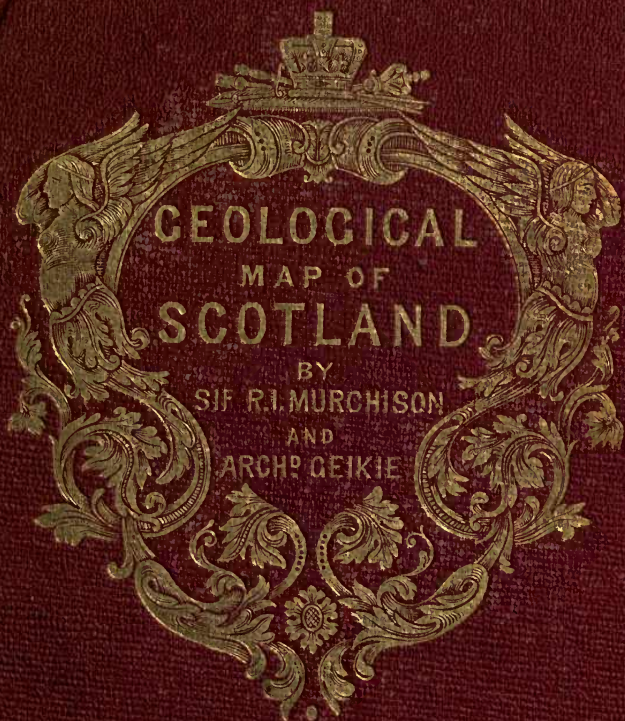


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FIRST SKETCH  
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NEW GEOLOGICAL MAP OF SCOTLAND

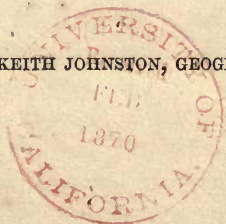
WITH  
EXPLANATORY NOTES

BY  
SIR RODERICK I. MURCHISON, D.C.L., F.R.S.  
DIRECTOR-GENERAL

AND  
ARCHIBALD GEIKIE, F.R.S.E., F.G.S.  
GEOLOGIST

OF THE GEOLOGICAL SURVEY OF GREAT BRITAIN

CONSTRUCTED BY A. KEITH JOHNSTON, GEOGRAPHER TO THE QUEEN



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## EXPLANATION OF THE MAP AND SECTIONS.

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IN laying before the public this Geological Sketch-Map as the basis of a new classification of the rocks of Scotland, I may say, on the part of my colleague and myself, that one of our leading objects is to carry out to their ultimate application the principles first promulgated by our illustrious countryman Hutton. The founder of that school of Physical Geology, which has prevailed, clearly explained the natural causes through which water-formed sediments, having been derived from the abrasion of pre-existing continents, had, under pressure, passed into stone, and further shewed how such stony masses had often been subsequently metamorphosed into crystalline stratified rocks, like those of the Scottish Highlands. The latter view was to a great extent confirmed by the experiments of Hall, and the researches of other followers of Hutton; whilst these principles, so admirably illustrated by Playfair, have since been philosophically extended by Lyell.

Still, such a classification of the various rock-formations as might lead to their delineation in a Geological Map of Scotland, has necessarily been a slowly progressive work.

Notwithstanding the long-continued lectures and descriptions of Jameson, and the numerous writings of Macculloch, no effort was made to embody the details furnished by these authors in a general map, until a distinguished foreign geologist, Dr Boué, acquiring knowledge from those teachers, and making journeys into various districts of Scotland, published his *Essai Géologique sur l'Ecosse*, and prefixed to it a minute



sketch-map, representing rudely the large groups in<sub>t<sub>0</sub></sub> which the rocks were then considered to be divisible.

Turning my own attention to the structure of Scotland as early as 1826, I began to construct for my information a geological map, which in the subsequent year I completed very roughly, by colouring the old topographical map of General Roy; but, besides descriptions of the lias and oolitic formations of Brora, in Sutherland, and the Hebrides, with map and sections,<sup>1</sup> the only general result was a small Geological Map of the North of Scotland, to illustrate a memoir by Professor Sedgwick and myself.<sup>2</sup>

In this brief explanation it is, of course, impossible to do justice to the many expositors of Scottish Geology to whose labours much of the information given on our map is due. In addition to the names of Hutton, Hall, Playfair, Webb Seymour, Jameson, Boué, and Macculloch, it would ill become us not to mention with respect those of Hay Cunningham,<sup>3</sup> Charles Maclaren,<sup>4</sup> and David Milne (now Mr Milne Home).<sup>5</sup> Besides these we may note, with others, Anderson,<sup>6</sup> Bald,<sup>7</sup> Craig,<sup>8</sup> Duff,<sup>9</sup> Fleming,<sup>10</sup> Edward Forbes,<sup>11</sup> James D. Forbes,<sup>12</sup> Harkness,<sup>13</sup> Hibbert,<sup>14</sup> Imrie,<sup>15</sup> Landale,<sup>16</sup> Lord Greenock,<sup>17</sup> Mac-

<sup>1</sup> Trans. Geol. Soc., 4to, 2d series, vol. ii. plates 31, 32, 35.

<sup>2</sup> Trans. Geol. Soc. Lond., 2d series, vol. iii. plate 13.

<sup>3</sup> Memoirs of Wernerian Society, vol. vii.; Trans. Highland Society, vols. xiii. and xiv.; Trans. Royal Society of Edinburgh, vol. xiv.

<sup>4</sup> Sketch of the Geology of Fife and the Lothians, 1839; and various papers in Trans. Roy. Soc. Edin., and Edin. Phil. Jour.

<sup>5</sup> Trans. Highland Society, vol. xii.; Trans. Roy. Soc. Edin., vols. xiv. and xv.

<sup>6</sup> Trans. High. Soc., vol. xiii.; and Monograph on Dura Den, 1858.

<sup>7</sup> Mem. Wernerian Soc., vol. iii.

<sup>8</sup> Trans. High. Soc., vol. xii.

<sup>9</sup> Sketch of the Geology of Moray, 1842.

<sup>10</sup> Mem. Wer. Soc., vol. ii.; and various papers in Edin. Phil. Jour., and Trans. Roy. Soc. Edin., &c.

<sup>11</sup> Quar. Jour. Geol. Soc., vol. vii.; and the Geology and Palæontology of the British Isles, in Keith Johnston's Physical Atlas.

<sup>12</sup> Edin. Phil. Journal, vol. xl. p. 76, and other papers.

<sup>13</sup> Quarterly Journal Geological Society.

<sup>14</sup> Trans. Roy. Soc. Edin., vol. xiii., "Description of Shetland Islands," 1822.

<sup>15</sup> Mem. Wer. Soc., vols. i. and ii.; and Trans. Roy. Soc. Edin., vol. vi.

<sup>16</sup> Trans. Highland Soc., vol. xii.

<sup>17</sup> Trans. Roy. Soc. Edin., vol. xiii.

knight,<sup>1</sup> Menteth,<sup>2</sup> Hugh Miller,<sup>3</sup> Montgomery,<sup>4</sup> Nicol,<sup>5</sup> Page,<sup>6</sup> Ramsay,<sup>7</sup> Stevenson,<sup>8</sup> Williams,<sup>9</sup> Witham.<sup>10</sup> Few of these authors produced even local geological maps, but they made such observations as were essential before any general map could be begun.

Although Dr Macculloch collected many valuable materials, and was indeed employed by government to lay the foundation of a geological survey, he did not so embody his data as to produce a general map in his lifetime; and it was only after his death, in the year 1832, that the Highland Society undertook the task of having the data put together and published. This map, though excellent as a beginning, was replete with errors, and left very much to be desired as respected order and classification.

Among the various authors who contributed valuable local data, by which any generalising geologist might profit, Mr Hay Cunningham produced a very creditable map of Sutherland, and also contributed a map of the Lothians—both accompanied by detailed descriptions.<sup>11</sup> Mr Charles Maclaren, in his excellent work, the *Geology of Fife and the Lothians*, pointed out the distinctive characters of that grand lower division of the carboniferous system around Edinburgh, and threw much new light on the trappean rocks of that district. In the southernmost counties, Mr D. Milne Home brought out a map and description of Berwick and Roxburgh,

<sup>1</sup> Mem. Wer. Soc., vols. ii. and iii.

<sup>2</sup> Edin. Phil. Jour., vols. xviii. and xix.

<sup>3</sup> The Old Red Sandstone, Footprints of the Creator, Testimony of the Rocks, Cruise of the Betsy, Sketch-book of Popular Geology, and various papers in the *Witness* newspaper.

<sup>4</sup> Trans. High. Soc., vol. xii.

<sup>5</sup> Trans. High. Soc., vols. xii. and xiv.; Guide to the Geology of Scotland, 1844; Quar. Jour. Geol. Soc., various papers; Geological Map of Scotland, 1858; Rep. Brit. Assoc., various papers.

<sup>6</sup> Rep. Brit. Assoc.; Text-books of Geology.

<sup>7</sup> Geology of Arran, 1840.

<sup>8</sup> Trans. Roy. Soc. Edin., and Quar. Jour. Geol. Soc.

<sup>9</sup> History of the Mineral Kingdom.

<sup>10</sup> Fossil Vegetables, 1831; Trans. Nat. Hist. Soc., Newcastle, vol. i.

<sup>11</sup> See Trans. of Highland Society of Scotland, vols. xiii. and xiv.



and also completed an elaborate survey of the Mid-Lothian Coal-field. In Dumfriesshire the basins of Red Sandstone and carboniferous rocks were separated from the underlying "grauwacke" by Mr Menteach.

Although our illustrious countryman, Hugh Miller, did not profess to produce geological maps, his writings have, in many instances, led his contemporaries and followers to define the relations of those strata of whose fossil contents he was so admirable an expositor. Again, we should fail in expressing the obligations we owe to various geologists of our country, were we not to advert to the successive clear and instructive works of Mr David Page; whilst, in the sequel, it will be seen that the labours of MM. Howell and Geikie of the Geological Survey have been of essential importance.

As soon as the hilly countries of the south of Scotland, hitherto classed under the unmeaning term of "Grauwacke," were shewn to contain fossils belonging to the great natural series which I had named "Silurian," my interest in endeavouring to bring the different rocks of my native country into correlation with those of England and other lands naturally augmented. With a view to the rectification of the errors of Macculloch's map, and in the hope of establishing a more correct classification, I induced Professor Nicol, who first brought Scottish Silurian fossils into prominent notice,<sup>1</sup> to accompany me in a survey of parts of Ayr, Wigton, Galloway, Dumfries, &c., during the summer of the year 1850; and the result, accompanied with a map, was communicated by me to the Geological Society,<sup>2</sup> shewing the relations of various Silurian deposits.

A great desideratum, however, which I had long had at heart, remained unaccomplished. An old observation of the year 1827, in company with Professor Sedgwick, when we noticed the *superposition* of the crystalline and micaceous schists of Sutherland to the less altered quartz-rocks and limestones of that tract, had for many years been present to my mind, and had led me to hope that the day might come when,

<sup>1</sup> Quar. Jour. Geol. Soc., vol. vi. p. 53.

<sup>2</sup> Ibid., vol. vii. p. 137.



by the discovery of fossils in a portion of that series, coupled with that clear order of superposition, the rocks of the Highlands might be brought into concordance with well-known palæozoic formations in other parts of the world. The discovery in 1854, by Mr Charles Peach, of certain organic remains in the limestone of Durness, in Sutherland—combined with the fact of the *infraposition* of that rock, and its enclosing quartzites, to vast masses of micaceous crystalline strata—at once seemed to me to afford the fairest grounds for determining the question; and in order to work it out, I requested Professor Nicol to be my companion, in the summer of 1855, in resurveying my old ground in the north-western Highlands.

The first result of these labours was in the same year laid before the meeting of the British Association at Glasgow, when Mr Nicol candidly stated his objections to some of my views; and afterwards (1856) revisiting the north-west of Scotland, published his own opinions as to the order and equivalents of the series.<sup>1</sup> By referring to the memoirs we have written,<sup>2</sup> the general reader who may compare the map of Nicol with that which is now issued, will at once see that there are essential and striking distinctions, both in the classification and delineation of the rock-masses, between his ideas and those of my colleague and myself.

Of such importance did the solution of the questions in dispute seem to me, that I revisited the typical districts of the north in 1859, accompanied by Professor Ramsay, and laid the main results before the meeting of the British Association at Aberdeen. In the following year I requested Mr Geikie not only to look at some of those northern types, but also to unite with me in shewing how they ranged into the southern Highlands. Now, as both my associates of the Geological Survey have confirmed my views, and as the main data have also been supported by the independent observations of Colonel Sir Henry James and Professor Harkness, I had no longer any hesitation in urging Mr Geikie to prepare this map, being fully aware that in addition to all that had been done in

<sup>1</sup> Quar. Jour. Geol. Soc., vol. xiii. p. 17.

<sup>2</sup> In the Quarterly Journal of the Geological Society.

the north, his intimate acquaintance with the rocks of the south of Scotland would render the work of essential service in advancing Scottish geology.<sup>1</sup>

If, in the absence of correct topographical maps, a very long time must elapse before any attempt can be made to publish a geological map of Scotland on even a moderately large scale, so as to offer details like those which are laid down in the published Edinburgh sheet of the Geological Survey,<sup>2</sup> enough has already been done to enable my coadjutor and myself to venture on the production of that which we consider to be a requisite prelude to such future works, by placing the chief rocks in their true sequence.

The map which we now issue has been prepared by Mr Geikie. The Shetland and Orkney islands, with the counties of Sutherland and Caithness (where their delineation differs from that shewn on previous maps), are given as coloured geologically by myself in my sketch-map of the north-west Highlands,<sup>3</sup> and the subdivisions of the Old Red Sandstone of

<sup>1</sup> In the year 1850 I satisfied myself that the chloritic schists and limestones, as well as the micaceous schists, forming a great arch between the Firth of Clyde and Loch Fyne, as well as the mica schists and limestones to the north of Inverary, would prove to be of Silurian age (See Quar. Jour. Geol. Soc. Lond., vol. vii. p. 168, and first edition of "Siluria," p. 163). During the autumn of the year 1860, the area of my observation in that quarter was extended by Mr Jamieson of Ellon, in Aberdeenshire, who has enabled us to define the south-western corner of the mainland of Argyll and of the island of Rothesay by additional data respecting the igneous rocks interpolated in the chloritic schists, on which subject he has communicated his views to the Geological Society. I have also to state that, early in the summer of 1860, Professor Harkness examined considerable tracts of country between the southern Highland frontier, near Dunkeld, and the western coast, on the Linnhe Loch, and arrived at the same conclusions as Mr Geikie and myself—*i. e.*, that the upper schistose series only, and occasionally based upon the upper quartz-rock, is the dominant division in that southern region of the Highlands.

<sup>2</sup> The joint work of Mr Howell and Mr Geikie. The memoir descriptive of this sheet is now published.

<sup>3</sup> By comparing the present map with my small sketch-map of the Highlands (Quarterly Journal Geol. Soc., vol. xvi. p. 419\*), it will be seen that the general view expressed in the latter, that the crystalline rocks of the southern Highlands would be found to be essentially repetitions of a portion of the stratified masses of the north Highlands, has been sustained by the last survey of Mr Geikie and myself; whilst, through the zeal and ability of my colleague, the outlines, which were simply suggestive, have now been rendered definite and clear.



the north generally are also inserted on my authority. The main features of the Hebrides, with the marked distinction, however, of the fundamental gneiss, remain as defined by Macculloch. Skye and Raasay have indeed been resurveyed by my colleague,<sup>1</sup> who has introduced considerable changes in those parts. The outlines of the islands of Islay and Jura, along with the whole of the subdivisions of the metamorphic series of the Highlands, from Sutherland to the Old Red Sandstone barrier, were also mapped by him during our joint survey last summer. The granitic tracts of the north-east, and part of the igneous rocks of Argyllshire, are taken from Professor Nicol's map; and the greenstones of Cantyre from the paper of Mr Jamieson referred to in a previous note.

The mapping of the greater part of the central region between the metamorphic Silurian rocks of the north and their less altered equivalents of the south, differing as it does so essentially from all previous delineations, has been effected by my colleague. The northern part of Haddingtonshire, however, was surveyed (for the Geological Survey) by Professor Ramsay and Mr Howell; and the eastern part of Fife (also for the Survey, but not yet published) is likewise the work of the latter able geologist, who also mapped the details of the Mid-Lothian coal-basin. The outlier of Permian and carboniferous rocks at Closeburn, in Dumfriesshire, is taken from a tracing sent us by Professor Harkness, to whom also are due any changes that have been inserted in the relative boundaries of these rocks in the valleys of the Nith and the Annan. The island of Arran is from Professor Ramsay's map, except that the New Red Sandstone of former geologists is coloured by us as carboniferous.

In the geological colouring of the Highlands, our work is distinguished from all previous maps. We have as the base

<sup>1</sup> We have coloured the islands of Tiree and Coll (which we did not visit) as fundamental or Laurentian gneiss, on the suggestion of the Duke of Argyll, who has recently assured me that the gneiss of which Tiree is composed is very distinct from the so-called gneiss of the old maps in Argyllshire and the mainland. On referring to Macculloch's description of the gneiss islands, I also find that Tiree and Coll come under precisely the same description of hornblendic gneiss which characterises Long Island and the outer Hebrides.

of the whole succession, in the island of Lewis, and the Outer Hebrides, as well as along the north-western shores of the mainland of Sutherland and Ross, a crystalline gneiss, which occupies the same position as a similar rock in Canada, described by Sir William Logan, and named by him the "Laurentian System."<sup>1</sup> This fundamental rock is marked on our map by the Greek ( $\alpha$ ) to denote its priority to the next formation—the Cambrian—for which the Roman (a) has been already adopted in the Geological Survey. Whilst the Cambrian is the oldest known rock in England, Wales, and Ireland, the Scottish fundamental gneiss is thus proved to be the oldest rock in the British isles; for it has no equivalent in England, Wales, and Ireland. This Laurentian gneiss has a prevalent N.W. S.E. strike, as is well shewn by the band of limestone which it contains on the north-east shore of Loch Maree, and which, it will be observed, is at right angles to the strike of the superposed limestones of the neighbouring mountainous tracts, and therefore wholly unconformable to them. The Cambrian (a) consists, in the north-west of Scotland, of brownish-red sandstones and conglomerates, resting in gently inclined beds on the convoluted edges of the older gneiss. It is admirably exhibited in the Applecross mountains, and also along the wild shores of Loch Torridon, onwards to the head of Loch Maree, as well as on the shores of Loch Broom, and in Assynt, and on the west coast of Sutherland. On the truncated edges of the Cambrian sandstones come the quartz-rock and limestone (b' 1<sup>x</sup>), which, in Sutherland and Ross, form the base of the lower Silurian, as proved by their included fossils. The limestone of Durness and Eriboll stretches southward by Loch Assynt to Loch Broom, and is seen at intervals onwards to the south end of Skye, where, as shewn on the map, a small outlier occurs on the margin of Loch Eishort. Through the whole of this long course it everywhere rests with its associated quartz-rocks unconformably on the Cambrian.

The wild tract of country from the west coast to the line of the Caledonian Canal may be regarded as a great synclinal

<sup>1</sup> Quar. Jour. Geol. Soc., May 1861. Section I., at the top of the present Map, exhibits the whole succession of rock-masses in the north of Scotland.



trough ; for the quartz-rocks and limestones which form its western boundary rise up again on its eastern side, and are seen along the chain of lochs that stretches from Inverness to Oban, whence they are continued in the islands of Garveloch, Scarba, Jura, and Islay. This remarkable line of lakes is, therefore, an anticlinal axis, broken through by a coincident line of fissure. From this line the limestones and quartz-rocks roll over to the eastward, but their upper portions rise again and again to the surface in a series of broad undulations, as has been attempted to be shewn on the map, and in the long section, No. 2. Above this group comes a perfectly conformable series of quartzose, gneissose, and schistose rocks (b' 1), which form the great mass of the mountains from the north coast of Sutherland to the Highland border. The thickness of this series must be very great ; but, at the same time, the endless plications of its component strata must increase enormously its apparent extent. The section, No. 2, is meant to exhibit a generalised view of the succession of this upper metamorphic group, which is clearly the equivalent of the greywacke, sandstone, and shale, that form the lower silurian tracts (b 1) of the south of Scotland.

The lower Silurian formation of the south of Scotland is likewise thrown into very numerous anticlinal and synclinal axes ; but it may be regarded, on the whole, as bent into a great arch, the centre of which runs from south-west to north-east, passing to the south of the town of Moffat. South of this line the strata dip, on the whole, towards the south-east, and, in the headlands of Kirkcudbright, as in the Cumberland mountains, are succeeded by upper Silurian strata. On the north side of the anticlinal line they dip north-west until they are flanked unconformably by the Old Red Sandstone and Carboniferous formations. But that the upper Silurian exists also on this side of the arch, is shewn by the two isolated patches of Lesmahagow and the Pentland Hills, which are abundantly fossiliferous, and are in both localities overlaid unconformably by upper Old Red or Carboniferous sandstones.

The triple division of the Old Red Sandstone, which exists in the north of Scotland, is clearly indicated, even on the small

scale of the present map. In the south, as shewn by Mr Geikie's recent researches, there is a great hiatus below the upper member of the formation, which shades up into the Carboniferous, and rests quite unconformably on the lower Old Red Sandstone, the middle portion not having been as yet satisfactorily established to the south of the Grampians. The igneous rocks,<sup>1</sup> associated with the Old Red Sandstone of Scotland, are of two kinds—first, felspathic rocks, as felstones, porphyries, amygdaloids, and interstratifications of submarine volcanic ejections or ashes, all contemporaneous with the strata among which they occur. Of this group, the Sidlaw, Ochil, and Pentland Hills may be taken as examples, as well as much of the igneous rock between the Campsie Hills and the south of Ayrshire. The second kind of Old Red igneous rocks are extensive masses of greenstone, basalt, and various felstones; which, however, have possibly no chronological union with the rocks which they traverse. The greenstones are well seen in some of the larger craggy hills near Jedburgh, at Dunse, and at different localities along the great central basin of the country. The felstones are abundant in the uplands of Lanarkshire, Tinto, and many of the neighbouring hills of this group.

Another chief feature of the present map, as distinguished from all previous maps of the country, exists in the subdivision of the Carboniferous formation. This group of rocks consists, in Scotland, of the following members :

	English equivalents.
Upper or "Flat" coals, . . .	= Coal-measures.
"Moor-rock" or Roslyn sandstones,	= Millstone grit and upper limestone shales.
Lower or "Edge" coals, . . .	} = Carboniferous limestone.
Carboniferous limestones, . . .	
Calcareous sandstones, . . .	= Lower limestone shales.

The upper coals represent, in whole or part, the true English

<sup>1</sup> A close scrutiny of the igneous rocks has enabled my colleague to establish certain marked distinctions between those which were formed contemporaneously with the sedimentary deposits, and those which have been subsequently erupted. The distinction is shewn on the map by two tints of crimson—the darker shade marking the intruded masses, while the lighter represents those of contemporaneous origin.



coal-measures which lie above the millstone grit. They occur, in Scotland, in four basins—one in Mid-Lothian, a second in Fife, the third along the Clyde, south-east of Glasgow and eastwards to Bathgate, while the fourth occupies a large area of Ayrshire. The position of the millstone grit in Scotland, although known, has not yet been satisfactorily traced, and is therefore not shewn on the present map. The lower coals are interstratified in their higher and lower portions with seams of marine limestone, the fossils of which identify the series as the equivalent, partly terrestrial, partly marine, of the Carboniferous limestones of England. This series is coloured on our map with one tint, it being found impossible, on so small a scale, to insert the lines of limestone. The Calciferous sandstone group consists of a great series of sandstones, shales, and thin limestones of a mingled marine, estuarine, or fluvial character, containing plants, as *stigmariæ*, *sigillariæ*, *calamites*, ferns, conifers, &c. It occurs in its greatest development in the eastern part of the great central basin of the country, and thins out rapidly to the south-west, so that in Lanarkshire and Ayrshire it is in many places wholly wanting, and the Carboniferous limestones rest directly on the felstones and sandstones of the Old Red group.<sup>1</sup>

The igneous rocks associated with the Carboniferous formation in Scotland are both contemporaneous and intrusive. Of the former kind (greenstones, basalts, felstones, and ashes or tuffs), the area of the Lothians, especially Arthur's Seat at Edinburgh, the Garlton Hills of Haddingtonshire, and the Bathgate Hills of Linlithgowshire, afford characteristic examples. To the intrusive igneous rocks (chiefly greenstones and basalts, more rarely felstones) belong the craggy hills throughout the centre of the country, as Stirling Rock, Binny Craig, Castle Rock of Edinburgh, and many others.

To the Permian formation (e) we refer provisionally those red sandstones of Dumfriesshire in which the footsteps of tortoises occur at Corncockle Moor; but on this point we also

<sup>1</sup> See Mr Geikie's paper, *Quar. Jour. Geol. Soc.*, vol. xvi. p. 312 *et seq.*

think that some of the red rocks of that tract must certainly be grouped with carboniferous strata.

Of the small patches which are as yet uncertainly referred to the trias (f), we can say little or nothing until their relations be more accurately determined.

As to the lias and oolitic deposits of the north, to which some of my earliest labours were devoted,<sup>1</sup> I may say that, owing to the researches of the late Professor Edward Forbes and of my associate, their relations in the Hebrides, particularly in Skye and the adjacent isles, have been much more clearly eliminated.<sup>2</sup>

No attempt is made in this map to represent the small patches of the older tertiary rocks, which have as yet been recognised so very partially in Scotland; and still less is it practicable to define, on such a small scale, each tract which is covered by various superficial detritus, whether the ancient boulder or glacial drift, or the so-called "Till" of certain great estuaries. Our sole object is to give a view of the chief palæozoic and mesozoic deposits, together with the igneous rocks, of which the framework of Scotland is mainly composed, by classifying these according to their age—and to correlate such portions of them as have been subjected to metamorphism, with others in which the original sediment has been much less altered.

To make the present map as far as possible self-explanatory, my colleague has inserted along the margin several transverse sections, through different parts of the country, to shew the general succession of the rock-masses.

#### SECTION I.—*Generalised Section of the Crystalline Rocks of the Northern Highlands,*

at the head of the map, is enlarged from one in my memoirs on the Northern Highlands, and represents, in a generalised form, the order of superposition of the various sedimentary

<sup>1</sup> Trans. Geol. Soc., 2d series, 4to, vol. ii. p. 353.

<sup>2</sup> Quar. Jour. Geol. Soc., vols. vii. and xiv. p. 1.



deposits from the Hebrides across Sutherland to Brora. On the west coast, the fundamental gneiss ( $\alpha$ ) is shewn to be unconformably overlaid by the Cambrian sandstones (a); these, again, also unconformably by the lower Silurian quartz-rocks and limestones, with fossils ( $b' 1^*$ ), which pass upward in regular succession into the crystalline schists ( $b' 1$ ), that spread out in huge folds over the greater part of Sutherland, until their broken edges, much intermingled with granite, are covered by the Old Red Sandstone (c), which is formed out of their debris, and is itself unconformably overlaid by the lias and oolite (g) of Helmsdale, Brora, and Golspie, which I formerly described.<sup>1</sup>

SECTION II.—*From Dunvegan Head, Skye, across Scotland to the Cheviot Hills,*

is drawn along a line transverse to the strike of the country, and gives the best typical section of the rocks. The north-west end, as unravelled and described by Mr Geikie, begins at Dunvegan Head, Skye, among sheets of greenstone, which contain interstratified seams of estuary limestone, shale, and coal—all belonging to the middle Oolite. These stretch towards the south-east, until they are broken through by some enormous mountain-masses of syenite, which, at Loch Sligachan, have brought up a portion of the Cambrian sandstone that forms the pavement of the secondary rocks in this part of the country. Beyond the syenite lies the valley of Strath, occupied by Lias limestones and shales—the greatest breadth of that formation in Scotland. The Cambrian sandstones appear along an anticlinal ridge in the middle of the Strath, and come up again on the south side, from below the secondary rocks.<sup>2</sup> The ground here is much faulted, but eventually, on the south-east side, we get the limestone and quartz-rock of the lower Silurian series, forming, with their overlying schists, almost the whole of the peninsula of Sleat. Here

<sup>1</sup> Trans. Geol. Soc. Lond., 4to, 2d Series, vol. ii. p. 253, with map.

<sup>2</sup> See Mr Geikie's paper, Quar. Jour. Geol. Soc., vol. xiv. p. 1 *et seq.*

these strata have a south-east dip; so that, after crossing the narrow strait which intervenes between Skye and the mainland, we come to higher members of the same lower Silurian series, in the form of quartzose flagstones, graduating upward into schists with limestones. The schistose series, which now supervenes, is probably repeated upon itself in endless plications.<sup>1</sup> On the whole, however, the dip is south-easterly along this section, as far as a line drawn from the middle of Loch Quoich to the watershed between Kinloch-Aylort and Prince Charles's Monument. This line is a synclinal axis, and on its eastern side the same schistose series is repeated, with a prevailing north-westerly dip, until, about the head of Loch Eil, the quartzose flagstones are brought up again. These undulate to the line of the Caledonian Canal, and then dip again to the south-east, so that the schistose series reappears above them. The remarkable chain of Lochs from Inverness to Inverlochry has been already referred to as an anticlinal axis, broken through by a coincident line of fault. The folding of the arch is clearly shewn in the section. That part of the line which crosses Ben Nevis has been inserted from an examination of the two transverse sections to the north and south of that mountain—the one up Glen Spean, the other along the shores of Loch Leven. The schists and limestones undulate towards the Moor of Rannoch, where the subjacent quartzose flaggy beds reach the surface, arching among broken irregular masses of granite and porphyry. The whole of this region is pre-eminently mineralised. At Glen Lyon, however, the south-east dip returns, and the flagstones plunge below the schists and limestones. Ben Lawers, like Ben Nevis, stands in the centre of a synclinal trough—a monument of enormous denudation. The limestones of Glen Lyon, which sink below it on the north-west side, rise from under it on the south-east, and are well seen along the banks of Loch Tay. That valley lies on an anticlinal fold, so that the limestones bend over, and on the other bank dip away to the south-east, undulating with their superjacent schists,

<sup>1</sup> This is more fully shewn in our joint Memoir on the Highlands; Quar. Jour. Geol. Soc. for May 1861, p. 171 *et seq.*



until the whole is unconformably overlaid by the conglomerates of the Old Red Sandstone. The broad undulating country between the Highland border and the Ochil Hills is occupied by Old Red Sandstone. The relation of the felspathic rocks of these hills to the latter formation has not yet been adequately ascertained. My colleague believes that, in some part of the district, an unconformity will be found, and that the upper part of the series, graduating upward into the sandstones of Dura Den, will be seen to overlap the older or Arbroath flagstones. It remains yet to be discovered whether or not the felspathic rocks of the Ochils are of two ages, one series lying on the edges of the other. Altogether, this part of the section must still be held as doubtful ground. The Carboniferous rocks in the Devon valley, according to recent and unpublished observations of my colleague, seem to overlap the Ochil felstones. Here Mr Geikie finds the whole of the lower Carboniferous sandstones and shales (so enormous a depth of strata in the Lothians and the east of Fife) to be almost wholly wanting—the Carboniferous limestones forming nearly the base of the series at the point where the present line of section crosses. From this locality he has traced them dipping under the volcanic ash of the Saline Hills, and rising again on the south-east, where once more they sink below the lower group of coals which form the Dunfermline coal-field. The section now crosses the Forth, and shews, on the south side, some of the under portions of the great lower Carboniferous series, which was absent on the north side. Arthur's Seat occurs in this low part of the group, and is explained in a separate section (No. 4). It will be seen that the north-west side of the Mid-Lothian coal-basin is bounded by a line of powerful fissure, which flanks the south-eastern side of the Pentland Hills. The details of this coal-field have been completely elucidated by Mr Howell on the Edinburgh sheet of the Geological Survey, to which, and to its accompanying Memoir, now published, the reader must refer for fuller information. It is enough to remark here, that the anticlinal arch of Roman Camp Hill, consisting of the lower limestones, has thrown this great expanse of Car-

boniferous strata into two troughs, known as the basins of Edinburgh and Haddington (or Mid-Lothian and East Lothian). The great Silurian region of the south of Scotland becomes much attenuated towards the north-east, owing to the encroachment of later deposits. Where crossed by the present line of section, it consists of greywacke grits, sandstones, and shales, much hardened, and thrown into highly-inclined convoluted foldings. The prevailing dip, however, trends towards the north-west, below the central basin of the country, from under which the same strata (according to our belief) reappear on the north-west side, as the highly-metamorphosed schistose or gneissose rocks of the Highlands, already described. A cake of Old Red conglomerate lies in the hollow along the watershed near Soutra Hill; and similar deposits occupy the valley of the Leader (down which the line of section runs), and most of the intervening ground to the foot of the Cheviot Hills. Much has still to be done in disentangling the details of the igneous masses in this region. Some are older than the Old Red, others later; while some may possibly be contemporaneous with parts of that formation. The Cheviot Hills consist of an enormous succession of various felspathic masses, which were erupted previous to the deposition of the adjacent Old Red Sandstone and lower Carboniferous rocks, as was clearly shewn many years ago by Mr Milne Home.<sup>1</sup> As, however, all the Old Red Sandstone of this locality belongs to the upper part of that formation, it is quite possible that the Cheviot porphyries were thrown out during the deposition elsewhere of the middle Old Red Sandstone, as was probably the case with the porphyries of Lanarkshire.

### SECTION III.—*From Ben Lomond to the Cheviot Hills.*

Ben Lomond consists of the crystalline schists described in the previous sections, which here shew in some places pebble-

<sup>1</sup> Trans. Roy. Soc. Edin., vol. xiv. p. 253 (1836).



beds, clearly proving their original aqueous origin. The Old Red Sandstone and conglomerate rest unconformably upon these schists as in all other parts of the country. We infer that these strata belong here to the base of the formation, and are therefore a prolongation of the Forfarshire series. But on approaching the north-west flanks of the Campsie Hills, we find a series of sandstones, and marls, and thin limestones, the position of which is not yet adequately fixed.<sup>1</sup> They are known to Glasgow geologists by the name of the "Ballagan Beds," and, according to Mr John Young, of the College Museum, Glasgow, contain a few plants (*lepidodendra* and *calamites*). Mr Geikie compares them with a very similar series of deposits which, in Berwickshire, form the lower Carboniferous group; but he suggests that, as that group seems everywhere thinning out to the west, the Ballagan beds may rather be a prolongation of the red and green sandstones and marls (Upper Old Red Sandstone), which range from Dura Den along the north flank of the Lomond and Cleish Hills toward the plain of Stirling, and may reappear again in the Campsie range. If this be the case, he suggests further that a careful search should be instituted to note whether the limestone of Campsie can be traced transgressively over the Ballagan beds, and whether these latter lie unconformably on the Old Red Sandstones that range up towards the Highland Border. The igneous rocks of the Campsie Hills (felstones, greenstones, &c.) occur in great parallel sheets between the strata; but it has not been sufficiently determined whether they are truly contemporaneous ejections, though it seems most probable that they are. The Campsie limestones have been well described in Mr Young's paper quoted in a previous note. With their overlying coals forming, as a whole, the equivalent of the "edge" or lower coals of Mid-Lothian, Fife, and Linlithgow (= the Carboniferous limestone series of English geologists), they dip below the upper coals (= the English Coal-measures) that form the Clyde basin, and stretch east to Bathgate. At

<sup>1</sup> See Dr Bryce's volume on the Geology of Clydesdale, 1859; and a good palæontological paper by Mr Young, recently published by the Geological Society of Glasgow.

the latter locality the lower coals again emerge, along with their accompanying limestones. Here they are associated with one of the most interesting and complicated assemblages of contemporaneous and intruded igneous rocks to be found in Scotland.<sup>1</sup> From the Bathgate Hills the lower Carboniferous group (= the lower Limestone Shales of England and Ireland) occupies the whole district up to the summit of the Cairn Hills, at the south-west end of the Pentland range. This group consists chiefly of sandstones and shales; but there are also many seams of limestone, and one of coal. Of the limestones the most important is that which (from having been first studied at Burdie House, four miles south of Edinburgh<sup>2</sup>) has been termed the Burdie House limestone. It contains the remains of terrestrial plants, cyprides, and fishes—pointing to ancient estuarine conditions of deposit. The coal-seam of the lower Carboniferous group of Linlithgowshire is known as the Houston coal, but is very inconstant, and does not occur in Edinburghshire.<sup>3</sup> The whole lower Carboniferous series indicates the former existence of a wide estuary or series of brackish-water lagoons over the eastern part of central Scotland—a condition of things which was terminated by a subsidence below the sea which gave rise to the formation of the lower and purely marine part of the Carboniferous limestones, although terrestrial surfaces reappeared before these limestones had accumulated more than a few feet. From that period the area remained sometimes terrestrial, frequently subaqueous. After the deposition of the upper limestones, such calcareous beds ceased to be formed, although the alternations of sandstone, shale, fire-clay, and coal, sufficiently prove how completely the terrestrial surfaces were submerged and covered by accumulations of sediment. The Cairn Hills consist of the lower parts of the Carboniferous formation graduating downward into the upper Old Red Sandstone, which, as

<sup>1</sup> This district has been unravelled by Mr Geikie, and his detailed description will be found in the Memoir to accompany Sheet 32 of the Geological Survey of Scotland.

<sup>2</sup> See Dr Hibbert's Paper, *Trans. Roy. Soc. Edin.*, vol. xiii. p. 169.

<sup>3</sup> For further details, see Mr Geikie's Memoir just referred to.



shewn in the section, rests unconformably on the lower Old Red Sandstone and the upper Silurian shales and grits of the Pentland Hills. These Silurian rocks have been ascertained by Mr Geikie to be abundantly fossiliferous.<sup>1</sup> A fault on the south-east flank of the Pentland Hills, as shewn in the section, has thrown down the Carboniferous strata against the Old Red conglomerates. The section crosses here about the village of Carlops, where, in the bed of the river Esk, some instructive sections are visible. These Carboniferous rocks belong to the Carboniferous limestone series, and form a small basin, which is a prolongation of that of Mid-Lothian. Along the edge of this basin, south-east from Carlops, the limestones, with their associated strata, rest quite unconformably on the highly inclined lower Silurian shales and grits, and thus a great part of the lower Carboniferous series is here wanting. The Silurian Rocks seen in this part of the section belong to the same region traversed by the southern part of Section II. The upper Old Red Sandstone of the Teviot valley also corresponds to that of the Leader and Tweed, and the Cheviot Hills require no further description.

#### SECTION IV.—*Detailed Section of Arthur's Seat, Edinburgh.*

This Section explains the structure of Arthur's Seat as worked out by Mr Geikie during the progress of the Geological Survey in Scotland. It will be seen from the section that the hill is formed of two portions—one consisting of inclined sandstones, shales, greenstones, and ash-beds of lower Carboniferous age covered unconformably by the other, which is made up of various volcanic ejections. The lower and older series of igneous products shews that during the lower Carboniferous period a volcanic orifice existed at Edinburgh, which emitted showers of ash and streams of molten matter. After this vent had been dormant, apparently for a vast geological cycle, during which the rest of the Carboniferous formation

<sup>1</sup> For lists of fossils, and a description of the physical geology of these hills, see his Memoir.

had been deposited, and Scotland had assumed very much its present appearance, the volcanic forces broke forth again, and ejected the later mass of coarse conglomerate and basalt which covers over the denuded edges of the older series. The crater from which these materials issued was eventually closed by a column of basalt that rose up, and gradually hardened. Its denuded top forms now the summit of the hill. For complete details of this hill, and of the surrounding region generally, the reader must consult the Memoir descriptive of Sheet 32 of the Geological Survey of Scotland, and also the faithful description of Mr Maclaren in his *Sketch of the Geology of Fife and the Lothians*.

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In offering this outline to the public, we are well aware that the day is yet distant when the exact boundary-lines of formations, and the position of all the dislocations of the crust can be inserted; and hence we have chosen a sheet of such small dimensions only as will convey our general views as to the relative antiquity of the chief rock-masses.

Those who wish to make themselves more fully acquainted with the grounds on which this map is constructed, must consult the Memoirs and numerous sections we have already published in the *Quarterly Journal of the Geological Society*; as well as the various works by other geologists, quoted on a preceding page.<sup>1</sup>

<sup>1</sup> See *Murchison, Siluria*, p. 137; *Quar. Jour. Geol. Soc.*, vol. xii. p. 15; vol. xiv. p. 531; vol. xv. p. 353; *ib.* 419; vol. xvi. p. 215. Lecture before the Aberdeen Meeting of the British Association, 1859. *Geikie, ib.* vol. xvi. p. 1; and vol. xvi. p. 312. *Rep. Brit. Association for 1859*, p. 106. *Proc. Roy. Soc. Edin.*, iv. 309 and 453. *Trans. Roy. Soc. Edin.*, vol. xxii. p. 633. *Memoirs of Geological Survey (description of Sheet 32, Scotland)*. *Story of a Boulder, 1858*, p. 178 *et seq.* As bearing on the question of the metamorphism of the Scottish Highlands, reference should also be made here to the labours of foreign mineralogists; especially to the analyses of Berthier, Mitcherlich, &c., on simple minerals; Délesse on the metamorphism of rocks; and Dobrée's "*Experiences Synthétiques*," &c., Paris, 1859. See also Mr Sterry Hunt's papers in the *Memoirs of the Geological Survey of Canada*; as well as those of Mr Sorby, Professor Tyndall, and others in our own country.



In conclusion, let me say that, in publishing this general Geological Map of Scotland, Mr Keith Johnston, who has constructed the topography with his well-known ability, has also inserted the heights of the principal mountains, and that my colleague and self have added the names of certain places which are of geological importance.

RODERICK I. MURCHISON.

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