St Paul's. In disinterring from amid the antique remains of the Oolite the immensely more antique remains of the Old Red Sandstone, I have felt as such a traveller would feel if, on setting himself to dig among the scattered heaps for memorials of the ruined city, he had fallen on what had been once the Assyrian Gallery of the British Museum, and had found, mingling with the antiquities of perished London, the greatly older and more venerable antiquities of Nineveh or Babylon. The land of the Oolite in this northern locality must have been covered by a soil which . . . must have not a little resembled that of the lower plains of Cromarty, Caithness, and Eastern Ross. And on this Palæozoic platform, long exposed, as the Oolite Conglomerates abundantly testify, to denuding and disintegrating agencies—a platform beaten by the surf where it descended to the sea-level, and washed in the interior by rivers, with here a tall hill or abrupt precipice, and there a flat plain or sluggish morass—there grew vast forests of cone-bearing trees, tangled thickets of gigantic equisetaceæ, numerous forms of cycas and zamia, and wide rolling seas of fern, amid whose open spaces club mosses of extinct tribes sent forth their long creeping stems, spiky and dry, and thickly mottled with pseudo-spore-bearing catkins."*

XV.—The Great Ice Age.

After the broad seas of the Oolite had dried up, and the denudations of long succeeding ages had cut and carved the surface of the land into something of

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"Testimony of the Rocks," pp. 452, 453.

its present form, the climate began to grow colder. Britain was then joined to the European continent, and the Forth, Tay, and Spey probably meandered away eastwards over the great plain now covered by the North Sea, and joining the Rhine, Elbe, and other rivers, rolled with them in one mighty stream into the Northern Ocean.

As the climate deteriorated, the snow-clad mountains began to nourish glaciers, small at first, but always growing larger. Gradually they swelled to such a prodigious size that the valleys could no longer contain them, and Scotland at last became buried under an enormous sheet of ice, like that now enveloping Greenland or the Antarctic continent. This huge glacier must have been at least 3000 feet thick, as the rocks polished by the ice extend up to near the tops of the highest mountains. It may even have completely covered them, since the highest peaks have been most exposed to the weather, and the ice-markings, if originally present, may have all been denuded away.

After the cold had reached its maximum, the ice-sheet began to diminish, and the tops of the hills once more appeared above its surface. It became again subdivided into separate valley glaciers, such as can be seen in Switzerland or at the heads of the deep fiords of Norway. The great ice-sheet swept bare the surface of the rock, smoothing and polishing it, and engraving sharp lines on its face. These lines, or glacial striæ, are often to be seen at places where the protecting soil has been removed.

They are better preserved on the smooth hard surface of the quartzite than on the rough gneiss or red sandstone, and are often as sharply defined as on the day they were cut. They point out the track of the ice as surely as ruts show the track of a cart, and tell us that at the coldest part of the Great Ice Age the ice-sheet moved outwards on every side from the highest areas towards the sea. If a valley crossed its path, the ice did not turn aside, but flowed calmly on, the lower part of the stream gliding down one slope and up the other, till it reached its destination in the broad Atlantic, where it broke up into fleets of giant bergs.

The rock surface was not always directly exposed to the ice, but was covered by a mass of its own débris, ground up and dragged along below the glacier. This coating of kneaded rubbish, or boulder clay, was left by the retiring ice in the hollows, and under the lea of the larger knolls of rock, where it could not be easily swept away, but remained in the form of a tail, as does sand behind a stone in a burn. The boulder clay has nearly all been swept off the western part of Sutherland, and is only found in quantity in the lower eastern districts, and along the coast, where it forms the only extensive area of soil in the county.

As the ice melted away, the numerous blocks dropped from the neighbouring heights on its surface were gradually deposited on the rock below. Some were left perched on hill tops or strewn along the slopes and ridges of the gneiss,—

"And some, chance-poised and balanced lay,
So that a stripling arm might sway
A mass no host could raise.
In Nature's rage at random thrown,
Yet trembling like the Druid's stone
On its precarious base."

Boulders in such precarious positions have undoubtedly been laid down softly and gently, by gradually melting ice, and not dropped from icebergs during a time of submergence, as geologists used to suppose.

As they dwindled down and crept back to their mountain fastnesses, the smaller valley glaciers emptied great heaps of rubbish all along their wake. These mounds, known as "moraines," are abundant in the glens of Sutherland, and can be seen in legions all along the road between Loch Shin and Loch More. The rubbish is loose and incoherent, and quite different from the intensely hard stiff boulder clay; and the moraines can easily be recognised in the distance, by their shape, and by the blocks of rock with which they are generally studded. One of the finest collections of moraine heaps is seen at the head of Loch Dionard, and others occur on the top of the raised beaches that surround the head of Loch Eriboll.

When the Glacial Period was nearly ended, the sea rose higher over the land than now. Glaciers at that time descended from the mountains at the head of Loch Eriboll to sea-level, and deposited their moraine-heaps over the old foreshore and beaches. The land was afterwards upheaved, and the beaches, with their stratified gravels and moraine-mounds, were lifted up about fifty feet, forming a terrace at the foot of the hill-slopes and at sheltered places around the coast.*

Another feature left stamped on the face of the county by the ice, is the abundance of lochs and lochans everywhere visible. All recently glaciated countries are covered with lake basins, scooped out of the solid rock by the action of the ice. Each of the deep Scottish lochs has been gouged out by an ancient glacier, sometimes to depths approaching two hundred fathoms. In Norway this is still more striking. The great fiords are all, like our sea-lochs, submerged ice-scooped basins. They have been much more intensely eroded than ours, and in some cases have the enormous depth of 3000 or 4000 feet, while the adjacent sea is not more than 500 or 600 feet deep.

While passing across Canada lately, I was much struck with the similarity between the glaciated gneiss country north of Lake Superior and our own North-West Highlands. The same bare, rounded, hummocky features and small lakes are everywhere visible, showing that whatever processes have produced the scenery here, have also been at work on the North American continent.

* The sketch of the head of Loch Eriboll, p. 64, shows the raised beach with moraines on it at the foot of Crag na Faoilinn.

XVI.—The Sutherland Goldfield.

"This desert soil
Wants not her hidden lustre, gems and gold;
Nor want we skill or art, from whence to raise
Magnificence."

—*Paradise Lost.*

Gilbert de Moravia is said to have found gold at Durness as early as the year 1245, and as golden ornaments were used to adorn the prehistoric inhabitants of this and other parts of North Britain, the date of the discovery of the precious metal is lost in the mists of antiquity. Up till a quarter of a century ago, gold finding in Sutherland was practically one of the lost arts, as all the gold that was known to have been found was a nugget from the Helmsdale Water, weighing ten dwts. In 1869, Mr R. N. Gilchrist, a native of the county, returned after seventeen years residence in Australia, where he had been a successful gold-digger, and "guessing" from his experience at the Antipodes that the alluvium of his native strath had an auriferous look about it, tried a little prospecting, and was soon rewarded by discovering some of the precious metal in the Kildonan Burn. Other tributaries of the Ullie were searched, and gold was found in most of them. The richest of these was the Suisgill Burn. The gold was here rougher, or more nuggety, than in the Kildonan Burn, and yielded the largest nugget that has been found in Sutherland, with a weight of two ounces. Smaller quantities of gold were found in the Cinnpreas, Cnoc Fionn, Fri, Craggie, Torrish, Breacaich, and Duible Burns, all of which are also tributaries of the Ullie. The beds of the Uisgedubh or Black Water, and Allt Smeorale or Gordon Bush, which join the Brora, were also found to be auriferous, but none of these streams yielded such valuable returns as the Suisgill and Kildonan alluvia.

As a rule, the richest wash-dirt was from the lowest bed of the alluvium, an irregular stratum of ferruginous sand and gravel, or yellowish felspathic drift, resting immediately on the denuded edges of the schists, and hidden at places below a covering of stratified sand and clay. Gold was, however, found at some places in the upper alluvium also, and small nuggets have been obtained among the roots of the peat and heather which cover it.

The gold-diggings, where for nearly a year a considerable number of miners, sometimes four hundred, had been at work, were closed on the 1st of January 1870, as the licence fee of £1 per month, payable to the Duke, was insufficient to compensate for the damages claimed by his sporting tenants and by the sheep farmers, whose flocks were obliged during winter to quit the hills and take shelter in the valleys that were being ransacked by the miners. The Government also, to whom all the noble metal in the country belongs, exacted a royalty of 10 per cent. on all the gold found, and to this tax may be attributed the utterly unreliable returns supplied by the miners. Dr Joass, writing to the author, states that one who

H. M. Cadell.

BAILE 'N OIR,
The Site of the Kildonan "Diggings."

knew many of the diggers informed him that although royalty was only paid on about £3000, their private estimate after the works were closed put the total results down at £12,000.

Although the diggings were publicly closed in 1870, private visits have been paid to the strath during the succeeding quarter of a century, and a considerable amount of washing has been done on the sly, without, I suspect, any benefit to the Government at all. No doubt some gold has thus been got; but the story current in the district, that the total value of the gold found since the field was discovered amounts to £22,000, is probably greatly exaggerated, like many other stories relating to gold-mines. Let us hope it is, for the sake of the future yield of this limited goldfield, if not for any better reason. The author must confess that he himself was one of the number who last year paid a sly visit to the Kildonan and Suisgill Burns and did a little prospecting, without paying his mite of royalty on the results obtained. Not for dishonest reasons, however, but because the said mite would, with the cost of the necessary Post-Office Order to send it, have probably amounted to considerably more than 10 per cent., and a smaller coin of the realm could not be found to enable Her Majesty to deal honestly with such a loyal and patriotic subject as he.

My chief object in making this excursion, on which I was accompanied by Mr E. Greenly, of H.M. Geological Survey, who had been engaged in mapping the district, was to form an independent opinion as to the vexed question of the origin of the gold, and the probable value of this goldfield. As the County Council have lately obtained leave from the Duke to reopen the field and have it practically examined, this seems a fitting time to add something to the account given of the Sutherland Goldfield in the first edition of this little book.

The "yellow fever" is a most infectious disorder, and I must admit that I have not altogether escaped the contagion, and can fully sympathise with others who may have been temporarily smitten with it. I say "temporarily" advisedly, as it is generally easily cured, and the after effects are not permanently injurious. Well, to proceed to business. We set about with the customary tin basin to wash samples of gravel in the most promising spots, the best results being obtained from the deposits in crannies of the rock in the streams, or from the bottom bed of the alluvial terraces along the banks. The light rough dirt was first washed off, and there remained a dark, heavy residue, consisting almost entirely of grains of black magnetite and titaniferous oxide of iron, with about an equal quantity of pink garnets of the almandine variety, and occasional crystals of tourmaline, zircon, rutile, hornblende, and epidote. The black magnetite was, however, most conspicuous, and among this our delight was great to spy the glitter of a few yellow metallic particles.

There was not the least difficulty in finding gold, as nearly every basin yielded a few specks of it; and in the course of our peregrinations we came across another party of older hands bent on a similar errand, who had got "the colour" far more successfully, and had half filled a quarter-ounce phial with their gains. That the gold was there, could not be denied, and the search for it on a fine summer's day, with a clear sky above and the sparkling brook, rolling over its golden sands, at our feet, was capital amusement no doubt. But whether or not it is ever likely to be much more than amusement, is quite a different question. Gold-miners, as well as coal-miners, it must be remembered, are fond of good pay, and a substantial minimum wage of 5s. a day, if the state of trade will allow it, is about the smallest average remuneration they can be expected to be content with. Prospectors and diggers expect far more in general than this, as they toil on in the daily hope of making a large fortune by some lucky stroke, and but for such a hope very little prospecting, in new countries at least, would ever be done.

Now there are several important points of difference between the Sutherland, and, say, the Australian goldfields, which must not be disregarded by any who are inclined to build high their hopes on the former.

1. Australia has not been swept bare in recent geological times by a great continental ice-sheet like that of Greenland. In the Victorian goldfields, which I have lately visited, there are vast "leads" or beds of alluvium occupying ancient valleys where rivers have flowed during a large part of the Tertiary period. Some of these deposits are hundreds of feet

thick, and lie deeply buried under old lava streams, but nowhere are there any traces of a glacial visitation. This misfortune, as we have already seen, overtook the whole of Scotland, and the old accumulations of alluvium and rock-débris were either swept into the ocean, or mixed and kneaded up into the heterogeneous mass known as boulder clay or drift. The ice-sheet worked up the materials below it into a hard and solid mass, arranged without any regard to their several specific gravities. In river alluvia, on the other hand, the water, by a natural process of ore-dressing, has arranged the different minerals more or less according to their relative weights, the heaviest being left lying at the bottom, as they were the first to sink. The river gravels of Sutherland represent the work of the streams since the Ice Age, and all that has been done in this way is comparatively trifling, as the drift still spreads undisturbed over wide tracts of country, the streams not yet having had time enough to wash it down and rearrange its materials to any great extent. There may be plenty of gold in the drift, but it must be so disseminated through the mass as to put any chance of profitably concentrating it quite out of the question. Salt is a most valuable substance, and there is plenty of it in the sea, but since the discovery of solid rock-salt deposits and brine-wells, the concentration of sea-water, and extraction of salt from it, has ceased to be a profitable industry, the cost of extraction being more than the value of the extract. Good gold is worth a little over £4 per ounce, but if it costs £5 to extract it (as it often does), it might as well not be there at all, so far as the practical miner is concerned.

2. This brings us to the second consideration. In Australia the gold is found in its native condition in many quartz reefs, traversing the rocks of the districts where auriferous river-gravels are plentiful, and it is to such reefs that we look for anything like a permanent mining industry. So far as geological structure is concerned, there appears to be much similarity between the two regions. Both are built up of crystalline metamorphic rocks with igneous intrusions, but it is a remarkable fact that, notwithstanding the similarity in mineralogical composition, the rocks of the Scottish Highlands generally are conspicuously destitute of the metalliferous veins so common in other mountainous districts of like geological character. Not for want of searching, as the greater part of the ground has been examined with the utmost minuteness by the skilled officers of the Geological Survey, whose maps are a marvel of care and exactitude. Had there been many auriferous, or any other important metallic veins, they would have been detected long ago, and we are led to conclude that any gold which does occur must be disseminated in comparatively small quantities through its native matrix.

Of late years the improvements wrought in gold extraction processes by the use of cyanide of potassium, concentrators, etc., have greatly enhanced the value of the poorer ores, so that now an ore yielding only four or five pennyweights of gold per ton can be profitably mined when labour, fuel, and water are good and plentiful. In many of the best ores of South Africa the gold is quite invisible to the naked eye, and can only be discovered by the chemist in his laboratory. It was long before some of these ores were found to contain gold at all, and experts once ridiculed such an idea, until at last the laugh was turned against themselves. There may, in the same way, be places in Sutherland, and in other parts of Scotland also, where gold will yet be found in paying quantities in the native matrix; but to extract it expensive machinery will be required, and plenty of capital behind it. The alluvial "diggings" cannot be regarded as either permanent or certain, and this kind of work has an unsettling and demoralising tendency on the workers, who, instead of trying to make a living by regular, continuous, and solid work, learn to work by fits and starts—a tendency quite common enough in Sutherland already—and despise the less heroic-looking, but far nobler, steady toil by which honest men of the best sort are wont to earn their daily bread.

Recent investigations by the Geological Survey, and especially by Mr Ed. Greenly, F.G.S.,* seem to confirm the views long ago propounded by Dr Joass and Professor Heddle, that the gold of Helmsdale is derived from several independent local centres. Vein quartz is very rare in the district, but granite

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* *Transactions Edinburgh Geological Society*, 1895.

veins are abundant. Dr James Bryce * found grains of gold in the granite of the Suisgill, which pierces the quartz, biotite, and "flaser" or flaky mica schists that predominate in this part of Sutherland. The schists have, however, been invaded by granite and other igneous rocks at many other places besides Strath Ullie, and it is quite possible that "pay-ore" may yet be discovered which will give fair and steady remuneration to unemployed natives of the county.

XVII.—The Course of Time.

Of all departments of the stony science, none perhaps so deeply impresses on the mind the immensity of time as the study of denudation, so strikingly displayed in the county of Sutherland.

The Torridon Sandstones were first built up out of the ruins of some long lost formation; the Cambrian rocks were next laid down on a sea-floor from which the sandstones had been swept away; and the Old Red Sandstone was long afterwards deposited on the crushed remnants of Cambria. Long ages afterwards the seas of the Oolite overspread the region once covered by the Old Red formations, and all that now remains to tell the tale is a tiny strip of shales and limestones, which mother-earth kept folded into her bosom as the besom of destruction was sweeping by.

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* *British Association Reports*, 1870.

When we reflect that the "everlasting hills" are gradually but surely being worn down, although they have, perhaps, not decreased more than a yard or two since man appeared on the scene; when, further, we find that at what in the history of our globe is a very recent period, they were some thousands of feet higher than now, and when we go still farther back to a time when they had not yet been upheaved from the ocean depths, but were then being built up grain by grain and particle by particle, out of the waste of some still older mountain land long since swept away by the same slow process,—when we muse over these things, and gaze in awe through the dim corridors of time, words fail and imagination lags far behind, and we are made to feel our own utter littleness and insignificance as we thus follow afar off the workings of Him in whose sight "a thousand years are but as yesterday."

OROGRAPHICAL MAP

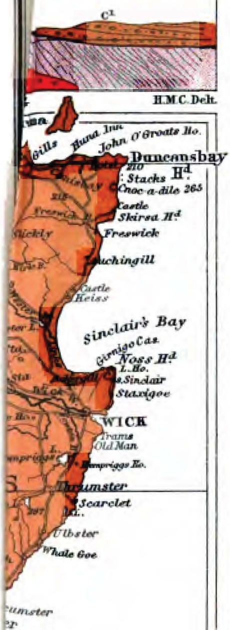
OF

SUTHERLAND AND CAITHNESS

Scale 1 inch = 10 miles.

0 5 10 15 20

OF SUTHERLAND.



MAP

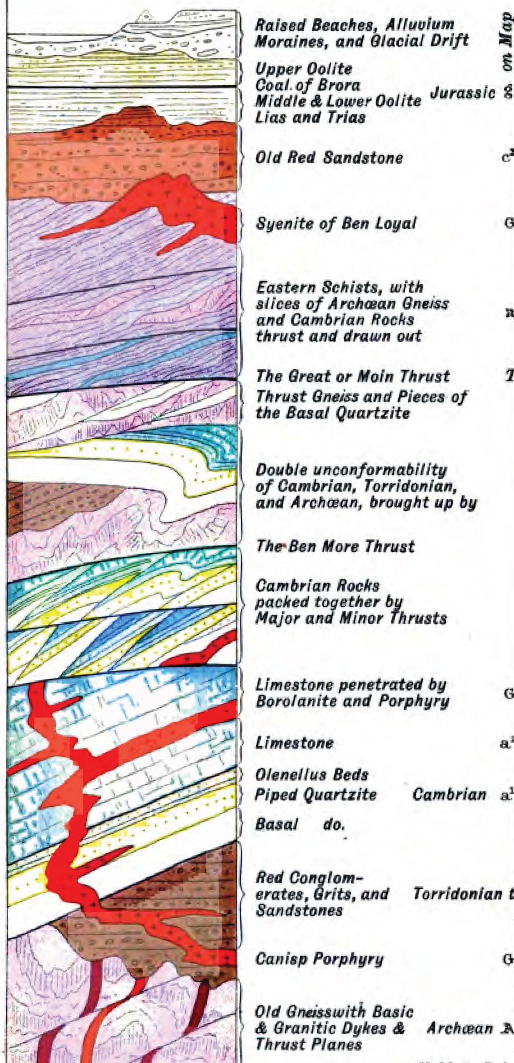
CAITHNESS

miles.

15 20

Faults

DIAGRAM OF THE GEOLOGICAL SUCCESSION IN SUTHERLAND



J. G. Bartholomew.

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