GEIKIE JAMES

FRAGMENTS OF EARTH LORE: SKETCHES & ADDRESSES GEOLOGICAL AND GEOGRAPHICAL

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Содержание

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PREFACE

The articles in this volume deal chiefly with the history of Glacial times and the origin of surface-features. As they were not written with any view to their subsequent appearance in a collected form, each is so far independent and complete in itself. Under these circumstances some repetition was unavoidable, if the articles were not to be recast, and I did not think it advisable to make such radical alteration. With the exception of verbal changes and some excisions, therefore, the papers remain substantially in their original state. Here and there a footnote has been added to indicate where the views expressed in the text have since been modified; but I have not been careful to insert such notes throughout. Geologists, like other folk, live and learn, and the reader will probably discover that the opinions set forth in some of the later articles are occasionally in advance of those maintained in the writer's earlier days.

I have to thank the Publishers of *Good Words* for allowing me to republish the articles on the Cheviot Hills and the Outer Hebrides. My acknowledgments are also due to Mr. Bartholomew for the excellent maps with which the volume is so well illustrated.

Edinburgh, *April 5th, 1893*.

I.
Geography and Geology. [1]

The teaching of Geography naturally occupies a prominent place in every school curriculum. It is rightly considered essential that we should from an early age begin to know something of our own and other countries. I am not sure, however, that Geography is always taught in the most interesting and effective manner. Indeed, according to some geographers, who are well qualified to express an opinion, the manner in which their subject is presented in many of our schools leaves much to be desired. But a decided advance has been made in recent years, and with the multiplication of excellent text-books, maps, and other appliances, I have no doubt that this improvement will continue. When I attended school the text-books used by my teachers were about as repellent as they could be. Our most important lesson was to commit to memory a multitude of place-names, and the maps which were supposed to illustrate the text-books were, if possible, less interesting and instructive. Nowadays, however, teachers have a number of more or less excellent manuals at their service, and the educational maps issued by our cartographers show in many cases a very great advance on the

[1] Portion of a lecture given in 1886 to the Class of Geology in the University of Edinburgh.

bald and misleading caricatures which did duty in my young days as pictures of the earth's surface.

During the progress of some war we often remark that the task of following the military operations compels us to brush up our Geography. I am uncharitable enough to suspect that it would frequently be truer to say that, before these campaigns commenced, we had no such knowledge to brush up. The countries involved in the commotion were probably mere names to many of us. We had no immediate interest in them or their inhabitants, and had we been asked, before the outbreak of hostilities, to indicate the precise positions of the places upon a map, some of us perhaps might have been sorely puzzled to do so. Nor is such ignorance always discreditable. One cannot know everything; the land-surface of the globe contains upwards of 50 millions of square miles, and one may surely be excused for not having a detailed knowledge of this vast area. I have referred to the subject simply because I think it gives us a hint as to how the teaching of Political Geography might be made most instructive and interesting. Historical narrative might often be interwoven with the subject in such a way as to fix geographical features indelibly on the memory. Striking and picturesque incidents, eventful wars, the rise and progress of particular trades, the routes followed by commerce, the immigration and emigration of races, the gradual development of the existing political divisions of the Old World, the story of Columbus and the early voyagers, the geographical discoveries of later times – all these, and such as these, might be introduced into our lessons in Political Geography. The wanderings of a Mungo Park, a Bruce, a Livingstone, a Stanley, traced on a good map, could not fail to arrest the attention of the youthful student of African geography. In like manner, the campaigns of the great Napoleon might be made to do good service in illustrating the geographical features of large portions of our own continent. Then, as regards Britain, what a world of poetry and romantic story clings to every portion of its surface – why, the very place-names themselves might suggest to any intelligent teacher themes and incidents, the deft treatment of which would make the acquisition of Geography a delightful task to the dullest boy or girl.

The intimate relation that obtains between Political Geography and History has indeed long been recognised, and is in fact self-evident. And we are all well aware that in our school manuals of Geography it has been usual for very many years to note the scenes of remarkable events. Such notes, however, are of necessity extremely brief; and it need hardly be said that to fully incorporate history in a text-book of general Geography would be quite impracticable. It might be done to a certain extent for our own and a few of the more important countries; but similar detail need not be attempted in regard to regions which are of less consequence from the political point of view. Indeed, I should be inclined to leave the proper application of historical knowledge in the teaching of Geography very much to the teacher himself, who would naturally select such themes and incidents as seemed best adapted to attract the attention of his pupils. Be that, however, as it may, it is enough for my present purpose if I insist upon the fact that the proper study of Political Geography involves the acquisition of some historical knowledge. One can hardly conceive the possibility of an intelligent student taking pains to become acquainted with the political geography of a country without at the same time endeavouring to learn something of its history – otherwise, his geographical attainments would hardly surpass those of a commercial traveller, whose geographical studies have been confined to the maps and tables of his Bradshaw.

But if it be impossible to ignore History in the teaching of Political Geography, it is just as impossible to exclude from our attention great physical features and characteristics. Surface-configuration, climate, and natural products all claim our attention. It is obvious, in fact, that the proper study of Political Geography must give us at least a general notion of the configuration, the river-systems, and climatic conditions of many different lands. For has not the political development of races depended most largely on the physical conditions and natural resources of the countries occupied by them? So far, then, as these have sensibly influenced the progress of peoples, they come naturally under the consideration of Political Geography. Thus, if Political Geography be closely connected and interwoven, as it were, with History, not less intimate are its relations to Physical Geography. It does not embrace all Physical Geography, but it introduces us to many facts and phenomena, the causes and mutual relations of which we cannot understand without first mastering the teachings of Physical Geography. In the study of this latter science we come more closely into contact with Nature; we cease to think of the surface of the earth as parcelled out into so many lots by its human occupants – we no longer contemplate that surface from the limited point of view of the political geographer – we are now not merely members of one particular community, but have become true citizens of the world. To us north and south, east and west are of equal interest and importance. Our desire now is to understand, if haply we may, the complex system of which we ourselves form a part. The distribution of land and water – the configuration of continental areas and oceanic basins – the circulation of oceanic and terrestrial waters – earth-movements and volcanoes – ice-formations – the atmosphere – climatology – the geographical distribution of plants and animals – in a word, *the world as one organic whole* now forms the subject of our contemplation. Such being the scope of Physical Geography, it is satisfactory to know that its importance as a subject of study in our schools has been fully recognised. This being admitted, I shall now proceed to show that Physical Geography, although, like Political Geography, it is a separate and distinct subject, yet, just as the study of the latter involves some knowledge of History, so the prosecution of Physical Geography compels us to make a certain acquaintance with Geology. We cannot, in fact, learn much about the atmosphere, about rain and rivers, glaciers and icebergs, earthquakes and volcanoes, and the causes of climate, without at the same time becoming more or less familiar with the groundwork on which geological investigations are based. And just as a knowledge of history enables us better to understand the facts of Political Geography, so some acquaintance with the results of geological inquiry are necessary before we can hope to comprehend many of the phenomena of which Physical Geography treats. Let me try to make this plain. The physical geographer, we shall suppose, is considering the subject of terrestrial waters. He tells us what is meant by the drainage-system of a country, points out how the various minor water-courses or brooks and streams unite to form a river, describes for us the shape of the valley through which a typical river makes its way – how the valley-slope diminishes from the mountains onwards to the sea-coast – how, at first, in its upper or mountain-track, the flow of the river is torrential – how, as the slope of the valley decreases, the river begins to wind about more freely, until it reaches the head of its plain-track or delta, when, no longer receiving affluents, it begins to divide, and enters the sea at last by many mouths. He tells us further what proportion of the rainfall of the country passes seawards in our river, and he can measure for us the quantity of water which is actually discharged. All this is purely Physical Geography; but when we come to ask why some rivers flow in deep ca¤ons, like those of the Colorado – why valleys should widen out in one part and contract, as it were, elsewhere – why the courses of some rivers are interrupted by waterfalls and rapids, and many other similar questions, the physical geographer must know something of Geology before he can give an answer. He can describe the actual existing conditions; without the aid of Geology, he can tell us nothing of their origin and cause. So the political geographer can map out for us the present limits of the various countries of Europe, but History must be invoked if we would know how those boundaries came to be determined. The moment, therefore, the physical geographer begins to inquire into the origin of any particular physical feature, he enters upon the domains of the geologist. And as he cannot possibly avoid doing so, it is quite common now to find a good deal of the subject-matter of Geology treated of in text-books of Physical Geography. I state this merely to show how very closely the two sciences are interlocked. Take, for example, the configuration of river valleys just referred to. The physical geographer recognises the fact that a river performs work; by means of the sediment which it carries in suspension and rolls along its course, it erodes its bed in many places, and undermines its banks, and thus its channel is deepened and widened. He can measure the amount of sediment which it carries down to the sea, and the quantity of saline matters which its waters hold in solution: and knowing that all these substances have been abstracted from the land, he is able to estimate approximately the amount of material which is annually transferred from the surface of the drainage-area involved. He discovers this to be so relatively enormous that he has no difficulty in believing that the valleys in which rivers flow might have been hollowed out by the rivers themselves. But, without trespassing further into the geologist's domains, he cannot go beyond this: and you will at once perceive that something more is required to prove that any particular valley owes its origin to the erosive action of running water. Suppose someone were to suggest to him that his river-valley might be a minor wrinkle in the earth's crust caused by earth-movements, or that it might indicate the line of a fissure or dislocation, due to some comparatively recent convulsion – how could his computation of the amount of material at present carried seawards by the river prove such suggestions to be erroneous? And what light could it throw upon the origin of the varied configuration of the river-valley – how would it explain the presence or absence of cascades and rapids, of narrow gorges and open expanses? None of these phenomena can be interpreted and accounted for without the aid of the geologist: without some knowledge of rocks and rock-structures, the origin of the earth's surface-features is quite inexplicable. To give an adequate explanation of all the surface-features of a country in detail would of course require a profound study of Geology; but a general acquaintance only with its elementary facts is quite sufficient to enable us to form a reasonable and intelligent view of the cause and origin of the main features of the land as a whole. Thus a few lessons in elementary Geology would make clear to any child how rivers have excavated valleys, why cataracts and gorges occur here, and open valleys with gently-flowing waters elsewhere.

Let me select yet another example to show how dependent Physical Geography is upon Geology. The physical geographer, in describing the features of the land, tells us how the great continental areas are traversed in various directions by what he calls mountain-chains. Thus, in speaking of America, he tells us that it may be taken as a type of the continental structure – namely a vast expanse of land, low or basin-like in the interior, and flanked along the maritime regions by elevated mountain borders – the highest border facing the deepest ocean. He points out further that the great continental areas are crossed from west to east by well-marked depressions, to a large extent occupied by water. Thus Europe is separated from Africa by the Mediterranean, a depression which is continued eastward through the Black Sea into the Aralo-Caspian area. South America is all but cut away from North America, while Australia is separated from Asia by the East India Seas. We find, in fact, all over the world that well-marked natural features are constantly being repeated. Not only do the great land-masses of the globe bear certain resemblances to each other, but even in their detailed structure similar parallelisms recur. The physical geographer notes all these remarkable phenomena, but he can give us no clue to their meaning. He may describe with admirable skill the characteristic features of plains and plateaux, of volcanic mountains and mountain-chains, but he cannot tell us why plains should occur here and mountains there; nor can he explain why some mountains, such as those of Scotland or Norway, differ so much in configuration from the Alps and the Pyrenees. The answer to all these questions can only be given by Geology. It is from this science we learn how continental areas and oceanic basins have been evolved. The patient study of the rocks has revealed the origin of the present configuration of the land. There is not a hill or valley, not a plateau or mountain-region, which does not reveal its own history. The geologist can tell you why continents are bordered by coast-ranges, and why their interiors are generally comparatively low and basin-shaped. The oceanic basins and continental areas, we learn, are primeval wrinkles in the earth's crust, caused by its irregular subsidence upon the gradually cooling and contracting nucleus. The continents are immense plateau-like areas rising more or less abruptly above those stupendous depressions of the earth's crust which are occupied by the ocean. While those depressions are in progress the maritime borders of the land-areas are subjected to enormous squeezing and crushing, and coast-ranges are the result – the elevation of those ranges necessarily holding some relation to the depth of the contiguous ocean. For, the deeper the ocean the greater has been the depression under the sea, and, consequently, the more intense the upheaval along the continental borders. It is for the same reason that destructive earthquakes are most likely to occur in the vicinity of coast-ranges which are of comparatively recent geological age. These, and indeed all, mountains of elevation are lines of weakness along which earth-movements may continue from time to time to take place. But all mountains are not mountains of elevation; many elevated regions owe their mountainous character simply to the erosive action of sub-aërial agents, such as rain, frost, ice, and running water, the forms assumed by the mountains being due to their petrological character and geological structure. There are, for example, no true mountains of elevation in Scotland; hence to write of the *chain of the Grampians* or the *range of the Lowthers* is incorrect and actually misleading. Without the aid of Geology the geographer cannot, in fact, discriminate between mountains of elevation and mountains of denudation; hence geographical terms so constantly in use as *mountain-range* and *mountain-chain* are very often applied by writers, ignorant of geological structure, to elevated regions which have no claim to be described either as *chains* or *ranges*. Some knowledge of Geology, therefore, is essential to us if we would have correct views of many of the grandest features of the globe. But it will be said that, after all, the physical geographer deals with the earth as we now find it; he does not need to trouble himself with the origin of the phenomena he describes. Well, as I have just shown, he cannot, even if he would, escape trenching on Geology; and if he could, his subject would be shorn of much of its interest. He recognises that the world he studies has in it the elements of change – the forces of Nature are everywhere modifying the earth's surface – considerable changes are sometimes brought about even in one's lifetime, while within the course of historical ages still greater mutations have taken place – he becomes conscious, in short, that the existing state of things is but the latest phase of an interminable series of changes stretching back into the illimitable past, and destined to be prolonged into the indefinite future. Thus he gladly welcomes the labours of the geologist, whose researches into the past have thrown such a flood of light upon the present. In fact, he can no more divorce his attention from the results of geological inquiry than the political geographer can shut his eyes to the facts of History.

Let me, in conclusion, give one further illustration of the close inter-dependence of the two sciences of which I am speaking. One of the subjects treated of by Physical Geography is the present geographical distribution of plants and animals. The land-surface of the globe has been mapped out into so many biological regions, each of which is characterised by its special fauna and flora. The greatest changes in the flora and fauna of a continent are met with as we pass from south to north, or *vice versa*. Proceeding in the direction of the latitude, the changes encountered are much less striking. Now, these facts are readily explained by the physical geographer, who points out that the distribution is due chiefly to climatic conditions – a conclusion which is obvious enough. But when we go into details we find that mere latitude will not account for all the phenomena. Take, for example, the case of the Scandinavian flora of our own Continent. It is true that this flora is largely confined to northern latitudes; but isolated colonies occur in our own mountains and in the mountains of middle and southern Europe. How are these to be accounted for? The physical geographer says that the plants grow there simply because they obtain at high levels in low latitudes the favourable climatic conditions underneath which they flourish at low levels in high latitudes. He therefore concludes that the distribution of life-forms is due to varying climatic and physical conditions. But if we ask him how those curious colonies of foreigners come to be planted on our mountains, he cannot tell. To get our answer we must come to the geologist; and he will explain that they are, as it were, living fossils – monuments of former great physical and climatic changes. He will prove to us that the climate of Europe was at a recent geological period so cold that the Scandinavian flora spread south into middle Europe, where it occupied the low grounds. When the climate became milder, then the northern invaders gradually retired – the main body migrating back to the north – while some stragglers, retreating before the stronger Germanic flora, took shelter in the mountains, whither the latter could not or would not follow, and so there our Scandinavians remain, the silent witnesses of a stupendous climatic revolution. Now, all the world over, plants and animals have similar wonderful tales to tell of former geographical changes. The flora and fauna of our country, for example, prove that the British Islands formed part of the Continent at a very recent geological period; and so, from similar evidence, we know that not long ago Europe was joined on to Africa. On the other hand, the facts connected with the present distribution of life demonstrate that some areas, such as Australia, have been separated from the nearest continental land for vastly prolonged periods of time.

It would be a very easy matter to adduce many further illustrations to show how close is the connection between the studies of the physical geographer and the geologist. I do not indeed exaggerate when I say that no one can hope to become a geologist who is not well versed in Physical Geography; nor, on the other hand, can the physical geographer possibly dispense with the aid of Geology. The two subjects are as closely related and interwoven, the one with the other, as History is with Political Geography. I do not see therefore how educationists who have admitted the great importance of Physical Geography as a branch of general education, can logically exclude Geology as a subject of instruction in schools. Already, indeed, it has been introduced by many teachers, and I am confident that ere long it will be as generally taught as Physical Geography. I would not, however, present the subject to young people as a lesson to be learned from books. A good teacher should be able to dispense with these helps, or rather hindrances – for such they really are to a young beginner. His pupils ought to have previously studied the subject of Physical Geography, and if they have been well taught they ought to have already acquired no mean store of geological knowledge. They ought, in fact, to have learned a good deal about the great forces which are continually modifying the surface of the globe, and what they have now to do is to study more particularly the results which have followed from the constant operation of those forces. We shall suppose, for example, that the teacher has described how rivers erode their channels, and waves tend to cut back a coast-line, and how the products of erosion, consisting of gravel, sand, and mud, are distributed along river-valleys and accumulated in lakes and seas. He now exhibits to his class good-sized fragments of conglomerate, sandstone, and shale, and points out how each of these rocks is of essentially the same character, and must therefore have had the same origin, as modern sedimentary accumulations. His pupils should be encouraged to examine the rocks of their own neighbourhood, whether exhibited in natural sections or artificial exposures, and to compare these with the products of modern geological action. One hour's instruction in the field is, in fact, worth twenty hours of reading or listening to lectures. Knowledge at first hand is what is wanted. There are many excellent popular or elementary treatises dealing with Historical Geology, and these have their uses, and may be read with profit as well as pleasure. But the mere reading of such books, it is needless to say, will never make us geologists. They help no doubt to store the mind with interesting and entertaining knowledge, but they do not cultivate the faculties of observation and reasoning. And unless geology is so taught as to accomplish this result, I do not see why it should enter into any school curriculum. Further, I would remark that, however interesting a geological treatise may be, it cannot possibly stimulate the imagination as the practical study of the science is bound to do. One may put into the hands of a youth a clear and well-written description of some particular fossiliferous limestone, and he may by dint of slavish toil be able to repeat verbatim all that he has read. That is how a good deal of book-knowledge of science is acquired. Only think, however, of the drudgery it involves – the absolute waste of time and energy. But let us illustrate our lesson by means of a lump of the limestone itself; let us show him the character of the rock and the nature of its fossil contents, and his difficulties disappear. Better still – let us take him, if we can, into a limestone quarry, and he will be a dull boy indeed if he fails fully to understand what limestone is, or to realise the fact that the rock he is looking at accumulated slowly, like existing oceanic formations, at the bottom of a sea that teemed with animal life. It is unnecessary, however, that I should illustrate this subject further. I would only repeat that the beginner should be taught from the very first to use his own eyes, and to draw logical conclusions from the facts which he observes. Trained after this manner, he would acquire, not only a precise and definite knowledge of what geological data really are, but he would learn also how to interpret those data. He would become familiar, in fact, with the guiding principles of geological inquiry.

How much or how little of Historical Geology should be given in schools will depend upon circumstances. Great care, however, should be taken to avoid wearying the youthful student with strings of mere names. What good is gained by learning to repeat the names of fifty or a hundred fossils, if you cannot recognise any one of these when it is put into your hand? With young beginners I should not attempt anything of that kind. If the neighbourhood chanced to be rich in fossils, I should take my pupils out on Saturday to the sections where they were found, and let them ply their hammers and collect specimens for themselves. I should describe no fossils which they had not seen and handled. Of the more remarkable forms of extinct animals and plants, which are often represented by only fragmentary remains, I should exhibit drawings showing the creatures as they have been restored by the labours of comparative anatomists. Such restorations and ideal views of geological scenes like those given by Heer, Dana, Saporta, and others, convey far more vivid impressions of the life of a geological period than the most elaborate description. In fine, the story of our earth should be told much in the same manner as Scott wrote the history of Scotland for his grandson. There is no more reason for requiring the juvenile student to drudge through minute geological data before introducing him to the grand results of geological investigation, than there is for compelling him to study the manuscripts in our Record Offices before allowing him to read the history which has been drawn from these and similar sources of information. It is enough if at the beginning of his studies he has already learned the general nature of geological evidence and the method of its interpretation. Provided with such a stock of geological knowledge as I have indicated, our youth would leave school with some intelligent appreciation of existing physical conditions, and a not inadequate conception of world-history.

II.

The Physical Features of Scotland. [2]

Scotland, like "all Gaul," is divided into three parts, namely, the Highlands, the Central Lowlands, and the Southern Uplands. These, as a correctly drawn map will show, are natural divisions, for they are in accordance not only with the actual configuration of the surface, but with the geological structure of the country. The boundaries of these principal districts are well defined. Thus, an approximately straight or gently undulating line taken from Stonehaven, in a south-west direction, along the northern outskirts of Strathmore to Glen Artney, and thence through the lower reaches of Loch Lomond to the Firth of Clyde at Kilcreggan, marks out with precision the southern limits of the Highland area and the northern boundary of the Central Lowlands. The line that separates the Central Lowlands from the Southern Uplands is hardly so prominently marked throughout its entire course, but it follows precisely the same north-east and south-west trend, and may be traced from Dunbar along the base of the Lammermoor and Moorfoot Hills, the Lowthers, and the hills of Galloway and Carrick, to Girvan. In each of the two mountain-tracts – the Highlands and the Southern Uplands – areas of low-lying land occur, while in the intermediate Central

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[2] *Scottish Geographical Magazine*, vol. i., 1885.

Lowlands isolated prominences and certain well-defined belts of hilly ground make their appearance. The statement, so frequently repeated in class-books and manuals of geography, that the mountains of Scotland consist of three (some writers say five) "ranges" is erroneous and misleading. The original author of this strange statement probably derived his ignorance of the physical features of the country from a study of those antiquated maps upon which the mountains of poor Scotland are represented as sprawling and wriggling about like so many inebriated centipedes and convulsed caterpillars. Properly speaking, there is not a true mountain-range in the country. If we take this term, which has been very loosely used, to signify a linear belt of mountains – that is, an elevated ridge notched by cols or "passes" and traversed by transverse valleys – then in place of "three" or "five" such ranges we might just as well enumerate fifty or sixty, or more, in the Highlands and Southern Uplands. Or, should any number of such dominant ridges be included under the term "mountain-range," there seems no reason why all the mountains of the country should not be massed under one head and styled the "Scottish Range." A mountain-range, properly so called, is a belt of high ground which has been ridged up by earth-movements. It is a fold, pucker, or wrinkle in the earth's crust, and its general external form coincides more or less closely with the structure or arrangement of the rock-masses of which it is composed. A mountain-range of this characteristic type, however, seldom occurs singly, but is usually associated with other parallel ranges of the same kind – the whole forming together what is called a "mountain-chain," of which the Alps may be taken as an example. That chain consists of a vast succession of various kinds of rocks, which at one time were disposed in horizontal layers or strata. But during subsequent earth-movements those horizontal beds were compressed laterally, squeezed, crumpled, contorted, and thrown, as it were, into gigantic undulations and sharper folds and plications. And, notwithstanding the enormous erosion or denudation to which the long parallel ridges or ranges have been subjected, we can yet see that the general contour of these corresponds in large measure to the plications or foldings of the strata. This is well shown in the Jura, the parallel ranges and intermediate hollows of which are formed by undulations of the folded strata – the tops of the long hills coinciding more or less closely with the arches, and the intervening hollows with the troughs. Now folded, crumpled, and contorted rock-masses are common enough in the mountainous parts of Scotland, but the configuration of the surface rarely or never coincides with the inclination of the underlying strata. The mountain-crests, so far from being formed by the tops of great folds of the strata, frequently show precisely the opposite kind of structure. In other words, the rocks, instead of being inclined away from the hill-tops like the roof of a house from its central ridge, often dip into the mountains. When they do so on opposite sides the strata of which the mountains are built up seem arranged like a pile of saucers, one within another.

There is yet another feature which brings out clearly the fact that the slopes of the surface have not been determined by the inclination of the strata. The main water-parting that separates the drainage-system of the west from that of the east of Scotland does not coincide with any axis of elevation. It is not formed by an anticlinal fold or "saddleback." In point of fact it traverses the strata at all angles to their inclination. But this would not have been the case had the Scottish mountains consisted of a chain of true mountain-ranges. Our mountains, therefore, are merely monuments of denudation, they are the relics of elevated plateaux which have been deeply furrowed and trenched by running water and other agents of erosion. A short sketch of the leading features presented by the three divisions of the country will serve to make this plain.

The Highlands. – The southern boundary of this, the most extensive of the three divisions, has already been defined. The straightness of that boundary is due to the fact that it coincides with a great line of fracture of the earth's crust – on the north or Highland side of which occur slates, schists, and various other hard and tough rocks, while on the south side the prevailing strata are sandstones, etc., which are not of so durable a character. The latter, in consequence of the comparative ease with which they yield to the attacks of the eroding agents – rain and rivers, frost and ice – have been worn away to a greater extent than the former, and hence the Highlands, along their southern margin, abut more or less abruptly upon the Lowlands. Looking across

Strathmore from the Sidlaws or the Ochils, the mountains seem to spring suddenly from the low grounds at their base, and to extend north-east and south-west, as a great wall-like rampart. The whole area north and west of this line may be said to be mountainous, its average elevation being probably not less than 1500 feet above the sea.

A glance at the contoured or the shaded sheets of the Ordnance Survey's map of Scotland will show better than any verbal description the manner in which our Highland mountains are grouped. It will be at once seen that to apply the term "range" to any particular area of those high grounds is simply a misuse of terms. Not only are the mountains not formed by plications and folds, but they do not even trend in linear directions. It is true that a well-trained eye can detect certain differences in the form and often in the colouring of the mountains when these are traversed from south-east to north-west. Such differences correspond to changes in the composition and structure of the rock-masses, which are disposed or arranged in a series of broad belts and narrower bands, running from south-west to north-east across the whole breadth of the Highlands. Each particular kind of rock gives rise to a special configuration, or to certain characteristic features. Thus, the mountains that occur within a belt of slate, often show a sharply cut outline, with more or less pointed peaks and somewhat serrated ridges – the Aberuchill Hills, near Comrie, are an example. In regions of gneiss and granite the mountains are usually rounded and lumpy in form. Amongst the schists, again, the outlines are generally more angular. Quartz-rock often shows peaked and jagged outlines; while each variety of rock has its own particular colour, and this in certain states of the atmosphere is very marked. The mode in which the various rocks yield to the "weather" – the forms of their cliffs and corries – these and many other features strike a geologist at once; and therefore, if we are to subdivide the Highland mountains into "ranges," a geological classification seems the only natural arrangement that can be followed. Unfortunately, however, our geological lines, separating one belt or "range" from another, often run across the very heart of great mountain-masses. Our "ranges" are distinguished from each other simply by superficial differences of feature and structure. No long parallel hollows separate a "range" of schist-mountains from the succeeding "ranges" of quartz-rock, gneiss, or granite. And no degree of careful contouring could succeed in expressing the niceties of configuration just referred to, unless the maps were on a very large scale indeed. A geological classification or grouping of the mountains into linear belts cannot therefore be shown upon any ordinary orographical map. Such a map can present only the relative heights and disposition of the mountain-masses, and these last, in the case of the Highlands, as we have seen, cannot be called "ranges" without straining the use of that term. Any wide tract of the Highlands, when viewed from a commanding position, looks like a tumbled ocean in which the waves appear to be moving in all directions. One is also impressed with the fact that the undulations of the surface, however interrupted they may be, are broad – the mountains, however they may vary in detail according to the character of the rocks, are massive, and generally round-shouldered and often somewhat flat-topped, while there is no great disparity of height amongst the dominant points of any individual group. Let us take, for example, the knot of mountains between Loch Maree and Loch Torridon. There we have a cluster of eight pyramidal mountain-masses, the summits of which do not differ much in elevation. Thus in Liathach two points reach 3358 feet and 3486 feet; in Beinn Alligin there are also two points reaching 3021 feet and 3232 feet respectively; in Beinn Dearg we have a height of 2995 feet; in Beinn Eighe are three dominant points – 3188 feet, 3217 feet, and 3309 feet. The four pyramids to the north are somewhat lower – their elevations being 2860 feet, 2801 feet, 2370 feet, and 2892 feet. The mountains of Lochaber and the Monadhliath Mountains exhibit similar relationships; and the same holds good with all the mountain-masses of the Highlands. No geologist can doubt that such relationship is the result of denudation. The mountains are monuments of erosion – they are the wreck of an old table-land – the upper surface and original inclination of which are approximately indicated by the summits of the various mountain-masses and the direction of the principal water-flows. If we in imagination fill up the valleys with the rock-material which formerly occupied their place, we shall in some measure restore the general aspect of the Highland area before its mountains began to be shaped out by Nature's saws and chisels.

It will be observed that while streams descend from the various mountains to every point in the compass, their courses having often been determined by geological structure, etc., their waters yet tend eventually to collect and flow as large rivers in certain definite directions. These large rivers flow in the direction of the average slope of the ancient table-land, while the main water-partings that separate the more extensive drainage-areas of the country mark out, in like manner, the dominant portions of the same old land-surface. The water-parting of the North-west Highlands runs nearly north and south, keeping quite close to the western shore, so that nearly all the drainage of that region flows inland. The general inclination of the North-west Highlands is therefore easterly towards Glenmore and the Moray Firth. In the region lying east of Glenmore the average slopes of the land are indicated by the directions of the rivers Spey, Don, and Tay. These two regions – the North-west and South-east Highlands – are clearly separated by the remarkable depression of Glenmore, which extends through Loch Linnhe, Loch Lochy, and Loch Ness, and the further extension of which towards the north-east is indicated by the straight coast-line of the Moray Firth as far as Tarbat Ness. Now, this long depression marks a line of fracture and displacement of very great geological antiquity. The old plateau of the Highlands was fissured and split in two – that portion which lay to the north-west sinking along the line of fissure to a great but at present unascertained depth.

Thus the waters that flowed down the slopes of the north-west portion of the broken plateau were dammed by the long wall of rock on the "up-cast," or south-east side of the fissure, and compelled to flow off to north-east and south-west along the line of breakage. The erosion thus induced sufficed in the course of time to hollow out Glenmore and all the mountain-valleys that open upon it from the west.

The inclination of that portion of the fissured plateau which lay to the south-east is indicated, as already remarked, by the trend of the principal rivers. It was north-east in the Spey district, nearly due east in the area drained by the Don, east and south-east in that traversed by the Tay and its affluents, westerly and south-westerly in the district lying east of Loch Linnhe.[3] Thus, a line drawn from Ben Nevis through the Cairngorm and Ben Muich Dhui Mountains to Kinnaird Point passes through the highest land in the South-east Highlands, and probably indicates approximately the dominant portion of the ancient plateau. North of that line the drainage is towards the Moray Firth; east of it the rivers discharge to the North Sea; while an irregular winding line, drawn from Ben Nevis eastward through the Moor of Rannoch and southward to Ben Lomond, forms the water-parting between the North Sea and the Atlantic, and doubtless marks another

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[3] The geological reader hardly requires to be reminded that many of the minor streams would have their courses determined, or greatly modified, by the geological structure of the ground. Thus, such streams often flow along the "strike" and other "lines of weakness," and similar causes, doubtless, influenced the main rivers during the gradual excavation of their valleys.

dominant area of the old table-land.

That the valleys which discharge their water-flow north and east to the Moray Firth and the North Sea have been excavated by rivers and the allied agents of erosion, is sufficiently evident. All the large rivers of that wide region are typical. They show the orthodox three courses – namely, a torrential or mountain-track, a middle or valley-track, and a lower or plain-track. The same is the case with some of the rivers that flow east from the great north-and-south water-parting of the North-west Highlands, as, for example, those that enter the heads of Beauly Firth, Cromarty Firth, and Dornoch Firth. Those, however, which descend to Loch Lochy and Loch Linnhe, and the sea-lochs of Argyllshire, have no lower or plain-track. When we cross the north-and-south water-parting of the North-west Highlands, we find that many of the streams are destitute of even a middle or valley-track. The majority are mere mountain-torrents when they reach the sea. Again, on the eastern watershed of the same region, a large number of the valleys contain lakes in their upper and middle reaches, and this is the case also with not a few of the valleys that open upon the Atlantic. More frequently, however, the waters flowing west pass through no lakes, but enter the sea at the heads of long sea-lochs or fiords. This striking contrast between the east and west is not due to any difference in the origin of the valleys. The western valleys are as much the result of erosion as those of the east. The present contrast, in fact, is more apparent than real, and arises from the fact that the land area on the

Atlantic side has been greatly reduced in extent by subsidence. The western fiords are merely submerged land-valleys. Formerly the Inner and Outer Hebrides were united to themselves and the mainland, the country of which they formed a part stretching west into the Atlantic, as far probably as the present 100 fathoms line. Were that drowned land to be re-elevated, each of the great sea-lochs would appear as a deep mountain-valley containing one or more lake-basins of precisely the same character as those that occur in so many valleys on the eastern watershed. Thus we must consider all the islands lying off the west coast of the Highlands, including the major portions of Arran and Bute, as forming part and parcel of the Highland division of Scotland. The presence of the sea is a mere accident; the old lands now submerged were above its level during a very recent geological period – a period well within the lifetime of the existing fauna and flora.

The old table-land of which the Highlands and Islands are the denuded and unsubmerged relics, is of vast geological antiquity. It was certainly in existence, and had even undergone very considerable erosion, before the Old Red Sandstone period, as is proved by the fact that large tracts of the Old Red Sandstone formation are found occupying hollows in its surface. Glenmore had already been excavated when the conglomerates of the Old Red Sandstone began to be laid down. Some of the low-lying maritime tracts of the Highland area in Caithness, and the borders of the Moray Firth, are covered with the sandstones of that age; and there is evidence to show that these strata formerly extended over wide regions, from which they have since been removed by erosion. The fact that the Old Red Sandstone deposits still occupy such extensive areas in the north-east of the mainland, and in Orkney, shows that the old table-land shelved away gradually to north and east, and the same conclusion may be drawn, as we have seen, from the direction followed by the main lines of the existing drainage-system. We see, in short, in the table-land of the Highlands, one of the oldest elevated regions of Europe – a region which has been again and again submerged either in whole or in part, and covered with the deposits of ancient seas and lakes, only to be re-elevated, time after time, and thus to have those deposits in large measure swept away from its surface by the long-continued action of running water and other agents of denudation.

The Central Lowlands. – The belt of low-lying ground that separates the Highlands from the Southern Uplands is, as we have seen, very well defined. In many places the Uplands rise along its southern margin as abruptly as the Highlands in the north. The southern margin coincides, in fact, for a considerable distance (from Girvan to the base of the Moorfoots) with a great fracture that runs in the same direction as the bounding fracture or fault of the Highlands. The Central Lowlands may be described, in a word, as a broad depression between two table-lands. A glance at the map will show that the principal features of the Lowlands have a north-easterly trend – the same trend, in fact, as the bounding lines of the division. To this arrangement there are some exceptions, the principal being the belt of hilly ground that extends from the neighbourhood of Paisley, south-east through the borders of Renfrewshire and Ayrshire, to the vicinity of Muirkirk. The major part of the Lowlands is under 500 feet in height, but some considerable portions exceed an elevation of 1000 feet, while here and there the hills approach a height of 2000 feet – the two highest points (2352 and 2335 feet) being attained in Ben Cleugh, one of the Ochils, and in Tinto. Probably the average elevation of the Lowland division does not exceed 350 or 400 feet. Speaking generally, the belts of hilly ground, and the more or less isolated prominences, are formed of more durable rocks than are met with in the adjacent lower-lying tracts. Thus the Sidlaws, the Ochil Hills, and the heights in Renfrewshire and Ayrshire, are composed chiefly of more or less hard and tough volcanic rocks; and when sandstones enter into the formation of a line of hills, as in the Sidlaws, they generally owe their preservation to the presence of the volcanic rocks with which they are associated. This is well illustrated by the Lomond Hills in Fifeshire, the basal and larger portion of which consists chiefly of somewhat soft sandstones, which have been protected from erosion by an overlying sheet of hard basalt-rock. All the isolated hills in the basin of the Forth are formed of knobs, bosses, and sheets of various kinds of igneous rock, which are more durable than the sandstones, shales, and other sedimentary strata by which they are surrounded. Hence it is very evident that the configuration of the Lowland tracts of Central Scotland is due to denudation. The softer and more readily disintegrated rocks have been worn away to a greater extent than the harder and less yielding masses.

Only in a few cases do the slopes of the hill-belts coincide with folds of the strata. Thus, the northern flanks of the Sidlaws and the Ochils slope towards the north-west, and this also is the general inclination of the old lavas and other rocks of which those hills are composed. The southern flanks of the same hill-belt slope in Fifeshire towards the south-east – this being also the dip or inclination of the rocks. The crest of the Ochils coincides, therefore, more or less closely, with an anticlinal arch or fold of the strata. But when we follow the axis of this arch towards the north-east into the Sidlaws, we find it broken through by the Tay valley – the axial line running down through the Carse of Gowrie to the north of Dundee. From the fact that many similar anticlinal axes occur throughout the Lowlands, which yet give rise to no corresponding features at the surface, we may conclude that the partial preservation of the anticline of the Ochils and Sidlaws is simply owing to the greater durability of the materials of which those hills consist. Had the arch been composed of sandstones and shales it would most probably have given rise to no such prominent features as are now visible.

Another hilly belt, which at first sight appears to correspond roughly to an anticlinal axis, is that broad tract of igneous rocks which separates the Kilmarnock coal-field from the coal-fields of the Clyde basin. But although the old lavas of that hilly tract slope north-east and south-west, with the same general inclination as the surface, yet examination shows that the hills do not form a true anticline. They are built up of a great variety of ancient lavas and fragmental tuffs or "ashes," which are inclined in many different directions. In short, we have in those hills the degraded and sorely denuded fragments of an ancient volcanic bank, formed by eruptions that began upon the bottom of a shallow sea in early Carboniferous times, and subsequently became sub-aërial. And there is evidence to show that after the eruptions ceased the volcanic bank was slowly submerged, and eventually buried beneath the accumulating sediments of later Carboniferous times. The exposure of the ancient volcanic bank at the surface has been accomplished by the denudation of the stratified masses which formerly covered it, and its existence as a dominant elevation at the present day is solely due to the fact that it is built up of more resistant materials than occur in the adjacent low-lying areas. The Ochils and the Sidlaws are of greater antiquity, but have a somewhat similar history. Into this, however, it is not necessary to go.

The principal hills of the Lowlands form two interrupted belts, extending north-east and south-west, one of them, which we may call the Northern Heights, facing the Highlands, and the other, which may in like manner be termed the Southern Heights, flanking the great Uplands of the south. The former of these two belts is represented by the Garvock Hills, lying between Stonehaven and the valley of the North Esk; the Sidlaws, extending from the neighbourhood of Montrose to the valley of the Tay at Perth; the Ochil Hills, stretching along the south side of the Firth of Tay to the valley of the Forth at Bridge-of-Allan; the Lennox Hills, ranging from the neighbourhood of Stirling to Dumbarton; the Kilbarchan Hills, lying between Greenock and Ardrossan; the Cumbrae Islands and the southern half of Arran; and the same line of heights reappears in the south end of Kintyre. A well-marked hollow, trough, or undulating plain of variable width, separates these Northern Heights from the Highlands, and may be followed all the way from near Stonehaven, through Strathmore, to Crieff and Auchterarder. Between the valleys of the Earn and Teith this plain attains an abnormal height (the Braes of Doune); but from the Teith, south-west by Flanders Moss and the lower end of Loch Lomond to the Clyde at Helensburgh, it resumes its characteristic features. It will be observed also that a hollow separates the southern portion of Arran from the much loftier northern or Highland area. The tract known as the Braes of Doune, extending from Glen Artney south-east to Strath Allan, although abutting upon the Highlands, is clearly marked off from that great division by geological composition and structure, by elevation and configuration. It is simply a less deeply eroded portion of the long trough or hollow.

Passing now to the Southern Heights of the Lowlands, we find that these form a still more interrupted belt than the Northern Heights, and that they are less clearly separated by an intermediate depression from the great Uplands which they flank. They begin in the north-east with the isolated Garleton Hills, between which and the Lammermoors a narrow low-lying trough or hollow appears. A considerable width of low ground now intervenes before we reach the Pentland Hills, which are in like manner separated from the Southern Uplands by a broad low-lying tract. At their southern extremity, however, the Pentlands merge more or less gradually into a somewhat broken and interrupted group of hills which abut abruptly on the Southern Uplands, in the same manner as the Braes of Doune abut upon the slate hills of the Highland borders. In this region the greatest heights reached are in Tinto (2335 feet), and Cairntable (1844 feet), and, at the same time, the hills broaden out towards north-west, where they are continued by the belt of volcanic rocks already described as extending between the coal-fields of the Clyde and Kilmarnock. Although the Southern Heights abut so closely upon the Uplands lying to the south, there is no difficulty in drawing a firm line of demarcation between the two areas – geologically and physically they are readily distinguished. No one with any eye for form, no matter how ignorant he may be of geology, can fail to see how strongly contrasted are such hills as Tinto and Cairntable with those of the Uplands, which they face. The Southern Heights are again interrupted towards the south-east by the valleys of the Ayr and the Doon, but they reappear in the hills that extend from the Heads of Ayr to the valley of the Girvan.

Betwixt the Northern and Southern Heights spread the broad

Lowland tracts that drain towards the Forth, together with the lower reaches of the Clyde valley, and the wide moors that form the water-parting between that river and the estuary of the Forth. The hills that occur within this inner region of the Central Lowlands are usually more or less isolated, and are invariably formed by outcrops of igneous rock. Their outline and general aspect vary according to the geological character of the rocks of which they are composed – some forming more or less prominent escarpments like those of the Bathgate Hills and the heights behind Burntisland and Kinghorn, others showing a soft rounded contour like the Saline Hills in the west of Fifeshire. Of the same general character as this inner Lowland region is the similar tract watered by the Irvine, the Ayr, and the Doon. This tract, as we have seen, is separated from the larger inner region lying to the east by the volcanic hills that extend from the Southern Heights north-west into Renfrewshire.

The largest rivers that traverse the Central Lowlands take their rise, as might be expected, in the mountainous table-lands to the north and south. Of these the principal are the North and South Esks, the Tay and the Isla, the Earn, and the Forth, all of which, with numerous tributaries, descend from the Highlands. And it will be observed that they have breached the line of the Northern Heights in three places – namely, in the neighbourhood of Montrose, Perth, and Stirling.

The only streams of importance coming north from the Southern Uplands are the Clyde and the Doon, both of which in like manner have broken through the Southern Heights. Now, just as the main water-flows of the Highlands indicate the average slope of the ancient land-surface before it was trenched and furrowed by the innumerable valleys that now intersect it, so the direction followed by the greater rivers that traverse the Lowlands mark out the primeval slopes of that area. One sees at a glance, then, that the present configuration of this latter division has been brought about by the erosive action of the principal rivers and their countless affluents, aided by the sub-aërial agents generally – rain, frost, ice, etc. The hills rise above the average level of the ground, not because they have been ridged up from below, but simply owing to the more durable nature of their component rocks. That the Northern and Southern Heights are breached only shows that the low grounds, now separating those heights from the adjacent Highlands and Southern Uplands, formerly stood at a higher level, and so allowed the rivers to make their way more or less directly to the sea. Thus, for example, the long trough of Strathmore has been excavated out of sandstones, the upper surface of which once reached a much greater height, and sloped outwards from the Highlands across what is now the ridge of the Sidlaw Hills. Here then, in the Central Lowlands, as in the Highlands, true mountain- or hill-ranges are absent. But if we are permitted to term any well-marked line or belt of high ground a "range," then the Northern and Southern Heights of the Lowlands are better entitled to be so designated than any series of mountains in the Highlands.

The Southern Uplands. – The northern margin of this wide division having already been defined, we may now proceed to examine the distribution of its mountain-masses. Before doing so, however, it may be as well to point out that considerable tracts in Tweeddale, Teviotdale, and Liddesdale, together with the Cheviot Hills, do not properly belong to the Southern Uplands. In fact, the Cheviots bear the same relation to those Uplands as the Northern Heights do to the Highlands. Like them they are separated by a broad hollow from the Uplands, which they face – a hollow that reaches its greatest extent in Tweeddale, and rapidly wedges out to south-west, where the Cheviots abut abruptly on the Uplands. Even where this abrupt contact takes place, however, the different configuration of the two regions would enable any geologist to separate the one set of mountains from the other. But for geographical purposes we may conveniently disregard these geological contrasts, and include within the Southern Uplands all the area lying between the Central Lowlands and the English Border.

If there are no mountains in the Highlands so grouped and arranged as to be properly termed "ranges," this is not less true of the Southern Uplands. Perhaps it is the appearance which those Uplands present when viewed from the Central Lowlands that first suggested the notion that they were ranges. They seem to rise like a wall out of the low grounds at their base, and extend far as eye can reach in an approximately straight line. It seems more probable, however, that our earlier cartographers merely meant, by their conventional hill-shading, to mark out definitely the water-partings. But to do so in this manner now, when the large contour maps of the Ordnance Survey may be in any one's hands, is inexcusable. A study of those maps, or, better still, a visit to the tops of a few of the dominant points in the area under review, will effectually dispel the idea that the Southern Uplands consist of a series of ridges zigzagging across the country. Like the Highlands, the area of the Southern Uplands is simply an old table-land, furrowed into ravine and valley by the operation of the various agents of erosion.

Beginning our survey of these Uplands in the east, we encounter first the Lammermoor Hills – a broad undulating plateau – the highest elevations of which do not reach 2000 feet. West of this come the Moorfoot Hills and the high grounds lying between the Gala and the Tweed – a tract which averages a somewhat higher elevation – two points exceeding 2000 feet in height. The next group of mountains we meet is that of the Moffat Hills, in which head a number of important rivers – the Tweed, the Yarrow, the Ettrick, and the Annan. Many points in this region exceed 2000 feet, others approach 2500 feet; and some reach nearly 3000 feet, such as Broad Law (2754 feet), and Dollar Law (2680 feet). In the south-west comes the group of the Lowthers, with dominant elevations of more than 2000 feet. Then follow the mountain-masses in which the Nith, the Ken, the Cree, the Doon, and the Girvan take their rise, many of the heights exceeding 2000 feet, and a number reaching and even passing 2500 feet, the dominant point being reached in the noble mountain-mass of the Merrick (2764 feet). In the extreme south-west the Uplands terminate in a broad undulating plateau, of which the highest point is but little over 1000 feet. All the mountain-groups now referred to are massed along the northern borders of the Southern Uplands. In the south-west the general surface falls more or less gradually away towards the Solway – the 500 feet contour line being reached at fifteen miles, upon an average, from the sea-coast. In the extreme north-east the high grounds descend in like manner into the rich low grounds of the Merse. Between these low grounds and Annandale, however, the Uplands merge, as it were, into the broad elevated moory tract that extends south-east, to unite with the Cheviots – a belt of hills rising along the English Border to heights of 1964 feet (Peel Fell), and 2676 feet (the Cheviot).

The general configuration of the main mass of the Southern Uplands – that is to say, the mountain-groups extending along the northern portion of the area under review, from Loch Ryan to the coast between Dunbar and St. Abb's Head – is somewhat tame and monotonous. The mountains are flat-topped elevations, with broad, rounded shoulders and smooth grassy slopes. Standing on the summits of the Higher hills, one seems to be in the midst of a wide, gently undulating plain, the surface of which is not broken by the appearance of any isolated peaks or eminences. Struggling across the bogs and peat-mosses that cover so many of those flat-topped mountains, the wanderer ever and anon suddenly finds himself on the brink of a deep green dale. He discovers, in short, that he is traversing an elevated undulating table-land, intersected by narrow and broad trench-like valleys that radiate outwards in all directions from the dominant bosses and swellings of the plateau. The mountains, therefore, are merely broad ridges and banks separating contiguous valleys; in a word, they are, like the mountains of the Highlands, monuments of erosion, which do not run in linear directions, but form irregular groups and masses.

The rocks that enter into the formation of this portion of the Southern Uplands have much the same character throughout. Consequently there is less variety of contour and colour than in the Highlands. The hills are not only flatter atop, but are much smoother in outline, there being a general absence of those beetling crags and precipices which are so common in the Highland regions. Now and again, however, the mountains assume a rougher aspect. This is especially the case with those of Carrick and Galloway, amongst which we encounter a wildness and grandeur which are in striking contrast to the gentle pastoral character of the Lowthers and similar tracts extending along the northern and higher parts of the Southern Uplands. Descending to details, the geologist can observe also modifications of contour even among those monotonous rounded hills. Such modifications are due to differences in the character of the component rocks, but they are rarely so striking as the modifications that arise from the same cause in the Highlands. To the trained eye, however, they are sufficiently manifest, and upon a geologically coloured map, which shows the various belts of rock that traverse the Uplands from south-west to north-east, it will be found that the mountains occurring within each of those separate belts have certain distinctive features. Such features, however, cannot be depicted upon a small orographical map. The separation of those mountains into distinct ranges, by reference to their physical aspect, is even less possible here than in the Highlands. Now and again, bands of certain rocks, which are of a more durable character than the other strata in their neighbourhood, give rise to pronounced ridges and banks, while hollows and valleys occasionally coincide more or less closely with the outcrops of the more readily eroded strata; but such features are mere minor details in the general configuration of the country. The courses of brooks and streams may have been frequently determined by the nature and arrangement of the rocks, but the general slope of the Uplands and the direction of the main lines of water-flow are at right angles to the trend of the strata, and cannot therefore have been determined in that way. The strata generally are inclined at high angles – they occur, in short, as a series of great anticlinal arches and synclinal curves, but the tops of the grand folds have been planed off, and the axes of the synclinal troughs, so far from coinciding with valleys, very often run along the tops of the highest hills. The foldings and plications do not, in a word, produce any corresponding undulations of the surface.

Mention has been made of the elevated moory tracts that serve to connect the Cheviots with the loftier Uplands lying to north-west. The configuration of these moors is tamer even than that of the regions just described, but the same general form prevails from the neighbourhood of the Moffat Hills to the head-waters of the Teviot. There, however, other varieties of rock appear, and produce corresponding changes in the aspect of the high grounds. Not a few of the hills in this district stand out prominently. They are more or less pyramidal and conical in shape, being built up of sandstones often crowned atop with a capping of some crystalline igneous rock, such as basalt. The Maiden Paps, Leap Hill, Needs Law, and others are examples. The heights draining towards Liddesdale and lower reaches of Eskdale, composed chiefly of sandstones, with here and there intercalated sheets of harder igneous rock, frequently show escarpments and terraced outlines, but have a general undulating contour; and similar features are characteristic of the sandstone mountains that form the south-west portion of the Cheviots. Towards the north-east, however, the sandstones give place to various igneous rocks, so that the hills in the north-east section of the Cheviots differ very much in aspect and configuration from those at the other extremity of the belt. They have a more varied and broken outline, closely resembling many parts of the Ochils and other portions of the Northern and Southern Heights of the Central Lowlands.

The low-lying tracts of Roxburghshire and the Merse, in like manner, present features which are common to the inner region of the Central Lowlands. Occasional ridges of hills rise above the general level of the land, as at Smailholm and Stitchell to the north of Kelso, while isolated knolls and prominences – some bald and abrupt, others smooth and rounded – help to diversify the surface. Bonchester Hill, Rubers Law, the Dunian, Penielheugh, Minto Hills, and the Eildons may be mentioned as examples. All of these are of igneous origin, some being mere caps of basalt resting upon a foundation of sandstone, while others are the stumps of isolated volcanoes.

In the maritime tracts of Galloway the low grounds repeat, on a smaller scale, the configuration of the lofty Uplands behind, for they are composed of the same kinds of rock. Their most remarkable feature is the heavy mountain-mass of Criffel, rising near the mouth of the Nith to a height of 1800 feet.

Everywhere, therefore, throughout the region of the Southern Uplands, in hilly and low-lying tracts alike, we see that the land has been modelled and contoured by the agents of erosion. We are dealing, as in the Highlands, with an old table-land, in which valleys have been excavated by running water and its helpmates. Nowhere do we encounter any linear banks, ridges, or ranges as we find described in the class-books, and represented upon many general maps of the country. In one of those manuals we read that in the southern district "the principal range of mountains is that known as the Lowther Hills, which springs off from the Cheviots, and, running in a zigzag direction to the south-west, terminates on the west coast near Loch Ryan." This is quite true, according to many common maps, but unfortunately the "range" exists upon those maps and nowhere else. The zigzag line described is not a range of mountains, but a water-parting, which is quite another matter.

The table-land of the Southern Uplands, like that of the Highlands, is of immense antiquity. Long before the Old Red Sandstone period, it had been furrowed and trenched by running water. Of the original contour of its surface, all we can say is that it formed an undulating plateau, the general slope of which was towards south-east. This is shown by the trend of the more important rivers, such as the Nith and the Annan, the Gala and the Leader; and by the distribution of the various strata pertaining to the Old Red Sandstone and later geological periods. Thus, strata of Old Red Sandstone and Carboniferous age occupy the Merse and the lower reaches of Teviotdale, and extend up the valleys of the Whiteadder and the Leader into the heart of the Silurian Uplands. In like manner Permian sandstones are well developed in the ancient hollows of Annandale and Nithsdale. Along the northern borders of the Southern Uplands we meet with similar evidence to show that even as early as Old Red Sandstone times the old plateau, along what is now its northern margin, was penetrated by valleys that drained towards the north. The main drainage, however, then as now, was directed towards south-east.

Many geological facts conspire to show that the Silurian table-land of these Uplands has been submerged, like the Highlands, in whole or in part. This happened at various periods, and each time the land went down it received a covering of newer accumulations

– patches of which still remain to testify to the former extent of the submergences. From the higher portions of the Uplands those accumulations have been almost wholly swept away, but they have not been entirely cleared out of the ancient valleys. They still mantle the borders of the Silurian area, particularly in the north-east, where they attain a great thickness in the moors of Liddesdale and the Cheviot Hills. The details of the evolution of the whole area of the Southern Uplands form an interesting study, but this pertains rather to Geology than to Physical Geography. It is enough, from our present point of view, to be assured that the main features of the country were chalked out, as it were, at a very distant geological period, and that all the infinite variety in the relief of our land has been brought about directly, not by titanic convulsions and earth-movements, but by the long-continued working of rain and rivers – of frost and snow and ice, supplemented from time to time by the action of the sea.

The physical features more particularly referred to in this paper are of course only the bolder and more prominent contours – those namely which can be expressed with sufficient accuracy upon sheets of such a size as the accompanying orographical map of Scotland (Plate I.). With larger maps considerably more detail can be added, and many characteristic and distinguishing features will appear according to the care with which such maps are drawn. In the case of the Ordnance Survey map, on the scale of 1 inch to a mile, the varying forms of the surface are so faithfully delineated as frequently to indicate to a trained observer the nature of the rocks and the geological structure of the ground. The artists who sketched the hills must indeed have had good eyes for form. So carefully has their work been done, that it is often not difficult to distinguish upon their maps hills formed of such rocks as sandstone from those that are composed of more durable kinds. The individual characteristics of mountains of schist, of granite, of quartz-rock, of slate, are often well depicted: nay, even the varieties of igneous rock which enter into the formation of the numerous hills and knolls of the Lowlands can frequently be detected by the features which the artists have so intelligently caught. Another set of features which their maps display are those due to glaciation. These are admirably brought out, even down to the smallest details. A glance at such maps as those of Teviotdale and the Merse, for example, shows at once the direction taken by the old *mer de glace*. The long parallel flutings of the hill-slopes, *roches moutonnées*, projecting knolls and hills with their "tails," the great series of banks and ridges of stony clay which trend down the valley of the Tweed – these, and many more details of interest to specialists, are shown upon the maps. All over Scotland similar phenomena are common, and have been reproduced with marvellous skill on the shaded sheets issued by the Ordnance Survey. And yet the artists were not geologists. The present writer is glad of this opportunity of recording his obligations to those gentlemen. Their faithful delineations of physical features have given him many valuable suggestions, and have led up to certain observations which might otherwise not have been made.

III.
Mountains: Their Origin, Growth, and Decay. [4]

Mountains have long had a fascination for lovers of nature. Time was, however, when most civilised folk looked upon them with feelings akin to horror; and good people, indeed, have written books to show that they are the cursed places of the earth – the ruin and desolation of their gorges and defiles affording indubitable proof of the evils which befell the world when man lapsed from his primitive state of innocence and purity. All this has changed. It is the fashion now to offer a kind of worship to mountains; and every year their solitudes are invaded by devotees – some, according to worthy Meg Dods, "rinning up hill and down dale, knapping the chuckie-stanes to pieces wi' hammers, like sae mony roadmakers run daft – to see, as they say, how the warld was made" – others trying to transfer some of the beauty around them to paper or canvas – yet others, and these perhaps not the least wise, content, as old Sir Thomas Browne has it, "to stare about with a gross rusticity," and humbly thankful that they are beyond the reach of telegrams, and see nothing to remind them of the *fumun et opes strepitumque Romæ*.

[4] *Scottish Geographical Magazine*, vol. ii., 1886.

But if the sentiment with which mountains are regarded has greatly changed, so likewise have the views of scientific men as to their origin and history. Years ago no one doubted that all mountains were simply the result of titanic convulsions. The crust of the earth had been pushed up from below, tossed into great billows, shivered and shattered – the mountains corresponding to the crests of huge earth-waves, the valleys to the intervening depressions, or to gaping fractures and dislocations. This view of the origin of mountains has always appeared reasonable to those who do not know what is meant by geological structure, and in some cases it is pretty near the truth. A true mountain-chain, like that of the Alps, does indeed owe its origin to gigantic disturbances of the earth's crust, and in such a region the larger features of the surface often correspond more or less closely with the inclination of the underlying rocks. But in many elevated tracts, composed of highly disturbed and convoluted strata, no such coincidence of surface-features and underground structure can be traced. The mountains do not correspond to great swellings of the crust – the valleys neither lie in trough-shaped strata, nor do they coincide with gaping fractures. Again, many considerable mountains are built up of rocks which have not been convoluted at all, but occur in approximately horizontal beds. Evidently, therefore, some force other than subterranean action must be called upon to explain the origin of many of the most striking surface-features of the land.

Every geologist admits – it is one of the truisms of his science

– that corrugations and plications are the result of subterranean action. Nor does any one deny that when a true mountain-chain was first upheaved the greater undulations of the folded strata probably gave rise to similar undulations at the surface. Some of the larger fractures and dislocations might also have appeared at the surface and produced mural precipices. So long a time, however, has elapsed since the elevation of even the youngest mountain-chains of the globe that the sub-aërial agents of erosion – rain, frost, rivers, glaciers, etc. – have been enabled greatly to modify their primeval features. For these mountains, therefore, it is only partially true that their present slopes coincide with those of the underlying strata. Such being the case with so young a chain as the Alps, we need not be surprised to meet with modifications on a still grander scale in mountain-regions of much greater antiquity. In many such tracts the primeval configuration due to subterranean action has been entirely remodelled, so that hills now stand where deep hollows formerly existed, while valleys frequently have replaced mountains. And this newer configuration is the direct result of erosion, guided by the mineralogical composition and structural peculiarities of the rocks.

It is difficult, or even impossible, for one who is ignorant of geological structure to realise that the apparently insignificant agents of erosion have played so important a *rôle* in the evolution of notable earth-features. It may be well, therefore, to illustrate the matter by reference to one or two regions where the geological structure is too simple to be misunderstood. The first examples I shall give are from tracts of horizontal strata. Many readers are doubtless aware of the fact that our rock-masses consist for the most part of the more or less indurated and compacted sediments of former rivers, lakes, and seas. Frequently those ancient water-formed rocks have been very much altered, so as even sometimes to acquire a crystalline character. But it is enough for us now to remember that the crust of the globe, so far as that is accessible to observation, is built up mostly of rocks which were originally accumulated as aqueous sediments. Such being the case, it is obvious that our strata of sandstone, conglomerate, shale, limestone, etc., must at first have been spread out in approximately horizontal or gently inclined sheets or layers. We judge so from what we know of sediments which are accumulating at present. The wide flats of our river valleys, the broad plains that occupy the sites of silted-up lakes, the extensive deltas of such rivers as the Nile and the Po, the narrow and wide belts of low-lying land which within a recent period have been gained from the sea, are all made up of various kinds of sediment arranged in approximately horizontal layers. Now, over wide regions of the earth's surface the sedimentary strata still lie horizontally, and we can often tell at what geological period they became converted into dry land. Thus, for example, we know that the elevated plateau through which the river Colorado flows is built up of a great series of nearly horizontal beds of various sedimentary deposits, which reach a thickness of many thousand feet. It is self-evident that the youngest strata must be those which occur at the surface of the plateau, and they, as we know, are of lacustrine origin and belong to the Tertiary period. Now, American geologists have shown that since that period several thousands of feet of rock-materials have been removed from the surface of that plateau – the thickness of rock so carried away amounting in some places to nearly 10,000 feet. Yet all that prodigious erosion has been effected since early Tertiary times. Indeed, it can be proved that the excavation of the Grand Ca¤on of the Colorado, probably the most remarkable river-trench in the world, has been accomplished since the close of the Tertiary period, and is therefore a work of more recent date than the last great upheaval of the Swiss Alps. The origin of the ca¤on is self-evident – it is a magnificent example of river-erosion, and the mere statement of its dimensions gives one a forcible impression of the potency of sub-aërial denudation. The river-cutting is about 300 miles long, 11 or 12 miles broad, and varies from 3000 to 6000 feet in depth.

Take another example of what denuding agents have done within a recent geological period. The Faröe Islands, some twenty in number, extend over an area measuring about 70 miles from south to north, and nearly 50 miles from west to east. These islands are composed of volcanic rocks – beds of basalt with intervening layers of fine fragmental materials, and are obviously the relics of what formerly was one continuous plateau, deeply trenched by valleys running in various directions.

Subsequent depression of the land introduced the sea to these valleys, and the plateau was then converted into a group of islands, separated from each other by narrow sounds and fiords. Were the great plateau through which the Colorado flows to be partially submerged, it would reproduce on a larger scale the general phenomena presented by this lonely island-group of the North Atlantic. The flat-topped "buttes" and "mesas," and the pyramidal mountains of the Colorado district would form islands comparable to those of the Faröes. Most of the latter attain a considerable elevation above the sea – heights of 1700, 2000, 2500, and 2850 feet being met with in several of the islands. Indeed, the average elevation of the land in this northern archipelago can hardly be less than 900 feet. The deep trench-like valleys are evidently only the upper reaches of valleys which began to be excavated when the islands formed part and parcel of one and the same plateau – the lower reaches being now occupied by fiords and sounds. It is quite certain that all these valleys are the work of erosion. One can trace the beds of basalt continuously across the bottoms, and be quite sure that the valleys are not gaping cracks or fractures. Now, as the strata are approximately horizontal, it is obvious that the hollows of the surface have nothing whatever to do with undulations produced by earth-movements. The sub-aërial erosion of the islands has resulted in the development of massive flat-topped and pyramidal mountains. These stand up as eminences simply because the rock-material which once surrounded them has been gradually broken up and carried away. Nothing can well be more impressive to the student of physical geology than the aspect presented by these relics of an ancient plateau. Standing on some commanding elevation, such as Nakkin in Suderöe, one sees rising before him great truncated pyramids – built up of horizontal beds of basalt rising tier above tier – the mountains being separated from each other by wide and profound hollows, across which the basalt-beds were once continuous. Owing to the parallel and undisturbed position of the strata, it is not hard to form an estimate of the amount of material which has been removed during the gradual excavation of the valleys. In order to do so we have simply to measure the width, depth, and length of the valleys. Thus in Suderöe, which is 19 miles long and 6 miles broad, the bottoms of the valleys are 1000 feet at least below the tops of the mountains, and some of the hollows in question are a mile in width. Now, the amount of rock worn away from this one little island by sub-aërial erosion cannot be less than that of a mass measuring 10 miles in length by 6 miles in breadth, and 800 feet in thickness. And yet the Faröe Islands are composed of rocks which had no existence when the soft clays, etc., of the London Basin were being accumulated. All the erosion referred to has taken place since the great upheaval of the Eocene strata of the Swiss Alps.

But if the evidence of erosion be so conspicuous in regions composed of horizontal strata, it is not less so in countries where the rocks are inclined at various angles to the horizon. Indeed, the very fact that inclined strata crop out at the surface is sufficient evidence of erosion. For it is obvious that these outcrops are merely the truncated ends of beds which must formerly have had a wider extension. But while the effects produced by the erosion of horizontal strata are readily perceived by the least-informed observer, it requires some knowledge of geological structure to appreciate the denudation of curved or undulating strata. And yet there is really no mystery in the matter. All we have to do is by careful observation to ascertain the mode of arrangement of the rocks – this accomplished, we have no difficulty in estimating the minimum erosion which any set of strata may have experienced. An illustration may serve to make this plain. Here, for example, is a section across a region of undulating strata. Let the line *A B* represent the surface of the ground, and *C D* be any datum line – say, the sea-level. An observer at *A*, who should walk in the direction of *B*, would cross successively eight outcrops of coal; and, were he incapable of reading the geological structure of the ground, he might imagine that he had come upon eight separate coal-seams. A glance at the section, however, shows that in reality he had met with only two coals, and that the deceptive appearances, which might be misread by an incautious observer, are simply the result of denudation. In this case the tops of a series of curved or arched beds have been removed (as at *E*), and, by protracting the lines of the truncated beds until they meet, we can estimate the minimum amount of erosion they have sustained. Thus, if the strata between *o* and *p* be 300 feet thick, it is self-evident that a somewhat greater thickness of rock must have been removed from the top of the anticlinal arch or "saddleback" at *E*.

Again, let us draw a section across strata which have been fractured and dislocated, and we shall see how such fractures likewise enable us to estimate the minimum amount of erosion which certain regions have experienced. In we have a series of strata containing a bed of limestone *L*, and a coal-seam *a*. The present surface of the ground is represented by the line *A B*. At *F* the strata are traversed by a fault or dislocation – the beds being thrown down for say 500 feet on the low side of the fault – so that the coal at a^2 occurs now at a depth of 500 feet below its continuation at a^1. At the surface of the ground there is no inequality of level – the beds overlying the coal (a^2) having been removed by denudation. Were the missing rocks to be replaced, they would occupy the space contained within the dotted lines above the present surface *A B*. Such dislocations are of common occurrence in our coal-fields, and it is not often that they give rise to any features at the surface. We may thus traverse many level or gently-undulating tracts, and be quite unconscious of the fact that geologically we have frequently leaped up or dropped down for hundreds of feet in a single step. Nay, some Scottish streams and rivers flow across dislocations by which the strata have been shifted up or down for thousands of feet, and in some places one can have the satisfaction of sitting upon rocks which are geologically 3000 yards below or above those on which he rests his feet. In other words, thousands of feet of strata have been removed by denudation from the high sides of faults. These, as I have said, often give rise to no feature at the surface; but, occasionally, when "soft" rocks have been shifted by dislocations, and brought against "hard" rocks, the latter, by better resisting denudation than the former, cause a more or less well-marked feature at the surface, and thus betray the presence of a fault to the geologist. The phenomena presented by faults, therefore, are just as eloquent of denudation as is the truncated appearance of our strata; and only after we have carefully examined the present extension and mutual relations of our rock-masses, their varied inclination, and the size of the dislocations by which they are traversed, can we properly appreciate the degree of erosion which they have sustained. Before we are entitled to express any opinion as to the origin of the surface-features of a country, we must first know its geological structure. Until we have attained such knowledge, all our views as to the origin of mountains are of less value than the paper they are written upon.

I have spoken of the evidence of denudation which we find in our truncated and dislocated rock-masses; there is yet another line of evidence which I may very shortly point out. As every one knows, there exist in this and many other countries enormous masses of igneous rocks, which have certainly been extruded from below. Now, some of these rocks, such as granite, belong to what is called the *plutonic* class of rocks; they are of deep-seated origin – that is to say, they never were erupted at the surface, but cooled and consolidated at great depths in the earth's crust. I need not go into any detail to show that this is the case – it is a conclusion based upon incontrovertible facts, and accepted by every practical geologist. When, therefore, we encounter at the actual surface of the earth great mountain-masses of granite, we know that in such regions enormous denudation has taken place. The granite appears at the surface simply because the thick rock-masses under which it solidified have been gradually removed by erosion.

The facts which I have now briefly passed in review must convince us that erosion is one of the most potent factors with which the geologist has to deal. We have seen what it has been able to effect in certain tracts composed of strata which date back to a recent geological period, such as the plateau of the Colorado and the pyramidal mountains of the Faröe Islands. If in regions built up of strata so young as the rocks of those tracts the amount of erosion be so great, we may well expect to meet with evidence of much more extensive denudation in regions which have been subjected for enormously longer periods to the action of the eroding agents.

The study of geological structure, or the architecture of the earth's crust, has enabled us to group all mountains under these three principal heads: —

1. *Mountains of Accumulation*

2. *Mountains of Elevation*

3. *Mountains of Circumdenudation*

1. Mountains of Accumulation. – Volcanoes may be taken as the type of this class of mountains. These are, of course, formed by the accumulation of igneous materials around the focus or foci of eruption, and their mode of origin is so generally understood, and, indeed, so obvious, that I need do no more than mention them. Of course, they are all subject to erosion, and many long-extinct volcanoes are highly denuded. Some very ancient ones, as those of our own country, have been so demolished that frequently all that remains are the now plugged-up pipes or flues through which the heated materials found a passage to the surface – all those materials, consisting of lavas and ashes, having in many cases entirely disappeared. In former times volcanic eruptions often took place along the line of an extensive fissure – the lava, instead of being extruded at one or more points, welled-up and overflowed along the whole length of the fissure, so as to flood the surrounding regions. And this happening again and

again, vast plateaux of igneous rock came to be built up, such as those of the Rocky Mountains, Iceland, the Faröes, Antrim and Mull, Abyssinia and the Deccan. These are called *plateaux of accumulation*, and all of them are more or less highly denuded, so that in many cases the plateaux have quite a mountainous appearance. Of course, plateaux of accumulation are not always formed of igneous rocks. Any area of approximately horizontal strata of aqueous origin, rising to a height of a thousand feet or more above the sea, would come under this class of plateau – the plateau of the Colorado being a good example. Although that plateau is of recent origin, yet its surface, as we have seen, has been profoundly modified by superficial erosion; and this is true to a greater extent of plateaux which have been much longer exposed to denudation. It is obvious that even mountains and plateaux of accumulation often owe many of their present features to the action of the surface-agents of change.

2. Mountains of Elevation. – We have seen that the strata which enter most largely into the composition of the earth's crust, so far as that is open to observation, consist of rocks which must originally have been disposed in horizontal or approximately horizontal layers. But, as every one knows, the stratified rocks are not always horizontally arranged. In Scotland they rarely are so. On the contrary, they are inclined at all angles from the horizon, and not infrequently they even stand on end. Moreover, they are often traversed by dislocations, large and small. No one doubts that these tilted and disturbed rocks

are evidence of wide-spread earth-movements. And it has been long known to geologists that such movements have happened again and again in this and many other countries where similar disturbed strata occur. Some of these movements, resulting in the upheaval of enormous mountain-masses, have taken place within comparatively recent geological times. Others again date back to periods inconceivably remote. The Pyrenees, the Alps, the Caucasus, the Himalaya, which form the back-bone of Eurasia, are among the youngest mountains of the globe. The Highlands of Scotland and Scandinavia are immeasurably more ancient; they are, in point of fact, the oldest high grounds in Europe, nor are there any mountain-masses elsewhere which can be shown to be older. But while the Alps and other recent mountains of elevation still retain much of their original configuration, not a vestige of the primeval configuration of our own Highlands has been preserved; their present surface-features have no direct connection with those which must have distinguished them in late Silurian times. Our existing mountains are not, like those of the Alps, mountains of elevation.

The structure of a true mountain-chain is frequently very complicated, but the general phenomena can be readily expressed in a simple diagram. Let be a section taken across a mountain-chain, *i. e.* at right angles to its trend or direction. The dominant point of the chain is shown at *B*, while *A* and *C* represent the low grounds. Now, an observer at *A*, advancing towards *B*, would note that the strata, at first horizontal, would gradually become undulating as he proceeded on his way – the undulations getting always more and more pronounced. He would observe, moreover, that the undulations, at first symmetrical, as at *a*, would become less so as he advanced – one limb of an arch or *anticline*, as it is termed, being inclined at a greater angle than the other, as at *b*. Approaching still nearer to **B**, the arches or anticlines would be seen eventually to bend over upon each other, so as to produce a general dip or inclination of the strata towards the central axis of the chain. Crossing that axis (*B*), and walking in the direction of the low grounds (*C*), the observer would again encounter the same structural arrangement, but of course in reverse order. Thus, in its simplest expression, a true mountain-chain consists of strata arranged in a series of parallel undulations – the greater mountain ridges and intervening hollows corresponding more or less closely to the larger undulations and folds of the strata. Now, could these plicated strata be pulled out, could the folds and reduplications be smoothed away, so as to cause the strata to assume their original horizontal position, it is obvious that the rocks would occupy a greater superficial area. We see, then, that such a mountain-chain must owe its origin to a process of tangential or lateral thrusting and crushing. The originally horizontal strata have been squeezed laterally, and have yielded to the force acting upon them by folding and doubling up. It seems most probable that the larger contortions and foldings which are visible in all true mountain-chains, owe their origin to the sinking down of the earth's crust upon the cooling and contracting nucleus. During such depressions of the crust the strata are necessarily subjected to enormous lateral compression; they are forced to occupy less space at the surface, and this they can only do by folding and doubling-back upon themselves. If the strata are equally unyielding throughout a wide area, then general undulation may ensue; but should they yield unequally, then folding and contortion will take place along one or more lines of weakness. In other words, the pressure will be relieved by the formation of true mountain-chains. Thus, paradoxical as it may seem, the loftiest mountains of the globe bear witness to profound depression or subsidence of the crust. The Andes, for example, appear to owe their origin to the sinking down of the earth's crust under the Pacific; and so in like manner the Alps would seem to have been ridged up by depression of the crust in the area of the Mediterranean. Mountain-chains, therefore, are true wrinkles in the crust of the earth; they are lines of weakness along which the strata have yielded to enormous lateral pressure.

A glance at the geological structure of the Alps and the Jura shows us that these mountains are a typical example of such a chain; they are mountains of elevation. In the Jura the mountains form a series of long parallel ridges separated by intervening hollows; and the form or shape of the ground coincides in a striking manner with the foldings of the strata. In these mountains we see a succession of symmetrical flexures, the beds dipping in opposite directions at the same angle from the axis of each individual anticline. There each mountain-ridge corresponds to an *anticline*, and each valley to a *syncline*, or trough-shaped arrangement of strata. But as we approach the Alps the flexures become less and less symmetrical, until in the Alps themselves the most extraordinary convolutions and intricate plications appear, the strata being often reversed or turned completely upside down.

Though it is true that the slopes of this great mountain-chain not infrequently correspond more or less closely to the slope or inclination of the underlying rocks, it must not be supposed that this correspondence is often complete. Sometimes, indeed, we find that the mountains, so far from coinciding with anticlines, are in reality built up of synclinal or basin-shaped strata; while in other cases deep and broad valleys run along the lines of anticlinal axes. All this speaks to enormous erosion. A study of the geological structure of the Alps demonstrates that thousands of feet of rock have been removed from those mountains since the time of their elevation. A section drawn across any part of the chain would show that the strata have been eroded to such an extent, and the whole configuration so profoundly modified, that it is often difficult, or even impossible, to tell what may have been the original form of the surface when the chain was upheaved. And yet the Alps, it must be remembered, are of comparatively recent age, some of their highly-confused and contorted rocks consisting of marine strata which are of no greater antiquity than the incoherent clays and sands of the London Tertiary basin.

Now, when we reflect upon the fact that, in the case of so young a mountain-chain, the configuration due to undulations of the strata has been so greatly modified, and even in many places obliterated, it is not hard to believe that after sufficient time has elapsed – after the Alps have existed for as long a period, say, as the mountains of middle Germany – every mountain formed of anticlinal strata shall have disappeared, and those synclines which now coincide with valleys shall have developed into hills. The reader who may have paid little or no attention to geological structure and its influence upon the form of the ground, will probably think this a strange and extravagant statement; yet I hope to show presently that it is supported by all that we know of regions of folded strata which have been for long periods of time subjected to denudation.

3. Mountains of Circumdenudation. – In countries composed of undulating and folded strata which have been for long ages exposed to the action of eroding agents, the ultimate form assumed by the ground is directly dependent on the character of the rocks, and the mode of their arrangement. The various rock-masses which occur in such a neighbourhood as Edinburgh, for example, differ considerably in their power of resisting denudation. Hence the less readily eroded rocks have come in time to form hills of less or greater prominence. Such is the case with the Castle Rock, Corstorphine Hill, the Braids, the Pentlands, etc. These hills owe their existence, as such, to the fact that they are composed of more enduring kinds of rock than

the softer sandstones and shales by which they are surrounded, and underneath which they were formerly buried to great depths. Some hills, again, which are for the most part built up of rocks having the same character as the strata that occur in the adjacent low grounds, stand up as prominences simply because they have been preserved by overlying caps or coverings of harder rocks – rocks which have offered a stronger resistance to the action of the denuding agents. The Lomond Hills are good examples. Those hills consist chiefly of sandstones which have been preserved from demolition by an overlying sheet of basalt-rock.

But the mode in which rocks are arranged is a not less important factor in determining the shape which the ground assumes under the action of the agents of erosion. Thus, as we have already seen, flat-topped, pyramidal mountains, and more or less steep-sided or trench-like valleys, are characteristic features in regions of horizontal strata. When strata dip or incline in one general direction, then we have a succession of escarpments or dip-slopes, corresponding to the outcrops of harder or less readily eroded beds, and separated from each other by long valleys, hollows, or undulating plains, which have the same trend as the escarpments. This kind of configuration is well exemplified over a large part of England. The general dip or inclination of the Mesozoic or Secondary strata throughout that country, between the shores of the North Sea and the English Channel, is easterly and south-easterly – so that the outcrops of the more durable strata form well-defined escarpments that face the west and north-west, and can be followed almost continuously from north to south. Passing from the Malvern Hills in a south-easterly direction, we traverse two great escarpments – the first coinciding with the outcrop of the Oolite, and forming the Cotswold Hills; and the second corresponding to the outcrop of the Chalk, and forming the Chiltern Hills. The plains and low undulating tracts that separate these escarpments mark the outcrops of more yielding strata – the low grounds that intervene between the Cotswolds and the Malvern Hills being composed of Liassic and Triassic clays and sandstones. In Scotland similar escarpments occur, but owing to sudden changes of the dip, and various interruptions of the strata, the Scottish escarpments are not so continuous as those of the sister-country. Many of the belts of hilly ground in the Scottish Lowlands, however, exemplify the phenomena of escarpment and dip-slope. Thus, the Sidlaws in Forfarshire consist of a series of hard igneous rocks and interbedded sandstones and flags – the outcrops of which form a succession of escarpments with intervening hollows. The same appearances recur again and again all over the Lowlands. Wherever, indeed, any considerable bed of hard rock occurs in a series of less enduring strata – the outcrop of the harder rock invariably forms a well-marked feature or escarpment. As examples, I may refer to Salisbury Crags, Craiglockhart Hill, Dalmahoy Crags, the Bathgate Hills, King Alexander's Crag, etc. All these are conspicuous examples of the work of denudation – for it can be demonstrated that each of these rock-masses was at one time deeply buried under sandstones and shales, and they now crop out at the surface, and form prominent features simply because the beds which formerly covered and surrounded them have been gradually removed.

From what has now been said it will be readily understood that in regions composed of strata the inclination or dip of which is not constant but continually changing in direction, the surface-features must be more or less irregular. If the strata dip east the outcrops of the harder beds will form escarpments facing the west, and the direction of the escarpments will obviously change with the direction of the dip. Undulating strata of variable composition will, in short, give rise to an undulating surface, but the superficial undulations will not coincide with those of the strata. On the contrary, in regions consisting of undulating strata of diverse consistency the hills generally correspond with synclinal troughs – or, in other words, trough-shaped strata tend to form hills; while, on the other hand, arch-shaped or anticlinal strata most usually give rise to hollows. This remarkable fact is one of the first to arrest the attention of every student of physical geology, and its explanation is simple enough. An anticlinal arrangement of strata is a weak structure – it readily succumbs to the attacks of the denuding agents; a synclinal arrangement on the contrary, is a strong structure, which is much less readily broken up. Hence it is that in all regions which have been exposed for prolonged periods to sub-aërial denudation synclinal strata naturally come to form hills, and anticlinal strata valleys or low grounds. In the case of a mountain-chain so recently elevated as that of the Alps, the mountain-ridges, as we have seen, often coincide roughly with the greater folds of the strata. Such anticlinal mountains are weakly built, and consequently rock-falls and landslips are of common occurrence among them – far more common, and on a much larger scale, than among the immeasurably older mountains of Scandinavia and Scotland. The valleys of the Pyrenees, the Alps, and the Apennines, are cumbered with enormous chaotic heaps of fallen rock-masses. From time to time peaks and whole mountain-sides give way, and slide into the valleys, burying hamlets and villages, and covering wide tracts of cultivated land. Hundreds of such disastrous rock-falls have occurred in the Alps within historical ages, and must continue to take place until every weakly-formed mountain has been demolished. The hills and mountains of Scotland have long since passed through this phase of unstable equilibrium. After countless ages of erosion our higher grounds have acquired a configuration essentially different from that of a true mountain-chain. Enormous landslips like that of the Rossberg are here impossible, for all such weakly-constructed mountains have disappeared.

A little consideration will serve to show how such modifications and changes have come about. When strata are crumpled up they naturally crack across, for they are not elastic. During the great movements which have originated all mountains of elevation, it is evident that the strata forming the actual surface of the ground would often be greatly fissured and shattered along the crests of the sharper anticlinal ridges. In the synclinal troughs, however, although much fissuring would take place, yet the strata would be compelled by the pressure to keep together. Now, when we study the structure of such a region as the Alps, we find that the tops of the anticlines have almost invariably been removed, so as to expose the truncated ends of the strata – the ruptured and shattered rock-masses having in the course of time been carried away by the agents of erosion. Such mountains are pre-eminently weak structures. Let us suppose that the mountains represented in the diagram consist of a succession of strata, some of which are more or less permeable by water, while others are practically impermeable. It is obvious that water soaking down from the surface will find its way through the porous strata (*p*), and come out on the slopes of the mountains along the joints and cracks (*c*) by which all strata are traversed. Under the influence of such springs and the action of frost, the rock at the surface will eventually be broken up, and ever and anon larger and smaller portions will slide downwards over the surface of the underlying impermeable stratum. The undermining action of rivers will greatly intensify this disintegrating and disrupting process. As the river deepens and widens its valley (*v*), it is apparent that in doing so it must truncate the strata that are inclined towards it. The beds will then crop out upon the slopes of the valley (as at *b*, *b*), and so the conditions most favourable for a landslip will arise. Underground water, percolating through the porous beds (p), and over the surface of the underlying impermeable beds (*i*, *i*, *i*), must eventually bring about a collapse. The rocks forming the surface-slopes of the mountain will from time to time give and slide into the valley, or the whole thickness of the truncated strata may break away and rush downwards; and this process must continue so long as any portion of the anticlinal arch remains above the level of the adjacent synclinal troughs.

Thus it will be seen that an anticlinal arch is a weak structure – a mountain so constructed falls a ready prey to the denuding agents; and hence in regions which have been exposed to denudation for as long a period as the Scottish or Scandinavian uplands, a mountain formed of anticlinally arranged strata is of very exceptional occurrence. When it does appear, it is only because the rocks of which it is composed happen to be of a more enduring character than those of the adjacent tracts. The Ochil Hills exemplify this point. These hills consist of a great series of hard igneous rocks, which are arranged in the form of a depressed anticlinal arch – the low grounds lying to the north and south being composed chiefly of sandstones and shales. Here it is owing to the more enduring character of the igneous rocks that the anticlinal arch has not been entirely removed. We know, however, that these igneous rocks were formerly buried under a great thickness of strata, and that their present appearance at the surface is simply the result of denudation.

If an anticlinal arch be a weak structure, a synclinal arrangement of strata is quite the opposite. In the case of the former each bed has a tendency to slip or slide away from the axis, while in a syncline it is just the reverse – the strata being inclined towards and not away from the axis. Underground water, springs, and frost are enabled to play havoc with anticlinal strata, for the structure is entirely in their favour. But in synclinal beds the action of these powerful agents is opposed by the structure of the rocks – and great rock-falls and landslips cannot take place. Synclinal strata therefore endure, while anticlinal strata are worn more readily away. Even in a true mountain-range so young as the Alps, denudation has already demolished many weakly-built anticlinal mountains, and opened up valleys along their axes; while, on the other hand, synclinal troughs have been converted into mountains. And if this be true of the Alps, it is still more so of much older mountain-regions, in which the original contours due to convolutions of the strata have entirely disappeared.

The mountains of such regions, having been carved out and modelled by denuding agents, are rightly termed *mountains of circumdenudation*, for they are just as much the work of erosion as the flat-topped and pyramidal mountains which have been carved out of horizontal strata. The Scottish Highlands afford us an admirable example of a mountainous region of undulating and often highly-flexed strata, in which the present surface-features are the result of long-continued erosion. As already remarked, this region is one of the oldest land-surfaces in the world. In comparison with it, the Pyrenees, the Alps, and the Himalayas are creations of yesterday. The original surface or configuration assumed by the rocks composing our Highland area at the time when these were first crushed and folded into anticlines and synclines had already been demolished at a period inconceivably more remote than the latest grand upheaval of the Alps. Even before the commencement of Old Red Sandstone times, our Archæan, Cambrian, and Silurian rocks had been planed down for thousands of feet, so that the bottom beds of the Old Red Sandstone were deposited upon a gently undulating surface, which cuts across anticlines and synclines alike. In late Silurian and early post-Silurian times the North-west Highlands probably existed as a true mountain-chain, consisting of a series of parallel ranges formed by the folding and reduplication of the strata. The recent observations of my friends, Professor Lapworth and Messrs. Peach and Horne, in Sutherland, have brought to light the evidence of gigantic earth-movements, by which enormous masses of strata have been convoluted and pushed for miles out of place. We see in that region part of a dissected mountain-chain. The mountain-masses which are there exposed to view are the basal or lower portions of enormous sheets of disrupted rock, the upper parts of which have been removed by denudation. In a word, the mountains of Sutherland are mountains of circumdenudation – they have been carved out of elevated masses by the long-continued action of erosion. To prove this, one has only to draw an accurate section across the North-west Highlands, when it becomes apparent that the form or shape of the ground does not correspond or coincide with the convolutions of the strata, and that a thickness of thousands of feet of rock has been denuded away since those strata were folded and fractured. All over the Highlands we meet with similar evidence of enormous denudation. The great masses of granite which appear at the surface in many places are eloquent of the result produced by erosion continued for immeasurable periods of time. Every geologist knows that granite is a rock which could only have been formed and consolidated at great depths. When, therefore, such a rock occurs at the surface, it is evidence beyond all doubt of prodigious erosion. The granite has been laid bare by the removal of the thick rock-masses underneath which it cooled and consolidated.

A glance at any map of Scotland will show that many river-valleys, and not a few lakes, of the Highlands have a north-east and south-west trend. This trend corresponds to what geologists call the *strike* of the strata. The rocks of the Highlands have been compressed into a series of folds or anticlines and synclines, which have the direction just stated – namely, north-east and south-west. A careless observer might therefore rashly conclude that these surface-features resembled those of the Jura – in other words, that the long parallel hollows were synclinal troughs, and that the intervening ridges and high grounds were anticlinal arches or saddle-backs. Nothing could be further from the truth. A geological examination of the ground would show that the features in question were everywhere the result of denudation, guided by the petrological character and geological structure of the rocks. Several of the most marked hollows run along the backs of anticlinal axes, while some of the most conspicuous mountains are built up of synclinal or trough-shaped strata. Ben Lawers, and the depression occupied by Loch Tay, are excellent examples; and since that district has recently been mapped in detail by Mr. J. Grant Wilson, of the Geological Survey, I shall give a section to show the relation between the form of the ground and the geological structure of the rocks. This section speaks for itself. Here evidently is a case where "valleys have been exalted and mountains made low." A well-marked syncline, it will be observed, passes through Ben Lawers, while Loch Tay occupies a depression scooped out of an equally well-defined anticline – a structure which is just the opposite of that which we should expect to find in a true mountain-chain. It will be also noted that Glen-Lyon coincides neither with a syncline nor a fault; it has been eroded along the outcrops of the strata. Many of the north-east and south-west hollows of the Highlands indeed run along the base of what are really great escarpments – a feature which, as we have seen, is constantly met with in every region where the strata "strike" more or less steadily in one direction. In the Highlands the strata are most frequently inclined at considerable angles, so that the escarpments succeed each other more rapidly than would be the case if the strata were less steeply inclined. In no case does any north-east and south-west hollow coincide with a structural cavity. Loch Awe has been cited as an example of a superficial depression formed by the inward dip of the strata on either side. But, as was shown many years ago by my brother, A. Geikie,[5] this lake winds across the *strike* of the strata. Moreover, if it owed its existence to a great synclinal fold, why, he asks, does it not run along the same line as far as the same structure continues? It does not do so: it is not continuous with the synclinal fold, while vertical strata appear in the middle of the lake, where, as my brother remarks, they have clearly no business to be if the sides of the lake are formed by the inward dip of the schists.

The Great Glen, as I mentioned in the preceding article, coincides with a fracture or dislocation – a line of weakness along which the denuding agents had worked for many ages before the beginning of Old Red Sandstone times; and it is possible that smaller dislocations may yet be detected in other valleys. But in each and every case the valleys as we now see them are valleys of erosion; in each and every case the mountains are mountains of circumdenudation; they project as eminences because the rock-masses which formerly surrounded them have been gradually removed. We have only to protract the outcrops of the denuded strata – to restore their continuations – to form some faint idea of the enormous masses of rock which have been carried away from the surface of the Highland area since the strata were folded and fractured. All this erosion speaks to the lapse of long ages. The mountains of elevation which doubtless at one time existed within the Highland area had already, as we

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[5] *Trans. Edin. Geol. Soc.* vol. ii. p. 267.

have seen, suffered extreme erosion before the beginning of Old Red Sandstone times, much of the area having been converted into an undulating plateau or plain, which, becoming submerged in part, was gradually overspread by the sedimentary deposits of the succeeding Old Red Sandstone period. Those sediments were doubtless derived in large measure from the denudation of the older rocks of the Highlands, and since they attain in places a thickness of 20,000 feet, and cover many square miles, they help us to realise in some measure the vast erosion the Highland area had sustained before the commencement of the Carboniferous period. Nor must we forget that the Old Red Sandstone formation which borders the Highlands has itself experienced excessive denudation: it formerly had a much greater extension, and doubtless at one time overspread large tracts of the Highlands. Again, we have to remember that during the Carboniferous and Permian periods, and the later Mesozoic and Cainozoic eras, the Highlands probably remained more or less continuously in the condition of land. Bearing this in mind, we need not be surprised that not a vestige of the primeval configuration brought about by the great earth-movements of late Silurian times has been preserved. Indeed, had the Highland area, after the disappearance of the Old Red Sandstone inland seas, remained undisturbed by any movement of elevation or depression, it must long ago have been reduced by sub-aërial erosion to the condition of a low-lying undulating plain. But elevation en masse from time to time took place, and so running water and its numerous allies have been enabled to carry on the work of denudation.

Thus in the geological history of the Scottish Highlands we may trace the successive phases through which many other elevated tracts have passed. The Scandinavian plateau, and many of the mountains of middle Germany – such, for example, as the Harz, the Erzgebirge, the Thüringer-Wald, etc. – show by their structure that they have undergone similar changes. First we have an epoch of mountain-elevation, when the strata are squeezed and crushed laterally, fractured and shattered – the result being the production of a series of more or less parallel anticlines and synclines, or, in other words, a true mountain-chain. Next we have a prolonged period of erosion, during which running water flows through synclinal troughs, works along the backs of broken and shattered anticlines, and makes its way by joints, gaping cracks, and dislocations, to the low grounds. As time goes on, the varying character of the rocks and the mode of their arrangement begin to tell: the weaker structures are broken up; rock-falls and landslips ever and anon take place; anticlinal ridges are gradually demolished, while synclines tend to endure, and thus grow, as it were, into hills, by the gradual removal of the more weakly-constructed rock-masses that surround them. Valleys continue to be deepened and widened, while the intervening mountains, eaten into by the rivers and their countless feeders, and shattered and pulverised by springs and frosts, are gradually narrowed, interrupted, and reduced, until eventually what was formerly a great mountain-chain becomes converted into a low-lying undulating plain. Should the region now experience a movement of depression, and sink under the sea, new sedimentary deposits will gather over its surface to a depth, it may be, of many hundreds or even thousands of feet. Should this sunken area be once more elevated en masse – pushed up bodily until it attains a height of several thousand feet – it will form a plateau, composed of a series of horizontal strata resting on the contorted and convoluted rocks of the ancient denuded mountain-chain. The surface of the plateau will now be traversed by streams and rivers, and in course of time it must become deeply cleft and furrowed, the ground between the various valleys rising into mountain-masses. Should the land remain stationary, its former fate shall again overtake it; it will inevitably be degraded and worn down by the sub-aërial agents of erosion, until once more it assumes the character of a low-lying undulating plain.

Through such phases our Highlands have certainly passed. At a very early epoch the Archæan rocks of the north-west were ridged up into great mountain-masses, but before the beginning of the pre-Cambrian period wide areas of those highly-contorted rocks had already been planed across, so that when subsidence ensued the pre-Cambrian sandstones were deposited upon a gently undulating surface of highly convoluted strata. Another great epoch of mountain-making took place after Lower Silurian times, and true mountain-ranges once more appeared in the Highland area. We cannot tell how high those mountains may have been, but they might well have rivalled the Alps. After their elevation a prolonged period of erosion ensued, and the lofty mountain-land was reduced in large measure to the condition of a plain, wide areas of which were subsequently overflowed by the inland seas of Old Red Sandstone times – so that the sediments of those seas or lakes now rest with a violent unconformity on the upturned and denuded edges of the folded and contorted Silurian strata. At a later geological period the whole Highland area was elevated *en masse*, forming an undulating plateau, traversed by countless streams and rivers, some of which flowed in hollows that had existed before the beginning of Old Red Sandstone times. Since that epoch of elevation the Highland area, although subject to occasional oscillations of level, would appear to have remained more or less continuously in the condition of dry land. The result is, that the ancient plateau of erosion has been deeply incised – the denuding agents have carved it into mountain and glen – the forms and directions of which have been determined partly by the original surface-slopes of the plateau, and partly by the petrological character of the rocks and the geological structure of the ground.

Thus, in the evolution of the surface-features of the earth, the working of two great classes of geological agents is conspicuous – the subterranean and the sub-aërial. The sinking down of the crust upon the cooling nucleus would appear to have given rise to the great oceanic depressions and continental ridges, just as the minor depressions within our continental areas have originated many mountain-chains. In the area undergoing depression the strata are subjected to intense lateral pressure, to which they yield along certain lines by folding up. The strata forming the Alps, which are 130 miles broad, originally occupied a width of 200 miles; and similar evidence of enormous compression is conspicuous in the structure of all mountains of elevation. Great elevation, however, may take place with little or no disturbance of stratification: wide continental areas have been slowly upheaved *en masse*, and sea-bottoms and low-lying plains have in this way been converted into lofty plateaux.[6] Many of the most conspicuous features of the earth's surface, therefore, are due directly to subterranean action. All those features, however, become modified by denudation, and eventually the primeval configuration may be entirely destroyed, and replaced by contours which bear no direct relation to the form of the original surface. In the newer mountain-chains of the globe the surface-features are still largely those due directly to upheaval; so in some recently elevated plateaux the ground has not yet been cut up and converted into irregular mountain-masses. Many of the more ancient mountain-chains and ranges, however, have been exposed so long to the abrading action of the denuding agents that all trace of their original

[6] This is the generally accepted view of modern geologists. It is very difficult, however, to understand how a wide continental area can be vertically upheaved. It seems more probable that the upheaval of the land is only apparent. The land seems to rise because the sea retreats as the result of the subsidence of the crust within the great oceanic basins. See Article xiv. (1892.)

contour has vanished. And in like manner plateaux of great age have been so highly denuded, so cut and carved by the tools of erosion, that their plateau character has become obscured. They have been converted into undulating mountainous and hilly regions. Everywhere throughout the world we read the same tale of subsidence and accumulation, of upheaval and denudation. The ancient sedimentary deposits which form the major portion of our land-surfaces, are the waste materials derived from the demolition of plains, plateaux, and mountains of elevation. In some mountain-regions we read the evidence of successive epochs of uplift, separated by long intervening periods of erosion, followed by depression and accumulation of newer sediments over the denuded surface. Thus the Alps began to be elevated towards the close of Palæozoic times. Erosion followed, and subsequently the land became depressed, and a vast succession of deposits accumulated over its surface during the long-continued Mesozoic era into early Cainozoic times. Again, a great upheaval ensued, and the Mesozoic and Eocene strata were violently contorted and folded along the flanks of the chain. Then succeeded another period of erosion and depression, which was again interrupted by one or more extensive upheavals. Away from those lines of weakness which we call mountain-chains, we constantly encounter evidence of widespread movements of elevation, during which broad areas of sea-bottom have been upheaved to the light of day, and, after suffering extensive denudation have subsided, to be again overspread with the spoils of adjacent lands, and then upheaved once more. And such oscillations of level have occurred again and again. Looking back through the long vista of the past, we see each continental area in a state of flux – land alternating with sea, and sea with land – mountains and plateaux appearing and disappearing – a constant succession of modifications, brought about by the antagonistic subterranean and sub-aërial agents.

> The hills are shadows, and they flow
> From form to form, and nothing stands;
> They melt like mists, the solid lands,
> Like clouds they shape themselves and go.

IV.
The Cheviot Hills. [7]

I

The ridge of high ground that separates England from Scotland is not, like many other hilly districts, the beloved of tourists. No guide-book expatiates upon the attractiveness of the Cheviots; no cunningly-worded hotel-puffs lure the unwary vagrant in search of health, or sport, or the picturesque, to the quiet dells and pastoral uplands of the Borders. Since the biographer of Dandie Dinmont, of joyous memory, joined the shades, no magic sentences, either in verse or prose, have turned any appreciable portion of the annual stream of tourists in the direction of the Cheviots. The scenery is not of a nature to satisfy the desires of those who look for something piquant – something "sensational," as it were. It is therefore highly improbable that the primeval repose of these Border uplands will ever be disturbed by inroads of the "travelling public," even should some second Burns arise to render the names of hills and streams as familiar as household words. And yet those who can spare the time to make themselves well acquainted with that region should do so; they

[7] From *Good Words* for 1876.

will have no reason to regret their visit, but very much the reverse. For the scenery is of a kind which grows upon one. It shows no clamant beauties – you cannot have its charms photographed – the passing stranger may see nothing in it to detain him; but only tarry for a while amongst these green uplands, and you shall find a strange attraction in their soft outlines, in their utter quiet and restfulness. For those who are wearied with the crush and din of life, I cannot think of a better retreat. One may wander at will amongst the breezy hills, and inhale the most invigorating air; springs of the coolest and clearest water abound, and there are few of the brooks in their upper reaches which will not furnish natural shower-baths. Did the reader ever indulge in such a mountain-bath? If not, then let him on a summer day seek out some rocky pool, sheltered from the sun, if possible, by birch and mountain-ash, and, creeping in below the stream where it leaps from the ledges above, allow the cool water to break upon his head, and he will confess to having discovered a new aqueous luxury. Then from the slopes and tops of the hills you have some of the finest panoramic views to be seen in this island. Nor are there wanting picturesque nooks, and striking rock scenery amongst the hills themselves: the sides of the Cheviot are seamed with some wild, rugged chasms, which are just as weird in their way as many of the rocky ravines that eat into the heart of our Highland mountains. The beauty of the lower reaches of some of the streams that issue from the Cheviots is well known; and few tourists who enter the vale of the Teviot neglect to make the acquaintance of the sylvan Jed. But other streams, such as the Bowmont, the Kale, the Oxnam, and the Rule will also well repay a visit. In addition to all these natural charms, the Cheviot district abounds in other attractions. Those who are fond of Border lore, who love to seek out the sites of old forays, and battles, and romantic incidents, will find much to engage them; for every stream, and almost every hill, is noted in tale and ballad. Or if the visitor have antiquarian tastes, he may rival old Monkbarns, and do his best to explain the history of the endless camps, ramparts, ditches, and terraces which abound everywhere, especially towards the heads of the valleys. To the geologist the district is not less interesting, as I hope to be able, in the course of these papers, to show. The geological history of the Cheviots might be shortly summed up, and given in a narrative form, but it will perhaps be more interesting, and, at the same time more instructive, if we shall, instead, go a little into detail, and show first what the nature of the evidence is, and, second, how that evidence may be pieced together so as to tell its own story. I may just premise that my descriptions refer almost exclusively to the Scottish side of the Cheviots – which is not only the most picturesque, but also the most interesting, both from an antiquarian and geological point of view.

The Cheviots extend from the head of the Tyne in Northumberland, and of the Liddel in Roxburghshire, to Yeavering Bell and the heights in its neighbourhood (near Wooler), a distance of upwards of thirty miles. Some will have it that the range goes westward so as to include the heights about the source of the Teviot, but this is certainly a mistake, for after leaving Peel Fell and crossing to the heights on the other side of the Liddel Water, we enter a region which, both in its physical aspect and its geological structure, differs considerably from the hilly district that lies between Peel Fell and the high-grounds that roll down to the wide plains watered by the Glen and the Till. The highest point in the range is that which gives its name to the hills – namely, the Cheviot – a massive broad-topped hill, which reaches an elevation of 2767 feet above the sea, and from which a wonderful panorama can be scanned on a clear day. The top of the hill is coated with peat, fifteen to twenty feet thick, in some places. A number of deep ravines trench its slopes, the most noted of which are Hen Hole and the Bizzle. Peel Fell, at the other extremity of the range, is only 1964 feet high, while the dominant points between Peel Fell and the Cheviot are still lower – ranging from 1500 feet to 1800 feet. The general character of the hills is that of smooth rounded masses, with long flowing outlines. There are no peaks, nor serrated ridges, such as are occasionally met with in the northern Highlands; and the valleys as a rule show no precipitous crags and rocky precipices, the most conspicuous exceptions being the deep clefts mentioned as occurring in the Cheviot. The hills fall away with a long gentle slope into England, while on the Scottish side the descent is somewhat abrupt; so that upon the whole the northern or Scottish portion of the Cheviots has more of the picturesque to commend it than the corresponding districts in England. Indeed, the opposite slopes of the range show some rather striking contrasts. The long, flat-topped elevations on the English side, that sweep south and south-west from Carter Fell and Harden Edge, and which are drained by the Tyne, the Rede Water, and the Coquet, are covered for the most part with peat. Sometimes, however, when the slope is too great to admit of its growth, the peat gives place to rough scanty grass and scrubby heath, which barely suffice to hide the underlying barren sandstone rocks. One coming from the Scottish side is hardly prepared, indeed, for the dreary aspect of this region as viewed from the dominant ridge of the Cheviots. If in their physical aspect the English slopes of these hills are for the most part less attractive than the Scottish, it is true also that they offer less variety of interest to the geologist. Those who have journeyed in stagecoaching times from England into Scotland by Carter Fell, will remember the relief they felt when, having surmounted the hill above Whitelee, and escaped from the dreary barrens of the English border, they suddenly caught a sight of the green slopes of the Scottish hills, and the well-wooded vales of Edgerston Burn and Jed Water. On a clear day the view from this point is very charming. Away to the west stretch in seemingly endless undulations the swelling hills that circle round the upper reaches of Teviotdale. To east and north-east the eye glances along the bright-green Cheviots of the Scottish border, and marks how they plunge, for the most part somewhat suddenly, into the low grounds, save here and there, where they sink in gentler slopes, or throw out a few scattered outposts – abrupt verdant hills that somehow look as if they had broken away from the main mass of the range. From the same standpoint one traces the valleys of the Rule and the Jed – sweetest of border streams – stretching north into the well-clothed vale of the Teviot. Indeed, nearly the whole of that highly-cultivated and often richly-wooded country that extends from the base of the Cheviots to the foot of the Lammermuirs, lies stretched before one. Here and there abrupt isolated hills rise up amid the undulating low grounds, to hide the country behind them. Of these the most picturesque are dark Rubers Law, overlooking the Rule Water; Minto Crags, and Penielheugh with its ugly excrescence of a monument, both on the north side of the Teviot; and the Eildon Hills, which, as all the world knows, are near Melrose.

After he has sated himself with the rare beauty of this landscape (and still finer panoramic views are to be had from the top of Blackhall Hill, Hownam Law, the Cheviot, as also from various points on the line of the Roman Road and other paths across the hills into England), the observer will hardly fail to be struck by the great variety of outlines exhibited. Some of the hills, especially those to the west and north-west, are grouped in heavy masses, and present for the most part a soft, rounded contour, the hills being broad atop and flowing into each other with long, smooth slopes. Other elevations, such as those to the east and north-east of Carter Fell, while showing similar long gentle slopes, yet are somewhat more irregular in form and broken in outline, the hills having frequently a lumpy contour. Very noteworthy objects in the landscape also are the little isolated hills of the low grounds, such as Rubers Law, and the Dunian, above Jedburgh. They rise, as I have said, quite suddenly out of that low gently undulating country that sinks softly into the vales of the Teviot and the Tweed. This variety arises from the geological structure of the district. The hills vary in outline partly because they are made up of different kinds of rock, and partly owing to the mode in which these rocks have been arranged. But notwithstanding all this variety of outline, one may notice a certain sameness too. Flowing outlines are more or less conspicuous all over the landscape. Many of the hills, especially as we descend into Teviotdale, seem to have been smoothed or rounded off, as it were, so as to present their steepest faces as a rule towards the south-west. And if we take the compass-bearing of the hill-ridges of the same district, we shall find that these generally trend from south-west to north-east So much, then, at present for the surface configuration of the Cheviot region. When we come to treat of the various rock-masses, and to describe the superficial accumulations underneath which these are often concealed, we shall be in a better position to give an intelligible account of the peculiar form of the ground, and the causes to which that configuration must be ascribed.

The solid rocks which enter into the composition of the Cheviots consist mainly of (1) hard grey and blue rocks, called *greywacké* by geologists, with which are associated blue and grey shale; (2) various old igneous rocks; and (3) sandstones, red and white, interbedded with which occur occasional dark shales. Now, before we can make any endeavour towards reconstructing in outline the physical geography of the Cheviot Hills during past ages, it is necessary that we should discover the order in which the rock-masses just referred to have been amassed. I shall first describe, therefore, some sections where the members of the different series are found in juxtaposition, for the purpose of pointing out which is the lowest-lying, and consequently the oldest, and which occupy the uppermost and intermediate positions.

The first section to which reference may be made is exposed in the course of the River Jed, at Allars Mill, a little above Jedburgh. This section is famous in its way as having been described and figured by Dr. Hutton, who may be said to have founded the present system of physical geology. In the bed of the stream are seen certain confused ridges of a greyish blue rock running right across the river course – that is, in a direction a little north of east and south of west. These ridges are the exposed edges of beds of greywacké and shale, which are here standing on end. The beds are somewhat irregular, being inclined from the vertical, now in one direction and now in another, or, as a geologist would say, the "dip" changes rapidly, sometimes being up the valley and sometimes down. The same beds continue up the steep bank of the river for a yard or two, and are there capped by another set of rocks altogether, namely, by soft red sandy beds which at the bottom become *conglomeratic*– that is to say, they are charged with water-worn stones. The annexed diagram will show the general appearances presented: *g* represents the vertical greywacké and shale, and *c* the overlying deposits of conglomerate and red sandy beds. Now let us see what this section means. What, in the first place, is greywacké? The term itself has really no meaning, being a name given by the miners in the Harz Mountains to the unproductive rocks associated with the vein-stones which they work. When we break the rock we may observe that it is a granular mixture of small particles of quartz, to which sometimes felspar and other minerals are added. The grains are bound together in a hardened matrix of argillaceous or clayey and silicious matter, blue, or grey, or green, or brown and yellow, as the case may be. At Allars Mill, and generally throughout the Cheviot district, the prevailing colour is a pale greyish blue or bluish grey; but shades of green and brown often occur. The component particles of the rock are usually rounded or water-worn. Again, we notice that the ridges and bands of rock that traverse the course of the Jed at Allars Mill are merely the outcrops of successive *strata* or beds. It is clear then that greywacké and the grey shales that accompany it are *aqueous* rocks – that is to say, they consist of hardened sediment, which has undoubtedly been deposited in successive layers of variable thickness by water in motion. But since the sediments of rivers and currents are laid down in approximately horizontal planes, it is evident that if the greywacké and shale be sedimentary deposits they have suffered considerable disturbance since the time of their formation; for, as we have seen, the beds, instead of being horizontal or only gently inclined, actually approach the vertical. The fact is, that the outcrops which we see are only the truncated portions of what were formerly rapid undulations or folds of the strata, the tops of the folds or arches having been cut away by geological agencies, to which I shall refer by-and-by. What were at one time horizontal strata have been crumpled up into great folds, the folds being squeezed tightly together, and their upper portions planed away before the overlying red sandy beds were laid down. The accompanying diagram may serve to make all this clearer. Let A A represent the present surface of the ground, and B B a depth of say fifty feet or a hundred feet from the surface. The continuous lines between A and B represent the greywacké beds as we now see them in section; the dotted lines above A A indicate the former extension of the strata, and the dotted lines below B B their continuation below that datum line. Hence it is obvious that in a succession of vertical or highly inclined beds, we may have the same strata repeated many times, the same beds coming again and again to the surface. Thus the stratum at S is evidently the same bed as that at W, X, Y, and Z.

Such great foldings or redoublings of strata are most probably originated during subsidence of a portion of the earth's crust. While the ground is slowly sinking down, the strata underneath are perforce compelled to occupy less space laterally, and this they can only do by yielding amongst themselves. All folding or contortion on the large scale – that, namely, which has affected areas of strata extending over whole countries – seems to have taken place under great pressure; in other words, to have been produced at considerable depths from the earth's surface. We can conceive, therefore, of a wide tract of land sinking down for hundreds of feet, and producing at the surface comparatively little change. But a depression of a few hundred feet at the surface implies a considerably greater depression at a depth of several thousand feet from the surface, and it is at great depths, therefore, that the most violent folding must take place. Consequently considerable contortion, and much folding, and lateral crushing and reduplication of strata may occur, and yet no trace of this be observable at the surface, save only a gentle depression. For example, in Greenland, a movement of subsidence has been going on for many years – the land has been slowly sinking down. The rocks at the surface are of course quite undisturbed by this widely-extended movement, but the strata at great depths may be undergoing much compression and contortion. It follows from such considerations, that if we now get highly contorted strata covering wide areas at the surface, we suspect that very considerable *denudation* has taken place. That is to say, large masses of rock have been removed by the geological agents of change, so as to expose the once deeply-buried tops of the arched or curved and folded strata. We may therefore infer from a study of the phenomena in the Jed at Allars Mill, first, that the red sandy beds are younger than the greywacké and shale, seeing that they rest upon them; and, second, that a very long period of time must have elapsed between the deposition of the older and the accumulation of the younger set of strata; for it is obvious that considerable time was required for the consolidation and folding of the greywacké, and an incalculable lapse of ages was also necessary to allow of the gradual wearing away by rain, frost, and running water of the great thickness of rocks underneath which the greywacké was crumpled. And all this took place before the horizontally-bedded red sandstone and conglomerate gathered over the upturned ends of the underlying strata. The succession of rocks at Allars Mill is seen in many other places in the Cheviot district, but enough has been said to prove that the greywacké beds are the older of the two sets of strata.

There is another class of rocks, the relative position of which we must now ascertain, for no one shall wander much or far among the Cheviots without becoming aware of the existence of other kinds of rock than greywacké and sandstone. Many of the hills east of Oxnam and Jed Waters, for example, are composed of igneous masses – of rocks which have had a volcanic origin. As we shall afterwards see, the whole north-eastern section of the Cheviots is built up of such rocks. At present, however, we are only concerned with the relation which these bear to the greywacké and the red sandy beds. Now at various localities – for example, in Edgerston Burn, on the hill-face south of Plenderleith, and again along the steep front of Hindhope and

Blackball Hills, which are on the crest of the Cheviots – we find that the igneous rocks rest upon the greywacké and shale precisely in the same way as do the red sandy beds. They therefore belong to a later date than the greywacké. In other places, again, we meet with the conglomerates and red sandstones (*c*, resting upon and wrapping round the igneous rocks, *i*, and thus it becomes quite obvious that the latter occupy an intermediate position between the greywacké and shale on the one hand, and the conglomerate and red sandstone upon the other.

We have now cleared the way so far, preparatory to an attempt to trace the geological history of the Cheviots. The three sets of rocks, whose mutual relations we have been studying, are those of which the district is chiefly composed; but, as we shall see in the sequel, there are others, not certainly of much extent, but nevertheless having an interesting story to tell us. Nor shall we omit to notice the superficial accumulations of clay, gravel, sand, silt, alluvium, and peat; monuments as they are of certain great changes, climatic and geographical, which have characterised not the Cheviots only, but a much wider area.

II

If we draw a somewhat straight line from Girvan, on the coast of Ayrshire, in a north-east direction to the shores of the North Sea, near Dunbar, we shall find that south of that line, up to the English border, nearly the whole country is composed of various kinds of greywacké and shale like the basement beds of the Cheviot district. Here and there, however, especially in certain of the valleys and some of the low-lying portions of this southern section of Scotland, one comes upon small isolated patches and occasional wider areas of younger strata, which rest upon and conceal the greywackés and shales. Such is the case in Teviotdale, the Cheviot district, and the country watered by the lower reaches of the Tweed, in which regions the bottom beds are hidden for several hundreds of square miles underneath younger rocks. Indeed, the greywacké and shale form but a very small portion of the surface in the Cheviots, appearing upon a coloured geological map like so many islands or fragments, as it were, which have somehow been detached from the main masses of greywacké of which the Lammermuirs and the uplands of Dumfries and Selkirk shires are composed. Although the bottom rocks of the Cheviot Hills are thus apparently separated from the great greywacké area, there can be no doubt that they are really connected with it, the connection being obscured by the overlying younger strata. For if we could only strip off these latter, if we could only lift aside the great masses of igneous rock and sandstone that are piled up in the Cheviot Hills and the adjoining districts, we should find that the bottom upon which these rest is everywhere greywacké and shale. In part proof of this it may be mentioned that at various places in those districts which are entirely occupied by sandstone and igneous rock, the streams have cut right down through the younger rocks so as to expose the bottom beds, as in Jed Water at Allars Mill. Again, when we trace out the boundaries of any detached areas of greywacké we invariably find these bottom beds disappearing on all sides underneath the younger strata by which they are surrounded. One such isolated area occurs in the basin of the Oxnam Water, between Littletonleys and Bloodylaws, a section across which would exhibit the general appearance shown in the accompanying diagram. Another similarly isolated patch is intersected by Edgerston Burn and the Jed Water between Paton Haugh and Dovesford. But the largest of these detached portions appears, forming the crest of the Cheviots, at the head of the River Coquet. There the basement beds occupy the watershed, extending westward, some three or four miles, as far as the sandstones of Hungry Law, while to the north and east they plunge under the igneous rocks of Brownhart Law and the Hindhope Hills. Now it is evident that all those detached and isolated areas of greywacké and shale are really connected underground, and not only so, but they also piece on in the same way to the great belt of similar strata that stretches from sea to sea across the whole breadth of Scotland. Indeed, we may observe in the Cheviot district how long and massive promontories of greywacké jut out from that great belt, and extend often for miles into the areas that are covered with younger strata, as, for example, in the Brockilaw and Wolfelee Hills. A generalised section across the greywacké regions of the Cheviot Hills would therefore present the appearances shown in the annexed diagram, in which G represents the basement beds, I the igneous rocks, and C the red sandstones, etc.

Throughout the whole of the district under review the bottom beds are observed to dip at a high angle – the strata in many places being actually vertical – and the edges or crops of the strata run somewhat persistently in one direction, namely, from south by west to north by east; or, as a geologist would express it, the beds have an approximately south-west and north-east "strike." Now as the dip is sometimes to north-west and sometimes to south-east, it is evident that the rocks have been folded up in a series of rapid convolutions, and that some of the beds must be often repeated.

From the character of the fossils which the bottom beds have yielded we learn that the strata belong to that division of past time which is known as the Silurian age. These fossils appear to be of infrequent occurrence, and the creatures of which they are the relics occupied rather a humble place in the scale of being. They are called *graptolites* (from their resemblance to pens), an extinct group of hydroid zoophytes, apparently resembling the sertularians of our own seas.

The general appearance of the Silurian strata of the Cheviots is indicative of deposition in comparatively quiet water, but how deep that water was one cannot say. Upon the whole, the beds look not unlike the sediments that gather in calm reaches of the sea, such as estuaries, betokening the presence of some not distant land from which fine mud and sand were washed down. Another proof that some of the strata at all events were accumulated not far from a shore-line, is found in certain coarse bands of grit and pebbles, which are not likely to have been formed in deep water. This evidence, however, cannot be considered decisive, and in the present state of our knowledge all that we can assert with anything like confidence is simply this: – That during the deposition of the Silurian strata the whole of the Cheviot area lay under water – existed, in short, as a muddy sea-bottom, in the slime of which flourished here and there, in favourable spots, those minute hydroid animals called *graptolites*.

Between the deposition of the Silurian and the formation of the rocks that come next in order a long interval elapsed, during which the mud, sand, and grit that gathered on the floor of the ancient sea were hardened into solid masses, and eventually squeezed together into great folds and undulations. It has already been pointed out that these changes could hardly have been effected save under extreme pressure, and this consideration leads us to infer that a great thickness of strata has been removed entirely from the Cheviot district, so as to leave no trace of its former existence. Long before the deposition of the younger strata that now rest upon and conceal the Silurian rocks, the action of the denuding forces – the sea, frosts, rain, and rivers – had succeeded in not only sweeping gradually away the strata underneath which the bottom beds were folded, but in deeply scarping and carving these bottom beds themselves. Can we form any reasonable conjecture as to the geological age of the strata underneath which the bottom beds of the Cheviots were folded, and which, as we have seen, had entirely disappeared before the younger rocks of the district were accumulated? Well, it is obvious that the missing strata must have been of later formation than the bottom beds, and it is equally evident that they must have been of much more ancient date than the igneous rocks of the Cheviot Hills. Now, as we shall afterwards see, these igneous rocks belong to the Old Red Sandstone age, that is to say, to the age that succeeded the Silurian. How is it then, if the bottom beds be really of Silurian and the igneous rocks of Old Red Sandstone age, that a gap is said to exist between them? The explanation of this apparent contradiction is not far to seek. When we compare the fossils that occur in the Silurian strata of the Cheviot Hills and the districts to the west, with the organic remains disinterred from similar strata elsewhere, as in Wales for example, we find that the bottom beds of the Cheviots were in all probability accumulated at approximately the same time as certain strata that occur in the middle division of the Upper Silurian. In Wales and in Cumberland the strata that approximate in age to the Silurian of the Cheviots are covered by younger strata belonging to the same formation which reach a thickness of several thousand feet. It may quite well be, therefore, that the succession of Silurian strata in the Cheviots was at one time more complete than it is now. The upper portions of the formation which are so well developed in Wales and Cumberland, and which are likewise represented to a small extent in Scotland, had in all probability their equivalents in what are our border districts. In other words, there are good grounds for believing that the existing Silurian rocks of the Cheviots were in times preceding the Old Red Sandstone age covered with younger strata belonging to the same great system. The missing Silurian strata of the Cheviots may have attained a thickness of several thousand feet, and underneath such a mass of solid rock the lower-lying strata might well have been consolidated and subsequently squeezed into folds.

We now pass on to consider the next chapter in the geological history of the Cheviot Hills. As we proceed in our investigations it will be noticed that the evidence becomes more abundant, and we are thus enabled to build up the story of the past with more confidence, and with fuller details. For it is with geological history as with human records – the further back we go in time the scantier do the facts become. The rocks upon which Nature writes her own history are palimpsests, on which the later writing is ever the most easily deciphered. Nay, she cannot compile her newer records without first destroying some of those compiled in earlier times. The sediments accumulating in modern lake and sea are but the materials derived from the degradation of the rocks we see around us, just as these in like manner have originated from the demolition of yet older strata. Thus the further we trace back the history of our earth, the more fragmentary must we expect the evidence to be; and conversely, the nearer we approach to the present condition of things the more abundant and satisfactory must the records become. Accordingly, we find that the igneous rocks of the Cheviot Hills tell us considerably more than the ancient Silurian deposits upon which they rest. The surface of the latter appears to be somewhat irregular underneath the igneous rocks, showing that hills and valleys, or an undulating table-land, existed in the Cheviot district prior to the appearance of the younger formation. But before we attempt to summarise the history of that formation, it is necessary to give some description, however short, of the rocks that compose it.

These consist chiefly of numerous varieties of a rock called porphyrite by geologists, piled in more or less irregular beds, one on top of another, in a somewhat confused manner. The colour of the freshly fractured rocks is very variable, being usually some shade of blue or purple; but pink, red, brown, greenish, and dark grey or almost black varieties also occur. Some of the rocks are finely crystalline; others, again, are much coarser, while many are compact, or nearly so, a lens being required to detect a crystalline texture. The mineral called felspar is usually scattered more or less abundantly through the matrix or base, which itself is composed principally of felspathic materials. Besides distinct scattered crystals of felspar, other minerals often occur in a similar manner; mica and hornblende being the commonest. Occasionally the rocks contain numerous circular, oval, or flattened cavities, which are sometimes so abundant as to give the appearance of a kind of coarse slag to the porphyrite. These little cavities, however, are usually filled up with mineral matter – such as calcspar, calcedony, jasper, quartz, etc. Sometimes also cracks, crannies, and crevices of some size have been sealed up with similar minerals. Now nearly all these appearances are specially characteristic of rocks which have at one time been in a state of igneous fusion; nor can there be any doubt that the Cheviot porphyrites are merely solidified lava-beds, which have been poured out from the bowels of the earth. In modern lavas we may notice not only a crystalline texture, but frequently also we observe those in our porphyrites. Such cavities are due to the expansive force of the vapours imprisoned in the molten mass at the time of eruption. They form chiefly towards the upper surface of a lava stream, and are often drawn out or flattened in the direction in which the lava flows. Thus a stream of lava, as it creeps on its way, becomes slaggy and scoriaceous or cindery above and in front, and as the molten mass within continues to flow, the slags and cinders that cover its face tumble down before it, and form the pavement upon which the stream advances. In this way slags and cinders become incorporated with the bottom of the lava, and hence it is that so many volcanic rocks are scoriaceous, as well below as above. The vapours which produce the cavities usually contain minerals in solution, and these, as the lava cools, are frequently deposited, partially filling up the vesicles, so as to form what are called geodes. But many of the cavities have been filled in another way – by the subsequent infiltration of water carrying mineral matter in solution. And since we know that all rocks are so permeated by water, it is clear that the cavities may have received their contents during many successive periods, after the solidification of the rock in which they occur. It is in this manner that the jaspers, calcedony, and beautiful agates of commerce have been formed. Rocks abundantly charged with cavities are said to be *vesicular*, and when the vesicles are filled with mineral matter, then the mass becomes, in geological language, *amygdaloidal*, from the almond-like shape assumed by the flattened vesicles.

Now all the appearances described above, and many others hardly less characteristic of true lavas, are to be met with amongst those porphyrites which, as I have said, form the major portion of the Cheviot Hills. From the valley of the Oxnam, east by Cessford, Morebattle, and Hoselaw, and south by Edgerston, Letham, Browndeanlaws, and Hindhope, the porphyrites extend over the whole area, sweeping north-east across the border on to the heights above the Rivers Glen and Till. In the hills at Hindhope we notice a good display of the oldest beds of the series. At the base occurs a very peculiar rock resting upon the

Silurian, and thus forming the foundation of the porphyrites. It varies in colour, being pink, grey, green, red, brown, or variously mottled. Sometimes it is fine-grained and gritty, like a soft, coarse-grained sandstone; at other times it is not unlike a granular porphyrite; but when most typically developed it consists of a kind of coarse angular gravel embedded in a gritty matrix. The stones sometimes show distinct traces of arrangement into layers; but they are often heaped rudely together with little or no stratification at all. They consist chiefly of fragments of porphyrites; but bits of Silurian rocks also occur amongst them. This peculiar deposit unquestionably answers to the heaps of dust, sand, stones, and bombs which are shot out of modern volcanoes; it is a true tuff – that is, a collection of loose volcanic ejectamenta.

Upon what kind of surface did it fall? Long before the eruptions began, the Silurian rocks had been sculptured into hills and valleys by the action chiefly of the sub-aërial forces, and it was upon these hills and in these valleys that the igneous materials accumulated. It is difficult to say, however, whether at this period the Cheviot district was above or under water. The traces of bedding in the tuff would seem to indicate the assorting power of water; but the evidence is too slight to found upon, because we know that in modern eruptions, loose ejectamenta frequently assume a kind of irregular bedded arrangement. For aught we can say to the contrary, therefore, dry land may have extended across what is now southern Scotland and northern

England when the first rumblings of volcanic disturbance shook the Cheviot area. Be that as it may, we know that the volcanic outbursts began in those old times, as they almost invariably commence now, by a discharge of sand, small stones, blocks, and cinders. These, we may infer, covered a wide area round the centre of dispersion – the chief focus of eruption being probably in the vicinity of the big Cheviot, where a mass of granite seems to occupy the core or deep-seated portion of the old volcanic centre. The locality where the tuff occurs is some nine miles or so distant from this point, and the intervening ground could hardly have escaped being more or less thickly sprinkled with the same materials. The whole of that intervening ground, however, now lies deeply buried under the massive streams of once-molten rock that followed in succession after the first dispersion of stones and débris. Although, as I have said, it may be doubted whether at the beginning of their activity the Cheviot volcanoes were sub-aqueous, yet there are not a few facts that lead to the inference that the eruption of the porphyrites took place for the most part, if not exclusively, under water. The beds are occasionally separated by layers of sandstone, grit, and conglomerate; but such beds are rare, and true tuffs are rarer still. If the outbursts had been sub-aërial, we ought surely to have met with these latter in greater abundance, while we should hardly have expected to find such evidently water-arranged strata as do occur here and there. The porphyrites themselves present certain appearances which lead to the same conclusion. Thus we may observe how the bottoms of the beds frequently contain baked or hardened sand and mud, showing that the molten rock had been poured out over some muddy or sandy bottom, and had caught up and enclosed the soft, sedimentary materials, which now bear all the marks of having been subjected to the action of intense heat. Sometimes, indeed, the old lava-streams seem to have licked up beds of unconsolidated gravel, the water-worn stones being now scattered through their under portions. As no fossils occur in any of the beds associated with the porphyrites, one cannot say whether the latter flowed into the sea or into great freshwater lakes. Neither can we be certain that towards their close the eruptions were not sub-aërial. They may quite well have been so. The porphyrites attain a thickness of probably not less than fifteen hundred or two thousand feet, and the beds which we now see are only the basal, and therefore the older portions of the old volcanoes. The upper parts have long since disappeared, the waste of the igneous masses having been so great that only the very oldest portions now remain, and these, again, are hewn and carved into hill and valley. Any loose accumulation of stones and débris, therefore, which may have been thrown out in the later stages of the eruptions, must long ere this have utterly disappeared. We can point to the beds which mark the beginning of volcanic activity in the Cheviots; we can prove that volcanoes continued in action there for long ages, great streams of lava being poured out – the eruptions of which were preceded and sometimes succeeded by showers of stones and débris; we can show, also, that periods of quiescence, more or less prolonged, occasionally intervened, at which times water assorted the sand and mud, and rounded the stones, spreading them out in layers. But whether this water action took place in the sea or in a lake we cannot tell. Indeed, for aught one can say, some of the masses of rounded stones I refer to may point to the action of mountain torrents, and thus be part evidence that the volcanoes were sub-aërial. If we are thus in doubt as to some of the physical conditions that obtained in the Cheviot district during the accumulation of the porphyrites and their associated beds, we are left entirely to conjecture when we seek to inquire into the conditions that prevailed towards the close of the volcanic period. For just as we have proof that before this period began the Silurian strata had been subjected to the most intense denudation – had, in short, been worn into hill and valley – so do we learn from abundant evidence that the rocks representing the old volcanoes of the Cheviots are merely the wrecks of formerly extensive masses. Not only have the upper portions of these volcanoes been swept away, but their lower portions, likewise, have been deeply incised, and thousands of feet of solid rock have been carried off by the denuding forces. And by much the greater part of all this waste took place before the accumulation of those sandstones which now rest upon the worn outskirts of the old volcanic region.

III

Some reference has already been made (see p. 64) to the general appearance presented by the valleys of the Cheviots. In their upper reaches they are often rough and craggy; narrow dells, in fact, flanked with steep shingle-covered slopes, and occasionally overlooked by beetling cliffs, or fringed with lofty scaurs of decomposing rocks. As we follow down the valleys they gradually widen out; the hill-slopes becoming less steep, and retiring from the stream so as to leave a narrow strip of meadow-land through which the clear waters canter gaily on to the low grounds of the Teviot. In their middle reaches these upland dales are not infrequently well cultivated to a considerable height, as in the districts between Hownam and Morebattle, and between Belford and Yetholm – the former in the valley of the Kale, and the latter in that of the Bowmont. It is noticeable that all the narrower and steeper reaches lie among Silurian strata and Old Red Sandstone porphyrites. No sooner do we leave the regions occupied by these tough and hard rock-masses than the whole aspect of the scenery changes. The surrounding hills immediately lose in height and fall away into a softly undulating country, through which the streams and rivers have dug for themselves deep romantic channels. Nevertheless, it is a fact, as we shall see by-and-by, that south-west of the region occupied by the igneous rocks of the Cheviot Hills, all the higher portions of the range (Hungry Law, Carter Fell, Peel Fell, etc.) are built up of sandstones. For the present, however, I confine attention to those valleys whose upper reaches lie either wholly or in part among igneous rocks or Silurian strata. A typical and certainly the most beautiful example is furnished us by the vale of the River Jed. This stream rises among the sandstone heights which have just been mentioned as composing the south-west portion of the Cheviot range. The first seven or eight miles of its course lead us through a broad open valley, which has been hollowed out almost exclusively in sandstones and shales; by-and-by, however, we are led into a Silurian tract, and thereupon the valley contracts and the hill-slopes descend more steeply to the stream. But we soon leave the grassy glades of this Silurian tract and enter all at once upon what may be termed the lower reaches of the Jed. No longer cooped up in the rocky gully, painfully worn for itself in the hard greywacké and shales, the stream now winds through a much deeper and broader channel which has evidently been excavated with greater ease. Precipitous banks and scaurs here overlook the river at every bend, the banks becoming higher and higher and retiring further and further from each other, as the water glides on its way, until at last they fairly open upon the broad vale of the Teviot. Sometimes the river flows along one side of its valley for a considerable distance, and whenever this is the case, it gives us a line of bold cliffs which are usually flanked on the opposite side by sloping ground. This is the general character of all valleys of erosion, and especially of the lower reaches of the Jed.

A glance at the cliffs and scaurs of the Jed shows that they consist of horizontal or gently undulating strata of soft earthy, friable, shaly sandstone, arranged in thin beds and bands, which alternate rapidly with crumbling, sandy, and earthy shales; the whole forming a loose and unconsolidated mass that readily becomes a prey to the action of the weather, rain, frost, and running water. The prevailing colour is a dull red, but pale yellow, white, green, and purple discolorations are visible when the strata are closely scanned. The finest sections occur between Glen Douglas and Inchbonnie, and at Mossburnford, but the cliffs throughout present the same general appearance, and are picturesque in the highest degree. Everywhere the banks are thickly wooded, and even the steep red scaurs are dashed and flecked with greenery, which droops and springs from every ledge and crevice in which a root can fix itself. How vivid and striking is the contrast between the fresh delicate green of early summer and the rich warm tint of these rocks, which when lit up by the setting sun seem almost to glow and burn! Well may the good folk of Jedburgh be proud of the lovely valley in which their lot is cast. In no similar district in Scotland will the artist meet with a greater number of such "delicious bits," in which all the charms of wood and water, of meadow and rock are so harmoniously combined. It is not with the scenic beauties of the Jed, however, that we have at present to do. I wish the reader to examine with me certain appearances visible at the base of the red beds, where these rest upon those older rocks which have formed the subject of the preceding papers. In the bed of the river at Jedburgh, we see the junction between the red beds and the Silurian strata, and may observe how the bottom portions of the former, which repose immediately upon the greywackés, are abundantly charged with well-rounded and water-worn stones. Many of these stones consist of greywacké, hardened grit, and other kinds of rock, and most of them undoubtedly have been derived from Silurian strata. In other districts where the old igneous rocks of the Cheviots form the pavement upon which the red beds repose, the stones in the lower portions of the latter are made up chiefly of rounded fragments of the underlying porphyrites. All which clearly shows that the red beds have been built out of the ruins of the older strata of the district. This is unquestionably the origin not only of the conglomerates, but of all the red beds through which the River Jed cuts its way from the base of the hills to the Teviot. When we trace out the boundary of these beds, we find that this leads us along the base of the hills, close to the hill-foot; and not only so, but it frequently takes us into the hill-valleys also. And this shows that the Cheviots had already been deeply excavated by streams before any portion of the red beds was deposited.

I have said that the red beds are approximately horizontal; sometimes, however, they have a decided *dip* or inclination, and when this is continuous, it is invariably in a direction away from the hills. Thus as we traverse the ground from the hill-foot to the Teviot, we pass over the outcrops of the red beds and slowly rise from a lower to a higher geological position. The strata, however, are generally so flat that their dip is often not greater than the average slope or inclination of the ground. Hence when we ascend the valley-slopes from the stream, we soon reach the higher beds of the series, as, for example, in the undulating heights that overlook the Jed in the neighbourhood of Jedburgh. In that district a number of quarries have been opened, in which the upper beds of the red series are well exposed, as at Ferniehirst, Tudhope, etc. These consist of thick beds of greyish white, yellowish, and reddish sandstones, which, unlike the crumbling earthy deposits below, are quite suitable for building purposes. Scales of fish and plant remains are often met with in the thick sandstones, but the underlying earthy, friable red beds appear to be quite destitute of any organic remains.

Let us now briefly recapitulate the main facts we have just ascertained. They are these: – 1. All the low grounds that abut upon the hills are composed of horizontal or nearly horizontal strata, which consist chiefly of red earthy beds, passing down into conglomerates, and up into whitish and reddish sandstones. 2. The conglomeratic portion forms the boundary of the series, fringing the outskirts of the hills, and resting sometimes upon Silurian strata and sometimes upon Old Red Sandstone igneous rocks. 3. Fossils occur in the white and red sandstones, but seem to be wanting in the underlying red earthy beds.

The accompanying diagram gives a generalised view of the relation borne by the red beds to the older rocks of the Cheviots.

It will be seen that the former rest *unconformably* upon the Old Red Sandstone igneous rocks, and also, of course, upon the Silurian strata. The section shows that the red beds lie upon a worn and denuded surface. Now this speaks to the lapse of a long period of time. It may be remembered that we had some grounds for believing that the latest eruptions of the Cheviot volcanoes were sub-aërial. The evidence now enables us to advance further, and to state that after the close of the volcanic period, the whole Cheviot district existed as an elevated tract of dry land, from which streams flowed north and south. And for so long a time did these conditions endure, that the rivulets and streams were enabled to scoop out many channels and broad valleys before any of the outlying red beds had come into existence. Before the conglomerate beds were laid down, the ancient volcanic bank of the Cheviots had thus suffered great erosion. This is what "unconformability" means. It points to the prolonged continuance of a land-surface, subject as that must always be to the wearing action of the sub-aërial forces. Rain and frost disintegrate the rocks, and running water rolls the débris from higher to lower levels, and piles it up in the form of gravel, sand, and mud in lakes and the sea. While the old volcanic country of the Cheviots was being thus denuded, it would appear that a wide extent of land existed in the Northern Highlands and Southern Uplands of Scotland, and also in what are now the lake districts of England and the hilly tracts of Wales. And in all these regions valleys were formed, which at a subsequent time were more or less filled up with newer deposits.

The presence of the red beds that sweep round the base of the Cheviot Hills shows unmistakably that a period of submergence followed these land conditions. All the low grounds of Southern Scotland disappeared beneath a wide sheet of water, which stretched from the foot of the Lammermuirs up to the base of the Cheviots, and here and there entered the valleys, and so extended into the hills. This water, however, does not seem to have been that of an open sea; rather was it portion of a great freshwater lake, brackish lagoon, or inland sea. The lowest beds of the red series are merely hardened layers and masses of gravel and rolled shingle, which would seem at first sight to indicate the former action of waves along a sea-beach. There are certain appearances, however, which lead one to suspect that these ancient shingle beds may have had quite another origin. In some places the stones exactly resemble those which are found so abundantly in glacial deposits. They are sub-angular and blunted, and, like glaciated stones, occasionally show striæ or scratches. This, however, is very rarely the case. Most of the stones appear subsequently to have been rolled about in water, and in this process they must have lost any ice-markings they may have had, and become smoothed and rounded like ordinary gravel stones. The same appearances may be noted in the glacier valleys of Norway and Switzerland, where at the present day the glaciated stones which are pushed out at the lower ends of the glaciers are rolled about in the streams, and soon lose all trace of ice-work. It is impossible, however, to enter here into all the details of the evidence which lead one to suspect that glaciers may have existed at this early period among the Cheviot and Lammermuir Hills. In the latter district, the conglomerates occur in such masses and so exactly resemble the morainic débris and ice-rubbish of modern glacial regions, that the late Sir A. C. Ramsay long ago suggested their ice-origin.

Let us conceive, then, that when the ancient lake or inland sea of which I have spoken reached the base of the Cheviots, glaciers may have nestled in the valleys. Streams issuing from the lower ends of these would sweep great quantities of gravel down the valleys to the margin of the lake, and it is quite possible that there might be enough wave-action to spread the gravel out along the shores. It is evident, however, that the main heaps of shingle would gather opposite what were at that time the mouths of glacier valleys; and it is just in such positions that we now meet with the thickest masses of conglomerate. Ere long, however, the supposed glaciers would seem to have melted away, and only fine sand and mud, with here and there small rounded stones and grit, accumulated round the shores of the ancient lake. Of course, during all this time fine-grained sediment gathered over the deeper parts of the lake-bottom.

We have no evidence to show what kind of creatures, if any, inhabited the land at this time; nor do any fossils occur in the red earthy beds to throw light upon the conditions of life that may have obtained in the lake. If glaciers really existed and sent down ice-cold water, the conditions would hardly be favourable to life of any kind; for glacial lakes are generally barren. But the absence of fossils may be due to other causes than this. It is a remarkable fact, that red strata are, as a rule, unfossiliferous, and the few fossils which they do sometimes yield are generally indicative rather of lacustrine and brackish-water, than marine conditions. The paucity or absence of organic remains seems to have been often due to the presence in the water of a superabundance of salts. Now this excessive salinity may have arisen in either of two ways. First, we may suppose some wide reach of the sea to have been cut off from communication with the open ocean by an elevation of a portion of its bed; and in this case we should have a lagoon of saltwater, which evaporation would tend to concentrate to such a degree, that by-and-by nothing would be able to live in its waters. Or, again, we may have a lake so poisoned by the influx of springs and streams, carrying various salts in solution, as to render it uninhabitable by life of any kind, either animal or vegetable. Many red sandstone deposits, as Sir A. C. Ramsay has pointed out, are evidently lagoon-formations, which is proved by the presence of associated beds of rock-salt, gypsum, and magnesian limestone. They have slowly accumulated in great inland seas or lakes having no outlet, whose waters were subject to evaporation and concentration, although now and then they seem to have communicated more or less freely with the ocean. The red earthy beds of the Jed, however, though unfossiliferous, yet contain no trace of rock-salt or magnesian limestone. The only character they have in common with the salt-bearing strata of the New Red Sandstone of England is their colour, due to the presence of peroxide of iron, which we can hardly conceive could have been deposited in the mud of a sea communicating freely with the ocean. But a quiet lake, fed by rivulets and streams that drained an old volcanic district, is precisely the kind of water-basin in which highly ferruginous mud and sand might be expected to accumulate. Such a lake, tainted with the various salts, etc., carried into it by streams and springs (some of which may have been thermal; for, as we shall see presently, the volcanic forces, although quiescent, were yet not extinct), might well be unfitted for either animal or plant, and probably this is one reason why the red earthy beds of the Jed are so unfossiliferous.

After some time, the physical conditions in the regions under review experienced some further modification. Considerable depression of the land supervened, and the waters of our inland sea or lake rose high on the slopes of the Cheviots. Mark now how the character of the sediment changes. The prevailing red colour has disappeared, and white, yellow, and pale greenish or grey sand begins to be poured over the bed of the lake. Even yet, however, ferruginous matter exists in sufficient quantity to tint the sediment red in some places. With the appearance of these lighter-coloured sandy deposits, the conditions seem to have become better fitted to sustain life. Fish of peculiar forms, which, like the gar-pike of North American lakes, were provided with a strong scaly armour of tough bone, began to abound, weeds grew in the water, and the neighbouring land supported a vegetation now very meagrely represented by the few remains of plants which have been preserved. In some places fish-scales are found in considerable abundance. They belong to several genera and species which are more or less characteristic of the Old Red Sandstone formation. The most remarkable form was the *Pterichthys*, or wing-finned fish. Its blunt-shaped head and the anterior portion of its body were sheathed in a solid case of bone, formed by the union of numerous bony scales or plates. Two curious curved spine-like arms occupied the place of pectoral fins, and may have been used by the creature in paddling along the bottom of the sea or lake in which it lived. The posterior part of the body was covered with bony scales, but these were not suturally united. Other kinds of fish were the *Holoptychius* and *Coccosteus*, both of which were, like the Pterichthys, furnished with bony scales. The scales of the former overlapped, and had a curious wrinkled surface. The head of the Coccosteus was protected by a large bony shield or buckler, and a similar bony armour covered the ventral region.

The organic remains of these fish-bearing strata are too scanty, however, to enable us to form any idea of the kind of climate which characterised the district at this long-past period; but if we rely upon the fossils which have been met with in strata of the same or approximately the same age elsewhere, we may be pretty sure the climate was genial, and nourished on the land an abundant vegetation, consisting of ferns, great reeds, and club-mosses, which attained the dimensions of large trees, conifers, and other strange trees which have no living analogues.

It seems most likely that when the land sank down in the Cheviot district, so as to allow the old lake to reach as it were a higher level, some communication with the outlying ocean was effected. Red ferruginous mud would then cease to accumulate, or gather only now and then; the deposits would for the most part be white or yellow, or pale green; and fish would be able to come in from the sea. The communication with the ocean, however, was probably never very free, but liable to frequent interruption.

Here, then, ends the third great period of time represented by the rocks of the Cheviot district. The first period, as we have seen, closed with the deposition of the Silurian strata. Thereafter supervened a vast lapse of time, not recorded in the Cheviots by the presence of any rocks, but represented in other regions by younger members of the Silurian system. During this unrecorded portion of past time, the Silurian strata of the Cheviots were hardened, compressed, folded, upheaved to the light of day, and worn into hills and valleys by the action of the sub-aërial forces. Then began the second period of rock-forming in our district. Volcanoes poured out successive beds of molten matter and showers of stones and ashes, and so built up the rock-masses of the highest parts of the Cheviot Hills. These eruptions belong to the Old Red Sandstone age, and form a portion of what we term the Lower Old Red Sandstone. After the extinction of the volcanoes, another prolonged period elapsed, which is not accounted for in the Cheviots by the presence of any rocks. Then it was, as we know, that the great volcanic bank was denuded and worn into a system of hills and valleys. Now, since it is evident that the red beds of the Jed and other places are also of Old Red Sandstone age, it follows that they must belong to a higher place in the Old Red Sandstone formation than the much-denuded igneous rocks upon which they rest unconformably. The reasonable conclusion seems to be that the denudation or wearing away of the Lower Old Red Sandstone igneous rocks of the Cheviots was effected during that period which is represented in other districts of Scotland by what is called the Middle Old Red Sandstone, so that the Jed beds will thus rank as Upper Old Red Sandstone.

I come now to speak of certain rocks which, although they are developed chiefly beyond the limits of our district, yet require a little consideration before we can complete our account of the geological history of the Cheviots. The rocks referred to consist chiefly of old lava-beds, which very closely resemble those of the Lower Old Red Sandstone. They appear on the south side of the Tweed valley below Kelso, whence they extend south-west and west, crossing the river at Makerstoun, and sweeping north to form the hills about Smailholm, Stichill, and Hume. All to the east of these rocks, the valley of the Tweed is occupied by a great thickness of grey sandstones, and grey and blue shales and clays, with which are associated thin cement-stone bands, and occasional coarse sandy limestones called cornstone. These strata rest upon the outskirts of the Kelso igneous rocks, and are clearly of later date than these, since in their lower beds, which are often conglomeratic, we find numerous rounded fragments of the igneous rocks upon which the sandstones and shales abut. The latter have yielded a number of fossils, both animals and plants, to which I shall refer presently. In the bed of the Teviot near Roxburgh, and elsewhere, the Kelso igneous rocks are found reposing upon whitish and reddish sandstones, which are evidently the upper members of the red beds of the Jed Water and other localities.

Strata closely resembling the grey sandstones and shales of the Tweed valley appear among the Cheviot Hills at the head of the Jed Water, where they are marked by the presence of thick massive sandstones, which form all the tops of the hills between Hungry Law and the heights that overlook the sources of the Liddel Water – the greatest height reached being at Carter Fell, which is 1815 feet above the sea-level. The strata at this place contain some impure limestone and thin seams of coal, while beds of lava and tuff appear intercalated in the series.

Now let us rapidly sum up what seem to be the inferences suggested by these briefly-stated facts. We have seen that the Upper Old Red Sandstone began to be deposited in a lake which, as time wore on, probably communicated with the sea, while the land was undergoing a process of depression, so that the area of deposition was thus widely increased, and sediment gradually accumulated in places and at levels which had existed as land when the ancient lake first appeared in the Cheviot district. The old lava-beds of Kelso show that the volcanic forces, which had long been quiescent, again became active. Great floods of molten matter issued from the bowels of the earth, and poured over the bottom of the inland sea. But all the larger volcanoes of this period were confined to the centre of the Tweed valley. Not a few little isolated volcanoes, however, seem to have dotted the sea-bottom beyond the limits of the Kelso area. From these, showers of stones were ejected, and sometimes also they poured out molten matter. Their sites are now represented by rounded hills which stand up, more or less abruptly, above the level of the undulating tracts in which they occur. Among the most marked are Rubers Law, Black Law, the Dunian, and Lanton Hill. Of course it is only the plugged-up vents or necks that now remain; all the loose ejectamenta by which these must at one time have been surrounded have long since been worn and washed away. At last the Kelso volcanoes became extinct, and the little ones also probably died out at the same time. Another long period now ensued, during which the inland sea disappeared, and its dried-up bed was subjected to the denuding action of the sub-aërial forces. The volcanic rocks of the Kelso district suffered considerable erosion, while the softer sandy strata amongst which they were erupted no doubt experienced still greater waste. Ere long, however, the scene again changes; and what is now the vale of Tweed becomes a wide estuary, the shores of which are formed at first by the Kelso igneous rocks. Into this estuary, rivers and streams carry the spoil of the Southern Uplands, and strew its bed with sand and mud. Occasionally ferns and large coniferous trees are floated down, and, getting water-logged, sink to the bottom, where they become entombed in the slowly accumulating sediment. The character of these buried plants shows that the climate must have been genial. They belong to species which are characteristic of the Carboniferous system, and we look upon them with interest as the forerunners of that vast plant-growth which by-and-by was to cover wide areas in Britain, and to give rise to our coal-seams, the source of so much national wealth. In the waters of the estuary, minute crustaceous creatures called *cyprides* abounded, and with these was associated a number of small molluscs, chiefly univalves. Here and there considerable quantities of calcareous mud and sand gathered on the bed of the estuary, and formed in time beds of cement-stone, and impure limestone or cornstone. How long that condition of things obtained in the Tweed valley we cannot tell; but we know that after a very considerable thickness of sediment had accumulated, estuarine conditions prevailed over the south-west end of what is now the Cheviot range. This points to a considerable depression of the land. In this same region volcanic action appeared, and streams of lava and showers of fragmental materials were ejected – the remains of which are seen in Hungry Law, Catcleugh Shin, and the head-waters of the Jed. Genial climatic conditions continued; and here and there, along what were either low islets or the flat muddy shores of the estuary, plants grew in sufficient quantity to form masses of vegetation which, subsequently buried under mud and sand, were compressed and mineralised, and so became coal. The only place where these are now met with is on the crest of the Cheviots at Carter Fell. The process of depression still continuing, thick sand gradually spread over the site of the submerged forests. To trace the physical history immediately after this, we must go out of the Cheviot district; and it may suffice if I merely state that these estuarine or lacustrine conditions, which prevailed for a long time not only over the Tweed and Cheviot areas but in various other parts of Scotland, at last gave place to the sea. In this sea, corals, sea-lilies, and numerous molluscs and fishes abounded – all pointing to the prevalence of genial climatic conditions. The organic remains and the geological position of the estuarine beds of the Tweed and the Cheviots – resting as they do upon the Upper Old Red Sandstone – prove them to belong to the Lower series of the great Carboniferous system.

It was some time during the Carboniferous period that wide sheets of melted matter were forcibly intruded among the Old Red Sandstone and the Lower Carboniferous strata of the Cheviot district; but although these are now visible at the surface, as at Southdean, Bonchester, etc., they never actually reached that surface at the time of their irruption. They cooled in the crust of the earth amongst the strata between which they were intruded, and have only been exposed to view by the action of the denuding forces which have worn away the sedimentary beds by which they were formerly covered.

A very wide blank next occurs in the geological history of the Cheviots. We have no trace of the many great systems, comprising vast series of strata and representing long eras of time, which we know, from the evidence supplied by other regions, followed after the deposition of the Lower Carboniferous strata. The Middle and Upper Carboniferous groups are totally wanting, so likewise is the Permian system; and all the great series of "Secondary" systems, of which the major portion of England is composed, are equally absent. Nay, even Tertiary accumulations are wanting. There is one very remarkable relic, however, of Tertiary times, and that is a long dyke or vertical wall of basalt-rock which traverses the country from east to west, crossing the crest of the Cheviots near Brownhart Law, and striking west by north through Belling Hill, by the Rule Water at Hallrule Mill, on towards Hawick. This is one of a series of such dykes, common enough in some parts of Scotland, which become more numerous as we approach the west coast, where they are found associated with certain volcanic rocks of Tertiary age, in such a way as to lead to the belief that they all belong to the same period. The melted rock seems to have risen and cooled in great cracks or fissures, and seldom to have overflowed at the surface. Indeed it is highly probable that many or even most of the dykes never reached the surface at all, but have been exposed by subsequent denudation of the rocks that once overlaid them. Such would appear to have been the case with the great dyke of the Cheviot district.

We can only conjecture what the condition of this part of southern Scotland was in the long ages that elapsed between the termination of the Lower Carboniferous period and the close of the Tertiary ages. It is more than likely that it shared in some of the submergences that ensued during the deposition of the upper group of the Carboniferous system; but after that it may have remained, for aught we can tell, in the condition of dry land all through those prolonged periods which are unrecorded in the rocks of the Cheviot Hills, but have left behind them such noteworthy remains in England and other countries. Of one thing we may be sure, that during a large part of those unrecorded ages the Cheviot district could not have been an area of deposition. Rather must it have existed for untold eras as dry land; and this explains and accounts for the enormous denudation which the whole country has experienced; for there can be little doubt that the Lower Carboniferous strata of Carter Fell were at one time continuous with the similar strata of the lower reaches of the Tweed valley. Yet hardly a trace of the missing beds remains in any part of the country between the ridge of the hills at the head of the Jed Water and the Tweed at Kelso. Only little patches are found capping the high ground opposite Jedburgh, as at Hunthill, etc. Thus more than a thousand feet of Lower Carboniferous strata, and probably not less than five hundred or six hundred feet of Old Red Sandstone rocks, have been slowly carried away, grain by grain, from the face of the Cheviot district since the close of the Lower Carboniferous period.

IV

In the first of these papers some reference was made to the configuration of the ground in the Cheviot district. We have seen that the outlines assumed by the country have been determined in large measure by the nature of the rocks. Thus where igneous masses abound, the hills present a more or less irregular, and broken or lumpy contour, while the valleys are frequently narrow and deep. In the tracts occupied by Silurian strata, we have, as a rule, broad-topped hill-masses with a smoothly-rounded outline, whose slopes generally fall away with a long gentle sweep into soft green valleys, along the bottoms of which the streams often flow in deep gullies and ravines. Where the country is formed of sandstones, and other associated strata, the hills are generally broad and well-rounded, but the outline is not infrequently interrupted by lines of cliff and escarpment. These strata, however, are confined chiefly to the low-grounds, where they form a gently-undulating country, broken here and there, as in Dunian Hill, Bonchester Hill, Rubers Law, etc., by abrupt cones and knobs of igneous rock.

It is evident, then, that the diversified character of the Cheviot Hills and the adjoining low-grounds depends on the character of the rocks and also, as we shall see presently, upon geological structure. Each kind of rock has its own peculiar mode of weathering. All do not crumble away under the action of rain, frost, and running water in precisely the same manner. Some which yield equally and uniformly give rise to smooth outlines, others of more irregular composition, such as many igneous rocks, break up and crumble unequally in a capricious and eccentric way, and these in the course of time present a hummocky, lumpy, and rough irregular configuration. And as soft and readily-weathered rocks must wear away more rapidly than indurated and durable masses, it follows that the former will now be found most abundantly at low levels, while the latter will enter most extensively into the composition of the hills. But the contour of a country depends not only upon the relative durability of the rocks, but also upon the mode of their occurrence in the crust of the earth. Strata, as we have seen, do not all lie in one way; some are horizontal, others are inclined to the horizon, while yet others are vertical. Again, many rocks are amorphous; that is to say, they occur in somewhat thick masses which show no trace of a bedded arrangement. Such differences of structure and arrangement influence in no small degree the weathering and denudation of rocks, and cannot be left out of account when we are seeking to discover the origin of the present configuration of our hills and valleys. Thus, escarpments and the terraced aspect of many hill-slopes are due to inequalities in the strata of which such hills are built up. The softer strata crumble away more rapidly under the touch of the atmospheric forces than the harder beds which rest upon them, and hence the latter are undermined, and their exposed ends or crops, losing support, fall away and roll down the slopes. The igneous rocks of the Cheviots are arranged in beds; but so massive are these, that frequently a hill proves to be composed from base to summit of one and the same sheet of old lava. Hence there is a general absence of that terraced aspect which is so conspicuous in hills that are built up of bedded rock-masses. Here and there, however, the beds are not so massive, several cropping out upon a hill-side; and whenever this is the case (as near Yetholm) we find the hill-slopes presenting the usual terraced appearance – a series of cliffs and escarpments, separated by intervening slopes, rising one above the other. In the Silurian districts no such terraces or escarpments exist, the general high dip of the strata, which often approaches the vertical, precluding any such contour. In a region composed of highly-inclined greywacké and shale, however, we should expect to find that where the strata are of unequal durability, the harder beds will stand up in long narrow ridges, separated by intervening hollows, which have been worn out along the outcrops of the softer and more easily-denuded beds. And such appearances do show themselves in some parts of the Silurian area. As a rule, however, the Silurian strata are not thick-bedded, and harder and softer bands alternate so rapidly that they yield on the whole a smooth surface under the action of the atmospheric forces. In the low-lying districts, which, as I have said, are mostly occupied by sandstones and shaly beds, all the abrupt isolated hills are formed of igneous rocks, which are much harder and tougher than the strata that surround them. It is quite evident that these hills owe their present appearance to the durable nature of their constituent rocks, which now project above the general level of the surface, simply because they have been better able to resist the denuding agents than the softer rocks that once covered and concealed them.

We see, then, that each kind of rock has its own particular mode of weathering, and that the configuration of a country depends primarily upon this and upon geological structure. Indeed, so close is the connection between the geology and the surface-outline of a country, that to a practised observer the latter acts as an unfailing index to the general nature of the underlying rocks, and tells him at a glance whether these are igneous like basalt and porphyrite, aqueous like sandstone and shale, or hardened and altered strata like greywacké. But while one cannot help noticing how in the Cheviot district the character of the scenery depends largely upon the nature and structure of the rocks, he shall, nevertheless, hardly fail to observe that flowing outlines are more or less conspicuous over all the region. And as he descends into the main valleys, he shall be struck with the fact that the hill-slopes seem to be smoothed off in a direction that coincides with the trend of these valleys. In short, he cannot help noticing that the varied configuration that results from the weathering of different rock-masses has been subsequently modified by some agent which seems to have acted universally over the whole country. In the upper reaches of the Cheviot valleys, the rocks have evidently been rounded off by some force pressing upon them in a direction coinciding with that of the valleys; but soon after entering upon their lower reaches, we notice that the denuding or moulding force must have turned gradually away to the north-east – the northern spurs of the Cheviots, and the low-grounds that abut upon these being smoothed off in a direction that corresponds exactly with the trend of that great strath through which flow the Teviot and the Tweed, from Melrose downwards. Throughout this broad strath, which extends from the base of the Lammermuirs to the foot of the Cheviots, and includes the whole of Teviotdale, the ground presents a remarkable closely-wrinkled surface, the ridges and intervening hollows all coinciding in direction with the general trend of the great strath, which is south-west and north-east; but turning gradually round to east, as we approach the lower reaches of the Tweed.

Passing round the north-eastern extremity of the Cheviot range into Northumberland, we observe that the same series of ridges and hollows continues to follow an easterly direction until we near the sea-board, when the trend gradually swings round to the south-east, as in the neighbourhood of Belford and Bamborough, where the ridges run parallel with the coast-line.

The ridges and hollows are most conspicuous in the low-grounds of Roxburghshire and Berwickshire, especially in the regions between Kelso and Smailholm, and between Duns and Coldstream. The dwellers along the banks of the Tweed are quite familiar with the fact that the roads which run parallel with the river are smooth and level, for they coincide with the trend of the ridges and hollows; whilst those that cross the country at right angles to this direction must of course traverse ridge after ridge, and are therefore exceedingly uneven. In this low-lying district most of the ridges are composed of superficial deposits of stony and gravelly clay and sand, and the same is the case with those that sweep round the north-eastern spurs of the Cheviots by Coldstream and Ancroft. Some ridges, however, consist either of solid rock alone, as near Stichill, or of rock and overlying masses of clay and stones. In the hilly regions, again, nearly all the ridges are of rock alone, especially in the districts lying between Melrose and Selkirk and between Selkirk and Hawick. Indeed, the hills drained by the upper reaches of the Teviot and its tributaries are more or less fluted and channelled, as it were – many long parallel narrow hollows having been driven out along their slopes and even frequently across their broad tops. This scolloped and ridged aspect of the hills, however, disappears as we approach the upper reaches of the hill-valleys. From Skelfhill Pen (1745 feet) by Windburgh Hill (1662 feet), on through the ridge of the Cheviot watershed, none of the hills shows any appearance of a uniformly-wrinkled surface.

A close inspection of the rock-ridges satisfies one that they have been smoothed off by some agent pressing upon them in a direction that coincides with their own trend; and not only so, but the smoothing agent, it is clearly seen, must have come from the watersheds and then pressed outwards to the low-grounds which are now watered by the Teviot and the Tweed. This is shown by the manner in which the rocks have been smoothed off, for their smooth faces look towards the dominant watersheds, while their rough and unpolished sides point away in the opposite direction. Sometimes, however, we find that more or less steeply projecting rocks *face* the dominant watersheds. When such is the case, there is usually a long sloping "tail" behind the crag – a "tail" which is composed chiefly of superficial deposits. The hills between Hume and Stichill afford some good examples. The two kinds of appearances are exhibited in the accompanying diagram. The appearance shown in is of most common occurrence in the upland parts of the country, while "crag and tail" is seen to greatest advantage in the open low-grounds. In both cases it will be observed that superficial deposits (*t*) nestle behind a more or less steep face of rock.

When the rocks have not been much exposed to the action of the weather, they often show a polished surface covered with long parallel grooves and striæ or scratches. Such polished and scratched surfaces are best seen when the superficial deposits have been only recently removed. Often, too, when we tear away the thick turf that mantles the hill-slopes, we find the same phenomena. Indeed, wherever the rocks have not been much acted upon by the weather, and thus broken up and decomposed, we may expect to meet with more or less well-marked grooves and stride. Now the remarkable circumstance about these scratches is this – they agree in direction with the trend of the rock-ridges and the hollows described above. Nor can we doubt that the superficial markings have all been produced by one and the same agent. In the upper valleys of the Cheviots, the scratches coincide in direction with the valleys, which is, speaking generally, from south to north, but as we approach the low-grounds they begin to turn more to the east (just, as we have seen, is the case with the ridges and hollows), until we enter England to the east of Coldstream, where the striæ point first nearly due east, but eventually swing round to the south-east, as is well seen upon the limestone rocks between Lowick and Belford. In Teviotdale the general trend of the striæ is from south-west to north-east, a direction which continues to hold good until the lower reaches of the Tweed are approached, when, as we have just mentioned, they begin to turn more and more to the east. Thus it becomes evident that the denuding agent, whatever it was, that gave rise to these ridges and scratched rock-surfaces must have pressed outwards from all the dominant watersheds, and, sweeping down through the great undulating strath that lies between the Cheviots and the Lammermuirs, must have gradually turned away to the east and south as it rounded the northern spurs of the former range, so as to pass south-east over the contiguous maritime districts of Northumberland.

Конец ознакомительного фрагмента.