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The Physiography of Edinburgh

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THE SCOTTISH GEOGRAPHICAL MAGAZINE.

THE PHYSIOGRAPHY OF EDINBURGH.¹

A View from Arthur's Seat.

(*With Map.*)

By RALPH RICHARDSON, F.R.S.E., F.S.A. Scot. (Hon. Sec. R.S.G.S.)

THE term *Physiography* (literally "a description of Nature") was first applied by Professor Huxley to the subject of a series of lectures which he delivered to a general audience, "not on any particular branch of natural knowledge, but on natural phenomena in general." He states that he "wished to draw a clear line of demarcation, both as to matter and method, between it and what is commonly understood by *Physical Geography*." He endeavoured to give his audience, "in very broad but accurate outlines, a view of the *place in Nature* of a particular district of England—the basin of the Thames."

I shall venture to offer in very broad outlines and in very popular language—avoiding technical terms if I possibly can do so—a view of the *place in Nature* occupied by our

"own romantic town";

but, in justice to those whose names I venerate just as much as I do that of Huxley, I must state that there have been no exponents of the leading principles of the science of *Physiography*, as defined by him, more lucid, more eloquent, or more eminent than the founders of our own SCOTTISH SCHOOL OF GEOLOGY.

1. THE SCOTTISH SCHOOL OF GEOLOGY.

Whilst the great English geologists applied themselves particularly to the study of Rock-strata and the fossils which the rocks contained,

¹ Being a Lecture delivered, by request, in the Nelson Halls of Edinburgh Public Library, at Fountainbridge and Stockbridge, 19th and 21st February 1902.

the special characteristic of the Scottish School of Geology has been its devotion to the elucidation of the physical side of Geology. In this study of the Physiography of the globe Scottish geologists have stood conspicuous. Hutton, Playfair, Macculloch, Lyell, Murchison, Hugh Miller, Ramsay, Archibald and James Geikie, and others have raised this particular branch to the highest fame and dignity; have written upon it in language which is prized as classic and is known all over the English-speaking world; and have impressed by this means upon the public mind a knowledge of the fact that Geology is no mere dry-as-dust study of ancient rocks and ancient life-forms, but that it is a living interpreter of the world we inhabit, with all its natural beauties and wonders. These talented writers have cast a flood of light upon the last geological epoch—that epoch which is the most interesting to the general public, because it is the epoch during which Man made his appearance, and the world gradually assumed the form in which we find it to-day.

Why have Scottish geologists been so identified with this, the physical side of geology? I can only account for it by adducing the *genius loci*. The Scottish geologist does not, in his geological expeditions, find himself, as his English brother of the hammer too often does, standing in the midst of flat fields with a lazy stream meandering in a deep-cut channel through a country whose rocks belong to the later formations. On the contrary, the Scottish field-geologist—and all true Scottish geologists are field geologists—oftener finds himself standing on the mountain's brow surveying a strangely grand geological scene. The rocks around him are among the first created. Every modern rock has been removed from them, if it ever existed, by denudation. The rivers at his feet flow with the rapidity of mountain torrents. The lakes around him often occupy hollows scooped out by vast ice-sheets. He finds sand high up upon the mountains and all over their slopes. He thus obtains evidence of great movements which have taken place within recent times upon those ancient rocks which represent almost a previous eternity.

All these influences, acting upon his mind, turn its attention to the physical side of Geology. He begins to take an interest in the varied and often beautiful scene he sees around him, and not merely to admire its beauties, but to attempt to discover the agencies by which it acquired its present form. What shaped those mountains? What formed those terraces? How is sand strewed at such lofty elevations? Why are those rocks polished and striated? What placed that strange, far-travelled boulder on the very top of that hill? Why are Arctic shells found sometimes 500 feet above the nearest seashore?

In other words, every scene around him provokes its "Why" and "Wherefore," and his time is fully occupied in attempting to answer them, whilst health and vigour are imparted by the surveys he gladly undertakes. Contrast with this field geologist, so characteristic of the Scottish School, the student of fossils or minerals patiently studying at home, with the aid of lens and microscope, the internal secrets of the rocks, and you will, I think, admit that, although it is only one of the

provinces of Geology, we Scots have selected the most pleasing, the most healthful, and the most attractive. It is our side, too, that of Physiography, or the scientific study of Scenery, which has redeemed Geology from being styled, as the ignorant often call it, a dull and dead and dry science, for we have all lovers of Scenery upon our side, and these include every one worth the knowing.

2. ARTHUR'S SEAT.

In the true spirit, then, of our race, let us climb Arthur's Seat, and note the leading features of the physiography of Edinburgh. As we approach the hill, we remark its leonine configuration, which is due to the weathering it has received, and to the harder and softer rocks of which Arthur's Seat is composed, resisting or yielding to that weathering. Little does the average climber imagine the extraordinary character and assemblage of rocks comprised in Arthur's Seat. Looking at it from its southern side extending SW. and NE., we find, beginning at the SW., a series of sandstones and shales divided and penetrated by igneous rocks, such as the "Salisbury Crags," the "Echoing Rock," and "Samson's Ribs." Further east we come upon a mass of agglomerate, followed by one of porphyry forming the *Lion's nose*; a rounded mass of tuff, forming his noble *brow*. Then we observe the summit of the hill, and find that it forms the apex of a vast column of Basalt, one of the hardest of rocks, and which, like a huge stake driven into the ground, has defied denudation, and kept the whole assemblage of rocks together. Further east we find more tuff, a volcanic product, consisting of ash and pebbles blown out of the volcano which was once active here. The result of the softness of this tuff has been the production of the gracefully sloping *neck of the Lion*, whilst a series of Basalts and Amygdaloids further east have, owing to their hardness, resisted the weathering, and now form the *back or haunches* of the colossal Lion which guards the eastern approach to the Scottish metropolis.

Having gained the summit of the hill, let us look around upon the magnificent panorama which extends before us, perhaps the most splendid conjunction of hill, rock, city, and sea which Earth presents.

3. RAISED BEACHES.

I cannot help thinking that the first direction in which any one will look on attaining the summit of Arthur's Seat, and the first view he will enjoy, will be the view of the sea—the most glorious object in Nature. Let us, then, in considering the Physiography of Edinburgh, work from the coast inland, and begin with the sea-line.

Geologically, it is a very remarkable sea-coast, that which borders our familiar Firth of Forth. It attests several upward movements of the earth's crust here ere it settled down to become the scene of the history of our Scottish people.

A raised beach, some 25 to 30 feet above the present mean tide-

mark, skirts the entire shore-line. Musselburgh and Fisherrow are built upon it. So also is a considerable portion of Portobello. Leith Links and a large part of Leith stand upon it. Dalmeny House is situated upon the same raised beach, which indicates the old sea margin, now elevated considerably above flood-mark.

An older and still more remarkable raised beach occurs further inland. The Battle of Pinkie was fought upon or near it in 1547; the Battle of Prestonpans in 1745. It curves round behind Musselburgh and Portobello, and then passes through Edinburgh by Piershill, Abbeyhill, London Street, Royal Circus, the Dean Bridge, and Fettes College, continuing north-westwards behind Granton and Muirhouse. This raised beach is 100 feet above the level of the sea which once covered the land now occupied by Musselburgh, Portobello, Leith, and a large portion of the north side of Edinburgh.

4. LEADING CONTOURS.]

There is a gradual ascent of 300 feet and upwards from the sea-level at Leith to the higher portions of Edinburgh, such as the districts of Morningside, Merchiston, and Greenhill. My friend, Mr. J. G. Bartholomew, has kindly allowed me to see in manuscript an "Orographical" (or height-showing) map of Edinburgh, which he specially prepared some time ago, and which, besides others, exhibits the leading contours in the ascent from the level of the sea to the summit of the Castle, a distance of about $2\frac{1}{2}$ miles. From the sea at Leith to the junction of Balfour Street and Leith Walk marks a rise of 50 feet. Proceeding up Leith Walk to Haddington Place, we ascend another 50 feet. At the foot of Leith Street we have ascended 200 feet above the sea, and when we reach Princes Street we find its level to be 219 feet at the east end and 207 feet at the west end—for Princes Street is not level, as many suppose. We have to climb 130 feet above Princes Street ere we reach the Castle Esplanade (350 feet), and if we ascend to the highest point in the Castle we shall be 441 feet above the sea.

5. DENUDATION.

From a commanding height like that of Arthur's Seat (822 feet above the sea) we note a certain regularity and undulation in the general surface of the country around Edinburgh and on which the city is built. This is the result of the underlying rocks, consisting mainly of sandstones and shales, having been ground down by the passage over them, or by the action, of great denuding or eroding agencies in the past. The rocks here are very old, and belong to the Carboniferous period. The denudation of ages has passed over them, and has left them but the wreck of what they once were. They have been as thoroughly planed in surface and reduced in bulk as a piece of wood by a turning-lathe. Let us try and discover some of the agents which have imparted to them their present appearance.

As the volcanic rocks of Edinburgh were forced through the sandstones which once covered them by igneous agencies, and as the former

stand at present hundreds of feet above the latter, we can form a slight idea of the enormous removal of strata which denudation has occasioned in this district. Of the precise nature of that denudation we cannot be certain, as it occurred during distant geological ages, but of the more recent methods of denudation we have some knowledge, and I shall instance what our rocks have been subjected to during a period dating from at least the Glacial epoch to the present day.

6. GLACIAL ACTION.

The Glacial epoch began shortly before the appearance of Man, and continued after his advent, so we have at last some human chronology, however faint or distant, to give human interest to the picture. During this epoch the most intense cold prevailed, and the climate of Greenland was general over all Scotland. We had likewise all the Greenland concomitants at work—icebergs, glaciers, and that vast moving sheet of inland ice which covers Greenland to-day. And remark this, that all these glacial agencies were *active*—the Icebergs floating and depositing boulders, sand, and gravel—the Glaciers descending and forming moraines—the Icesheet moving and grinding the face of the rocks, and striating nearly every pebble it crushed, and producing that till or boulder clay which is found all over Midlothian, and is a tumultuous, unstratified substance, full of rounded, polished, scored, and travelled rocks and pebbles, some of the latter as finely striated as if by a diamond. Truly,

"The mills of God grind slowly,
But they grind exceeding small."

It is clear that, given these tremendous glacial engines moving over a district like ours for an enormous space of time, and the entire rock surface would be smoothened and worn down or covered with a deposit of boulder clay which is sometimes from 50 to 100 feet deep.

That is the modern and now accepted theory of the cause of the planing and polishing of rocks in the Edinburgh district, but it was not the theory advanced by several eminent old Edinburgh geologists. They thought that vast deluges had occurred, and that great streams of water had swept over the country and had given it its present undulating contour. It was the visit of the celebrated Swiss geologist Agassiz to Edinburgh in 1840 which led to our obtaining the key to the more recent denudation of rocks in Scotland. The guest of another great geologist, Charles Maclaren (Editor of *The Scotsman*), Agassiz visited with him several places in and around Edinburgh, and pronounced them to display the same evidences of ice-action which he knew so well in his native Alps. He reasoned, after the manner of our illustrious fellow-citizen James Hutton (the founder of the Scottish School of Geology), from the Known to the Unknown, and deciphered a riddle which had long puzzled local geologists.

One of these had been the celebrated Sir James Hall of Dunglass, one of the most famous of Scottish geologists. Sir James lived before Agassiz had promulgated his glacial theory, yet he went to Switzerland

to see whether the rocks there bore any resemblance to those of Corstorphine Hill and could throw any light upon the grooved, smoothed, and striated surfaces which the latter often present.

By a strange irony of fate this highly gifted man, standing with the whole glacial battery of the Alps displayed before him, remained blind to its teaching and power. He actually returned to Edinburgh after witnessing the glaciation of Switzerland, and in an elaborate paper read before our Royal Society, of which he was President, he gravely announced that the planed, grooved, and striated rocks of Corstorphine Hill were produced by great *débâcles* or torrents of water.

I remember when walking through the Hasli Thal in Switzerland, on my way from Meyringen to The Grimsel, being particularly struck with what are there called *roches moutonnées* (literally "sheep-backed rocks"). These long, smooth, rounded, striated rocks occur there in great profusion. I made sketches of several, and when I returned to Edinburgh I visited Corstorphine Hill to see whether there were any instances of *roches moutonnées* there also. I had no difficulty in recognising them, and I concluded, as all modern geologists have done, from these and other evidences, that that hill, like the entire neighbourhood of Edinburgh, had once been under the influence of a glacial epoch such as still exists on a small and shrunken scale in Switzerland and on a much greater scale in Greenland.

7. ACTION OF FROST.

I have instanced the action of Ice during the glacial epoch as helping to give the rocks around Edinburgh their present planed and mammilated form. But the action of Frost may at any time rend the hardest rock. The rock on which Edinburgh Castle stands is a particularly hard igneous rock, yet nearly every year the War Office employs men to remove the blocks and fragments which have been split off it by the action of Frost. Having frequently noticed the immense quantity of *débris* split by Frost from the Castle Rock during a single winter and collected in Johnston Terrace, I shall now state the reason for so large an amount of rock being displaced, and give you some statistics on the subject which have not been hitherto published.

The Basalt of which the Castle Rock is composed is excessively hard, but it is also jointed, and, during winter, Water filters into the joints and becomes frozen. The expansion caused by the conversion of the Water into ice bursts portions of the Basalt asunder, and, when a thaw comes, a heap of fragments marks where Frost, the quarryman, has been at work. As this process has been going on ever since the Castle Rock was exposed to the atmosphere, we can dimly imagine the enormous loss of rock to which the mass has been subjected. The area of the Rock presently exposed to the atmosphere measures about 700 feet by 800 feet with an elevation of 200 feet. I have ascertained from the Contractor employed by the War Office that, on an average, he annually removes 45 tons split off the Castle Rock during winter. So that even since the comparatively recent time when Prince Charlie appeared before the Castle in 1745 and vainly summoned it to surrender, the Rock has been

reduced in size by no less than 7065 tons. It will take, however, on the above calculation, more than 150,000 years before the action of Frost can remove the Castle Rock altogether.

8. ACTION OF WIND.

Another agent of what is called "sub-aërial" denudation is furnished by the proverbially frequent and powerful *Winds* of Edinburgh. Personally, I do not know a more wind-swept city. This, of course, has its advantages in freeing it from fogs (the curse of London), in promoting sanitation, and in rapidly drying the streets after rain. At the same time, very high winds have their drawbacks, and I have always desired to ascertain the scientific reason why they should be so prevalent in Edinburgh. I refer, of course, to our most frequent and most powerful winds, those from the west, which have caused so many of our tall chimneys and trees to lean towards the east. On an average, the strong south-west wind blows over the Edinburgh district during 119 days of the year. These tremendous winds have doubtless played for ages upon the rocks of the district and must have eroded them to a considerable extent. The position of our city—situated, as it is, generally 200 to 300 feet above the sea—at the end of a funnel which extends from the Atlantic by the Firth of Clyde to the Firth of Forth, whilst the comparatively level country traversed by the funnel does not break the force of the wind or shelter the city, forms, I venture to think, the reason why Edinburgh is so exposed to these great winds from the west. The elevation of the land following a straight line drawn from Greenock to Leith never exceeds 500 feet above the sea-level. It may be remarked, as a curious coincidence, that all the great denuding agencies which have affected the Edinburgh district—the preglacial, the glacial, and the prevalent winds—have come from the west and passed over it to the east.

Anecdotes of the force with which Edinburgh winds sometimes blow are not wanting. The first Editor of the *Edinburgh Review*, Sydney Smith, told how he rescued an Edinburgh citizen whom he found lying, blue in the face and helpless, having been blown by the wind against the door of Smith's house in George Street.

Writing in 1779, Hugo Arnot states in his *History of Edinburgh* (p. 319) that "the New Town is in a special manner exposed to very violent winds which rage in Edinburgh with incredible fury. Houses blown down, large trees torn up by the roots, people carried off their feet and beat down upon the pavement, are no uncommon circumstances in Edinburgh. It will hardly be credited," he adds, "that on Saturday the 3rd of January 1778, the Leith Guard, consisting of a sergeant and twelve men of the 70th Regiment, were all of them blown off the Castle Hill, and some of them sorely hurt."

An athletic country friend of my own told me that, arriving one night in Edinburgh, the wind suddenly carried him off his feet in Princes Street. His hat went in one direction, his spectacles in another, his bag in a third, and he had only time to clutch a lamp-post to save himself from being whirled into space.

9. EDINBURGH HURRICANES.

I can myself bear testimony to the violence of one hurricane, that of 24th January 1868, the details of which have been recorded in Dr. Buchan's *Handy Book of Meteorology* (p. 261), and in an article in *Good Words* by the father of Robert Louis Stevenson, Mr. Thomas Stevenson, C.E., President of the Royal Society of Edinburgh. I was then a W.S. apprentice in an office in South Castle Street, and never shall I forget the scenes I witnessed from its windows, for office-work and all business was at a standstill. Indeed, our junior partner (Mr. J. F. Rodger) was kept a close prisoner all day in Edmonston and Douglas's bookshop in Princes Street. The scene in South Castle Street was like the pandemonium occasionally enacted in the pantomime at the theatre when everything is set flying about at once. The wind tore the iron tops off the lamps and sent them hurtling through the air to the danger of any one daring enough to be in the street. Boys with fish trays had them swept off their heads and their contents scattered in every direction. Cabs were overturned. Cupolas were blown off. Slates descended in showers. Churches and houses were seriously damaged, and one house fell with a crash, killing its inmates and burying them in its ruins.

Dr. Buchan, who happened to be on that particular day at the Royal Observatory on the Calton Hill, says that between 2 and 3 P.M. the gravel on the platform facing the south was being blown off and about like hailstones in a shower of hail. Next morning every loose stone (several of them weighing 2 oz.) had been swept off this platform by the wind—a circumstance which is not known to have occurred before at the Observatory. Many cabs were blown down with their horses; in one case, the horse had somehow got disentangled from the tracings and was seen standing quietly beside the cab, when, on a sudden, it was blown to the ground, not even staggering as it fell, but falling just as if it had been a jointless piece of wood. While walking quickly against the wind, estimated at about 50 miles an hour—this was not the height of the storm,—Dr. Buchan says he was instantaneously brought to a stand by a gust so strong that the feeling produced was the same as if he “had unwittingly walked up against something solid, such as a shut door.”

This hurricane was from the south. Only the other day (12th and 13th November 1901) we had one from the north-east which wrecked a house causing the death of a girl, carried away a staircase causing a man's death, and which dashed the revenue cutter *Active* against Granton breakwater, whereby twenty-two lives were lost. The maximum velocity of the wind on this occasion was, however, only 67 miles an hour, whereas during the hurricane of 1868 and the great storm of 20th December 1900 it exceeded 90 miles an hour.

I have dwelt upon the influence of Wind as a leading erosive agent in the Edinburgh district because I think its action there is often forgotten or minimised.

If you consider the long continuance of the denudation in the later geological epochs effected by the agents I have mentioned—(1) The Glaciers, Icebergs, and Icesheet of the Glacial Age; (2) The Action of

Frost; and (3) The Action of Wind—you will understand the cause of the sedimentary and even the igneous rocks in and around Edinburgh having that rounded, polished, smoothened, and mammilated appearance which they exhibit to-day.

10. IGNEOUS ROCKS AND SCENERY.

We now come to a very interesting subject of which the Physiography of Edinburgh furnishes an admirable illustration, viz., the supreme influence exercised by the Igneous rocks of a district in forming the Scenery of the district. By igneous rocks I mean those formed and erupted by the action of the intense internal heat of the earth, and those volcanic rocks which are the products of the action of volcanoes. Of course, igneous or fire-formed rocks are as different from aqueous or water-formed rocks as the Castle Rock is from Craigleith Quarry.

After what we have seen of the degradation by denuding agencies of the water-formed rocks of Edinburgh, it must be evident that had their long, rounded, smoothened surfaces been all that met the eye of the stranger visiting Edinburgh, he would certainly not have described it as one of the fairest scenes he had ever witnessed. Fortunately that degradation and platitude have been redeemed and are forgotten by reason of another class of rocks making their appearance in this district. I refer to rocks which are the products of igneous action, and were not laid down, like the others, layer by layer, in regular strata, by water.

Standing, as we are supposed to do, on the summit of Arthur's Seat and looking at the scene around us, we observe romantic crags breaking at intervals from the tame undulating country surrounding them and imparting to the scene a picturesqueness which it would not otherwise possess. We observe, too, that they differ from the surrounding rocks by their ruggedness, their colour, and their bold and isolated character, and that they seem to have defied the elements to which the others succumbed, and to stand there like grim survivors from the wreck of a previous age.

These rocks, to which Edinburgh is so much indebted for her scenery, are *igneous* rocks, the products of the great volcanic outbursts which occurred during Old Red and early Carboniferous times. How many volcanoes then existed in the Edinburgh district it is difficult to say, but I think we may locate one at Arthur's Seat, others throughout the Braid Hills and Northern Pentlands, and another at Torduff near Bonally. Whilst these volcanoes were throwing up ash, scoriæ and bombs, and whilst lava-streams were issuing from their flanks, other masses of lava burst through the aqueous rocks at other places, and now (owing chiefly to the denudation of the latter) tower hundreds of feet above them.

11. THE CASTLE ROCK SECTION.

Such was the Castle Rock; and if you desire an object-lesson and to learn how lava breaks through sandstones and forces its way upwards, you can easily obtain it by inspecting the famous section on the southern

side of the Castle Rock at Johnston Terrace, where you will see the contact between the lava-stream and the aqueous rocks, and can picture to yourselves the former seizing the latter in its fiery grip, and, whilst breaking its way through the strata, baking and calcining the sandstones with its terrific heat, and carrying portions of them with it in its wild rush upwards.

12. EDINBURGH TRAP DYKES.

All over the City's site outbursts of lava occurred, and what are termed "trap dykes" prove that ancient lava-streams poured through localities now known as St. Leonards, Buccleuch Place, Nicolson Street, Hillside, Lauriston, Chambers Street, High Street, Cowgate, Grass-market, Spittal Street, Gilmore Place, Merchiston, Fountainbridge, Hanover Street, Water of Leith, Drummond Place, Brandon Street—in fact, no fewer than thirty Trap Dykes have been discovered in the area now occupied by the city, showing that the whole district had been subject to those great igneous convulsions and eruptions which we associate with areas of active volcanic disturbance.

13. EDINBURGH EARTHQUAKES.

Earthquakes are well-known concomitants of volcanoes, and although Edinburgh has experienced none of any importance in historical times, yet since the sixteenth century Earthquake shocks were felt in the Edinburgh district in November 1608, September 1789, September 1801, April 1886, February 1888, and somewhat remarkable shocks on 18th January 1889, the area of which I fully described and mapped in the *Scottish Geographical Magazine* for that year.

14. CRAG AND TAIL.

Looking once more from our lofty conning-tower on Arthur's Seat, our eyes instinctively fasten on that magnificent height

"where the huge Castle holds its state,
And all the steep slope down
Whose ridgy back heaves to the sky
Piled deep and massy, close and high,
Mine own romantic town!"

Sir Walter Scott here describes poetically, yet with his invariable accuracy, a natural phenomenon which is called "Crag and tail," and of which the Castle hill furnishes an excellent example. Let us consider its geology.

To the west we find at a low level stratified rocks, and rising through and far above them a mass of Basalt, a particularly hard igneous rock, which has been forced through the strata as already described. Upon this igneous mass Edinburgh Castle is built. Sloping gradually from the mass in an easterly direction, from the Castle Hill to Holyrood, are stratified rocks upon which the High Street and Canongate are built.

Thus we find a "crag" or igneous boss at the west end, with a "tail" of stratified rocks sloping down to the east. This is the phenomenon known as "Crag and tail." In this instance, the hard Castle rock has protected the softer sandstones behind it from some tremendous denuding agent issuing from the west—of the precise nature of which we are ignorant, but it was long before glacial times,—an agent which tore off the strata unprotected by the rock and left the Castle crag standing with its tail of strata extending behind it, just as you will see the stones on the seashore or in the brook each with a tail of sand or earth produced by the receding tide or the flowing stream.

Herculaneum was entombed under lava, whilst Pompeii was buried under clouds of ashes blown out of the volcano. The site of Edinburgh has known both of these terrible visitations. Whilst the Castle Rock represents a gigantic outburst of lava, the Calton Hill is largely the creation of volcanic ash. The layers of ash, however, being strengthened and upheld by layers of solid lava, the whole has proved a bulwark or "crag" to a "tail" of stratified rocks stretching to the east, thus furnishing another instance of the great denuding agent from the west having been defeated in its attempt to make a *tabula rasa* of the whole scene. It is, I repeat, owing to the successful resistance offered by these igneous rocks that eminences exist which impart beauty and variety to the scenery of Edinburgh.

In Corstorphine Hill we have an example of a vast sheet of Basalt towering above the sandstones which yielded to the denuding agencies of the past, whilst the hardness of the Basalt enabled it successfully to resist them. Similarly, the Porphyrite forming Blackford Hill and the greater part of the Pentland Hills had sufficient power to withstand the erosion which levelled the surrounding shales and sandstones. In a word, but for the outburst of igneous and volcanic violence which occurred in this district, the hills and crags we so much admire to-day, and which really *make* the scenery of Edinburgh, would not have existed, and a flat and uninteresting landscape would have been produced.

We have now discussed two of the four elements, EARTH and FIRE, as influencing in geological time the formation of the present physiography of our district. I propose to conclude this paper by glancing at the other two elements, WATER and AIR, the former as illustrated by the Rivers, Sea, and Lakes of our neighbourhood, the latter as connected with its Climate and Vegetation.

15. RIVERS AND FIRTH OF FORTH.

Viewed from a height like Arthur's Seat we survey a district watered by three rivers—the *Almond* on the west, the *Water of Leith* in the middle, and the *Esk* on the east. All are small streams, not exceeding thirty miles in length. The *Almond* rises among the uplands of Shotts in Lanarkshire, 900 feet above the sea, and falls into the Firth of Forth at Cramond. The *Water of Leith* springs from the north-western flanks of the Pentlands, 1000 feet above the sea, and falls into the Firth at

Leith. The *Esk* is divided into a North and a South *Esk*, the former rising amid the southern recesses of the Pentlands, over 1000 feet high, and the latter among the Moorfoot Hills at even a greater elevation. The North and South *Esks* unite below Dalkeith and fall into the Firth of Forth at Musselburgh. These three rivers form the natural water area of the Edinburgh district, and all flow northwards since the land slopes in that direction towards the sea. The antiquity of these streams may be judged from the fact that two of them, the Almond (a corruption of Avon) and the *Esk*, retain the names given them by the earliest Celtic settlers in Scotland, and both signify in Gaelic simply "water," or "a river."

The River Forth and its estuary at our doors, the Firth of Forth, nearly sever Scotland in twain, bisecting it as they do for nearly 90 miles from west to east. They have been formed since the sedimentary rocks were deposited, for these are found extending across the Firth, which follows a gradually deepening channel of 5, then 10, then 20 fathoms, and eventually discharges into a depression outside the Isle of May of 30 fathoms before reaching the great North Sea depression of 50 fathoms.

16. ANCIENT LAKES.

In comparatively recent times, however, the scenery of the Edinburgh district was diversified not only by rivers and sea, but also by lakes now represented by sorely shrunken descendants or by flat meadows, fields, and building stances. With the aid of Timothy Pont's map of Midlothian, published about 270 years ago, and other authorities, Mr. H. M. Cadell has described and mapped these old lakes, and has instanced the following as draining into the Water of Leith:—

1. A lake a mile in length which stretched from Gogar to Corstorphine, and communicated with

2. A lake two miles in length which stretched from Corstorphine to the Haymarket.

3. The "Burgh Loch," which occupied the entire "Meadows," drained into the latter lake. A windmill to the east of George Square raised water from the Burgh Loch to supply the Incorporation of Brewers.

4. A lake near Craigcrook.

5. A lake at Canonmills.

There was also the "Nor' Loch," occupying part of the site of the West Princes Street Gardens. This was, in 1742, a sheet of water 1800 feet long by 400 feet broad, although it had previously extended considerably further to the west.

Other lakes of greater antiquity were:—

1. A lake at Lochend (still partially remaining) which drained into the sea at Leith Links.

2. A lake nearly a mile long which covered the site of Holyrood and the east end of the Canongate and Cowgate. Its outflow and that of Dunsappie Loch entered the sea at Craighentinny.

3. Duddingston Loch, not in its present decrepitude, but a splendid

lake $1\frac{1}{2}$ miles in length by 1 mile in breadth. Its waters fell into the sea at the west end of the present Portobello. Connected by streams with Duddingston Loch were a lake between Craiglockhart and Morning-side, and another on the south side of the Grange.

17. FOSSIL WILD ANIMALS.

The wild animals of those olden times are worthy of notice to complete the picture. Remains of the moose or elk have been found at Duddingston Loch; those of the mammoth at Cliftonhall, near Edinburgh; and, with signs of the hyæna, those of the reindeer and the wolf at Dreghorn, near Edinburgh. The last-mentioned need not surprise us, for wolves were once so plentiful in Scotland that an act of the seventh Parliament of King James I., held in 1427, ordered barons to have them slain. The last Scottish wolf is said to have been killed in 1743.

18. THE CLIMATE OF EDINBURGH.

I next pass to a subject of some delicacy—the CLIMATE of Edinburgh. If you ask a person who does not reside in our city what he thinks of it he will probably reply, "It would be a nice place, if it weren't for its east winds." The deliberate opinion of outsiders is that we have east winds in Edinburgh all the year round. This, of course, is absurd. Our prevalent winds are from the west, there being, on an average, 199 days of westerly wind in the year against only 84 of easterly winds. We have east winds no more frequently than other places, and when we do get them (chiefly in spring) they are no more keen or disagreeable than elsewhere. In fact, a friend of mine from Edinburgh who stayed in Dublin during one spring declared that the east winds of Edinburgh were nothing to those of Dublin, so far as piercing cold went.

But I must admit that, meteorologically, the position of Edinburgh is not all that is to be desired. True, the influence of the marine atmosphere of the city and of its being constantly agitated by wind tends to produce a much higher temperature in winter than that of towns situated inland or in air-locked positions. This fact makes Edinburgh one of the best winter residences to be found north of the Riviera.

Nor is our winter sunshine deficient. In November 1900, invalid friends of mine went to Hastings, as it was said to be the sunniest place in England, and I had the curiosity to compare its sunshine returns, which they sent me as published weekly, with my own observations of sunshine in Edinburgh for the same period. I was surprised to find that our city had enjoyed more hours of sunshine than the English Heliopolis.

At the same time, Edinburgh is surrounded on the south and south-west by a circle of hills and uplands, and when these are covered with snow the winds blowing over them become necessarily chilled. Thus, it is common in winter to hear in Edinburgh the exclamation, "What a cold East wind!" when really the wind comes from the south-west, but had crossed the snow-covered Pentland Hills, which attain an elevation of nearly 1900 feet above the sea.

The dwellers in Old Edinburgh, the "Auld Reekie" of popular parlance, were not, like these of modern Edinburgh, exposed to every wind that blew, for their houses were so closely packed together that they defied both wind and cold. Gordon of Rothiemay's beautiful bird's-eye view of Edinburgh shows us the town as it was in 1647, and I have no doubt that, to this day, the ancient houses of the Cowgate occupy a much more sheltered position than many of the modern houses of the wealthy. *Beati sunt pauperes.*

Glasgow people say that when they arrive in Edinburgh they always feel a "bite in the air." This is true, for they come from the relaxing climate of the West to the bracing climate of the East of Scotland; and that they appreciate the sanitary value of the latter is shown by their now deserting so much, for summer quarters, the Firth of Clyde and patronising the shores and golf-links of the Firth of Forth.

The Edinburgh climate, being of a bracing and stimulating character, is very favourable to physical and intellectual activity. No city stands higher than ours in the literary and scientific annals of the world. Its schools and University have been famous for generations. Its publishers, printers, and men of letters have had a world-wide clientage. Intellectual pursuits are a marked feature of the citizens. They are unwearied attenders of public lectures. They are great readers of books. Indeed, there are said to be, per head of the population, more books in Edinburgh than in any other city, except Rome. And, while I am on the subject of Physiography, I may add that I have been informed that half of the maps used by the world are produced in the city of Johnston and Bartholomew.

19. LATITUDE AND LONGITUDE.

It is not generally recognised that Edinburgh is further west than Liverpool, and much further west than London, their respective longitudes being—

London,	0° 5' west of Greenwich.
Liverpool,	2° 59' "
Edinburgh,	3° 12' "

This is caused by Scotland making a bend to the west at the English frontier. With regard to the latitude of Edinburgh (55° 57' North), the fact that its latitude corresponds to that of Moscow proves that a city like ours, on a sea-coast influenced by the Gulf Stream, enjoys a mild winter climate, whilst an inland Continental city endures a rigorous one. Thus, whilst the mean temperature of Edinburgh in January is about 40° Fahrenheit, that of Moscow during that month is about 20°.

20. TEMPERATURE.

The temperature of Edinburgh is in winter much the same as that of London, but it is much lower than that of the latter in summer. Whilst in December the mean temperatures of Edinburgh and London may both be 40°, in July that of Edinburgh will be 58° against London's 64°. But Edinburgh has not, like London, a great river flowing through its midst and producing those most disagreeable fogs caused by a mixture of river-vapour, sulphur, and coal-dust. Again, although the tempera-

ture of Edinburgh is less than that of London in summer, the greater length of the day we then enjoy enables crops to ripen quite as well in Midlothian as in the south of England. On an average, the day at Edinburgh in June is 53 minutes longer than in London; in July 48 minutes, and in August 27 minutes. I am indebted to that eminent meteorologist, Dr. Buchan, for this calculation, which was kindly made by his directions, at my request, especially for this paper.

21. RAINFALL.

As the winter temperatures of London and Edinburgh are practically identical, so there is little difference in regard to their mean annual rainfall, which is about 25 inches. Both capitals belong to that dry bracing East Coast border of Great Britain which contrasts with the West Coast as regards rainfall and general humidity. The further west you go in Britain the wetter and more relaxing the climate becomes. Whilst at Edinburgh you will measure 25 inches of rain per annum, at Glasgow you will measure 43, at Greenock 61, and at the head of Loch Fyne 127.

But, just as you observe the rainfall increasing as you ascend a river towards the mountains among which the river springs, so, when you leave the city of Edinburgh, and ascend the spurs of the Pentland Hills to the south, you find the rainfall rising also. I have stated the City rainfall at 25 inches per annum. This is at a height of 200 feet above the sea. Leaving the City and ascending southwards to 555 feet at Swanston, we find the rainfall to be 34 inches; at Clubbiedean (780 feet) 38½ inches; and at Colzium (1000 feet) 42½ inches, or nearly as much as Glasgow.

The fact is not generally known that the rainfall of Edinburgh is considerably less than that of that favourite winter resort, the Riviera. Comparing the rainfalls of Edinburgh and Nice as recorded during a long series of years, I find the following averages for their winter months:—

	Edinburgh.	Nice.
	ins.	ins.
November	2·07	4·65
December	1·94	3·47
January	1·81	3·12
February	1·61	2·13
Total for winter	<u>7·43</u>	<u>13·37</u>

During 1901 the rainfall of Mentone was 46·85 inches, whilst that of Edinburgh was only 22·60 inches, or less than half.

Although we have surveyed the wonderful scene from Arthur's Seat from nearly every point of view, there remains one which appeals to every eye. I refer to the Vegetation and cultivation of the soil.

When the Celt or the Roman looked out from the spot on which we are supposed to be standing—the summit of Arthur's Seat—they beheld, no doubt, a lovely scene, where Nature displayed all her charms disturbed but little by Man. Great forests beautified by splendid lakes stretched

as far as the horizon, whilst here and there rose craggy strongholds, one of which was the *Castell Myned Agned* of the Celt, the *Castrum puellarum* of the Roman.

22. AGRICULTURE.

Now, however, Man has by his restless activity brought the whole district under his subjection, and the plough passes where the red-deer roamed. The country around Edinburgh is agriculturally famous—soil, climate, and agricultural skill combining to make it one of the richest and best-farmed districts of Great Britain.

One of the most elaborate surveys of the vegetation of this neighbourhood was that made and mapped in 1900 by Mr. Robert Smith, B.Sc., of University College, Dundee—a talented youth, whose death, in the midst of his labours last year, deprived Scotland of one of her most promising students of Nature. Mr. Smith found that all the district round Edinburgh, with the exception of the hills and uplands, was suited to the cultivation of *wheat*, which is the highest praise that can be bestowed upon an agricultural district in this country.

I have had myself some share in valuing the land comprised in the county of Edinburgh, having prepared and published in 1878 an agricultural map of Midlothian, which met with the approval of the official County Assessor, the late Mr. William Kennedy. In this map I showed the varying rentals for which the land of the county might fairly be let. These rentals naturally grew higher and higher as the City was approached, because market and labour facilities were thereby increased. Whilst the uplands of Midlothian yielded a rental of under £1 per acre, lower-lying ground yielded from £1 to £2, and lower still £2 to £3 and £3 to £4. The Dalkeith and Liberton districts yielded from £4 to £5, whilst the land encircling Edinburgh on the NE. and NW., from Duddingston to Saughton Hall, was valued at from £5 to £6 per acre. Extra fertile portions to the East and NW. of the city also averaged from £6 to £8. Finally, the Craigentenny Meadows, enriched by the city sewage, returned the extraordinary rental of £20 to £40 per acre, a proof that what are called "waste products" are often products which are only waiting to be turned to splendid account.

23. ECONOMIC GEOLOGY.

Boon Nature has, however, not merely dowered the surface-soil of the Edinburgh district with fertility, she has likewise laden the ground beneath with treasures of great economic value. Important *coalfields* (still largely undeveloped) extend to the east of Edinburgh; great *shalefields*, productive of paraffin, extend to the west; whilst, in the immediate vicinity of the city, the water percolating through certain sandstones has enabled *Brewers* to produce a beverage for which Edinburgh has long been famed. *Building stones*, often of the rarest quality, are found in many quarries of the district; some, no doubt, nearly worked out, but not until they had helped to make Edinburgh—not, like London, a wilderness of brick—but a noble city built entirely of stone, a city which it is our joy to behold, and every grace of which it should be our duty to preserve.

24. CITY IMPROVEMENTS.

The citizens and the Corporation of Edinburgh have, during the past half-century, done their best to conserve her beauty. Any one who has looked at the views of our city executed by Thomas H. Shepherd about 1830 will admit that her appearance has been greatly improved since then. In 1830 the East Princes Street Gardens were a public bleaching-field, the Mound was, according to Lord Cockburn, "a deposit of rubbish," and the site of the Waverley Market was occupied by a rookery of tenement-houses. I remember hearing our illustrious townsman, the late Lord Moncreiff, remark that in his time Edinburgh had immensely improved in appearance; and since his day she has, I think, made herself more and more worthy to occupy the magnificent site which Nature has given her, a site which Man may embellish, but which, fortunately, he cannot destroy.

We have now considered the Physiography of Edinburgh under many different aspects, and I trust that I have given, in however broad an outline, a fair, full, and faithful description of the "place in Nature" occupied by the Scottish capital. It must always be a privilege and a pleasure to a citizen of Edinburgh to dwell upon her features, to celebrate her charms. If I have afforded any one any pleasure in reading these pages, I shall feel that my endeavour to describe the Physiography of Edinburgh has been amply rewarded.

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II.—TABLES showing the Length of Day in Summer at London and Edinburgh respectively. Specially prepared by directions of Dr. Alex. Buchan, F.R.S., Secretary, Scottish Meteorological Society, 27th December 1901.

JUNE.

Day.	London.		Edinburgh.		The day at Edinburgh is
	H.	M.	H.	M.	
1	16	13	17	4	51 minutes longer.
2	16	15	17	7	52 " "
3	16	17	17	10	53 " "
4	16	20	17	12	52 " "
5	16	21	17	14	53 " "
6	16	23	17	16	53 " "
7	16	23	17	18	55 " "
8	16	25	17	20	55 " "
9	16	26	17	22	56 " "
10	16	28	17	23	55 " "
11	16	29	17	25	56 " "
12	16	30	17	26	56 " "
13	16	31	17	27	56 " "
14	16	31	17	28	57 " "
15	16	32	17	30	58 " "
16	16	32	17	31	59 " "
17	16	33	17	31	58 " "
18	16	33	17	32	59 " "
19	16	34	17	32	58 " "
20	16	34	17	32	58 " "
21	16	34	17	32	58 " "
22	16	34	17	32	58 " "
23	16	34	17	32	58 " "
24	16	34	17	32	58 " "
25	16	33	17	32	58 " "
26	16	33	17	31	58 " "
27	16	33	17	31	58 " "
28	16	32	17	31	59 " "
29	16	32	17	29	57 " "
30	16	30	17	28	58 " "
53'0 = Average.					

Hence—During the month of June the sun is above the horizon for 26 hours 30 minutes longer at Edinburgh than at London.

¹ These apparent irregularities are due to calculations having been made to minutes only, and not to seconds also.

JULY.

Day.	London.		Edinburgh.		The day at Edinburgh is
	H.	M.	H.	M.	
1	16	29	17	26	57 minutes longer.
2	16	29	17	25	56 " "
3	16	28	17	23	55 " "
4	16	26	17	21	55 " "
5	16	25	17	18	53 " "
6	16	23	17	16	53 " "
7	16	23	17	14	51 " "
8	16	21	17	12	51 " "
9	16	19	17	10	51 " "
10	16	18	17	8	50 " "
11	16	16	17	6	50 " "
12	16	13	17	4	51 " "
13	16	11	17	2	51 " "
14	16	9	17	0	51 " "
15	16	7	16	57	50 " "
16	16	5	16	54	49 " "
17	16	3	16	52	49 " "
18	16	1	16	48	47 " "
19	15	58	16	46	48 " "
20	15	56	16	42	46 " "
21	15	54	16	40	46 " "
22	15	51	16	36	45 " "
23	15	48	16	34	46 " "
24	15	46	16	30	44 " "
25	15	43	16	26	43 " "
26	15	40	16	22	44 " "
27	15	37	16	20	43 " "
28	15	34	16	16	42 " "
29	15	31	16	12	41 " "
30	15	28	16	8	40 " "
31	15	26	16	6	40 " "
					48'3 = Average.

Hence—During the month of July the sun is above the horizon for 24 hrs. 58 min. longer at Edinburgh than at London.

AUGUST.

Day.	London.		Edinburgh.		The day at Edinburgh is
	H.	M.	H.	M.	
1	15	22	16	2	40 minutes longer.
2	15	20	15	58	38 " "
3	15	16	15	54	38 " "
4	15	13	15	50	37 " "
5	15	10	15	46	36 " "
6	15	6	15	42	36 " "
7	15	2	15	38	36 " "
8	14	59	15	34	35 " "
9	14	56	15	30	34 " "
10	14	53	15	26	33 " "
11	14	50	15	20	30 " "
12	14	46	15	16	30 " "
13	14	43	15	12	29 " "

¹ These apparent irregularities are due to calculations having been made to minutes only, and not to seconds also.

AUGUST—continued.

Day.	London.		Edinburgh.		The day at Edinburgh is
	H.	M.	H.	M.	
14	14	39	15	7	28 minutes longer.
15	14	35	15	2	27 " "
16	14	32	14	58	26 " "
17	14	28	14	54	26 " "
18	14	25	14	50	25 " "
19	14	21	14	46	25 " "
20	14	17	14	42	25 " "
21	14	14	14	38	24 " "
22	14	10	14	33	23 " "
23	14	7	14	28	21 " "
24	14	3	14	24	21 " "
25	13	58	14	20	22 " "
26	13	55	14	16	21 " "
27	13	51	14	11	20 " "
28	13	48	14	6	18 " "
29	13	44	14	2	18 " "
30	13	41	13	57	16 " "
31	13	36	13	52	16 " "
27'5 = Average.					

Hence—During the month of August the sun is above the horizon for
14 hrs. 14 min. longer at Edinburgh than at London.

III.—TABLE showing the average number of days each Wind prevailed in the Edinburgh District (at Inveresk, Midlothian) during the 15 years ending 1871. (Founded on Dr. Buchan's statistics in *Journal*, Scottish Meteorological Society, July 1872, p. 302.)

SPRING—

MONTHS.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	CALM.
March, . . .	4	4	2	2	3	9	4	3	0
April, . . .	3	6	3	2	2	8	4	2	0
May, . . .	4	7	3	1	3	7	4	2	0
Spring, . .	11	17	8	5	8	24	12	7	0

SUMMER—

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	CALM.
June, . . .	4	4	1	2	3	8	5	3	0
July, . . .	3	4	1	1	3	12	5	2	0
August, . .	2	3	1	1	4	11	6	3	0
Summer, . .	9	11	3	4	10	31	16	8	0

AUTUMN—

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	CALM.
September, .	1	3	2	1	5	12	5	1	0
October, . .	2	2	3	2	5	10	5	2	0
November, .	2	2	2	2	6	9	5	2	0
Autumn, . .	5	7	7	5	16	31	15	5	0

WINTER—

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	CALM.
December, .	2	2	1	3	6	12	4	1	0
January, . .	2	1	1	3	7	11	4	2	0
February, .	2	2	2	2	4	10	5	1	0
Winter, . .	6	5	4	8	17	33	13	4	0
Total for year,	31	40	22	22	51	119	56	24	0