CHAPTER X.

Division of the subject into changes of the organic and inorganic world—Inorganic causes of change divided into the aqueous and igneous—Aqueous causes—Destroying and transporting power of running water—Sinuosities of rivers—Two streams when united do not occupy a bed of double surface—Heavy matter removed by torrents and floods—Recent inundations in Scotland—Effects of ice in removing stones—Erosion of chasms through hard rocks—Excavations in the lavas of Etna by Sicilian rivers—Gorge of the Simeto—Gradual recession of the cataracts of Niagara—Speculations as to the time required for their reaching Lake Erie.

We defined geology to be the science which investigates the former changes that have taken place in the organic, as well as in the inorganic kingdoms of nature; and we now proceed to inquire what changes are now in progress in both these departments. Vicissitudes in the inorganic world are most apparent, and as on them all fluctuations in the animate creation must in a great measure depend, they may claim our first consideration. We may divide the great agents of change in the inorganic world into two principal classes, the aqueous and the igneous. To the former belong Rivers, Torrents, Springs, Currents, and Tides; to the latter, Volcanos and Earthquakes. Both these classes are instruments of decay as well as of reproduction; but they may be also regarded as antagonist forces. The *aqueous* agents are incessantly labouring to reduce the inequalities of the earth's surface to a level, while the *igneous*, on the other hand, are equally active in restoring the unevenness of the external crust, partly by heaping up new matter in certain localities, and partly by depressing one portion, and forcing out another of the earth's envelope. It is difficult, in a scientific arrangement, to give an accurate view of the combined effects of so many forces in simultaneous operation; because, when we consider them separately, we cannot easily estimate either the extent of their efficacy, or the kind of results which they produce. We are in danger, therefore, when we attempt to examine the influence exerted singly by each, of overlooking the modifications which they produce on one another; and these are so complicated, that sometimes the igneous and aqueous forces co-operate to produce a joint effect, to which neither of them unaided by the other could give rise,—as when repeated earthquakes unite with running water to widen a valley. Sometimes the organic combine with the inorganic causes; as when a reef, composed of shells and corals, protects one line of coast from the destroying power of tides or currents, and turns them against some other point; or when drift timber floated into a lake, fills a hollow to which the stream would not have had sufficient velocity to convey earthy sediment.

It is necessary, however, to divide our observations on these various causes, and to classify them systematically, endeavouring as much as possible to keep in view that the effects in nature are mixed, and not simple, as they may appear in an artificial arrangement.

In treating, first, of the aqueous causes, we may consider them under two divisions: first, those which are connected with the circulation of water from the land to the sea, under which are included all the phenomena of rivers and springs; secondly, those which arise from the movements of water in lakes, seas, and the ocean, wherein are comprised the phenomena of tides and currents. In turning our first attention to the former division, we find that the effects of rivers may be subdivided into those of a destroying and those of a renovating nature. In the former are included the erosion of rocks and the transportation of matter to lower levels; in the latter, the formation of sand-bars and deltas, the shallowing of seas, &c.

Action of Running Water.—We shall begin, then, by describing the destroying and transporting power of running water, as exhibited by torrents and rivers. It is well known that the lands elevated above the sea attract in proportion to their volume and density a larger quantity of that aqueous vapour which the heated atmosphere continually absorbs from the surface of lakes and seas. By this means, the higher regions become perpetual reservoirs of water, which descend and irrigate the lower valleys and plains. In consequence of this provision, almost all the water is first carried to the highest regions, and is then made to descend by steep declivities towards the sea; so that it acquires superior velocity, and removes a greater quantity of soil than it would do if the rain had been distributed over the low plains and high mountains equally in proportion to their relative areas. Almost all the water is also made by these means to pass over the greatest distances which each region affords, before it can regain the sea. The rocks in the higher regions are particularly exposed to atmospheric influences, to frost, rain, and vapour, and to great annual alternations, of moisture and desiccation—of cold and heat. Among the most powerful agents of decay may be mentioned the mechanical action of water, which possesses the remarkable property of expanding during congelation. When water has penetrated into crevices and cavities, it rends open, on freezing, the most solid rocks with the force of a lever, and for this reason, although in cold climates the comparative quantity of rain which falls is very inferior, and although it descends more gradually than in tropical regions, yet the severity of frost, and the greater inequalities of temperature, compensate for this diminished power of degradation, and cause it to proceed with equal, if not greater rapidity than in high latitudes. The solvent power of water also is very great, and acts particularly on the calcareous and alkaline elements of stone, especially when it holds carbonic acid in solution, which is abundantly supplied to almost every large river by springs, and is collected by rain from the atmosphere. The oxygen of the atmosphere is also gradually absorbed by all animal and vegetable productions, and by almost all mineral masses exposed to the open air. It gradually destroys the equilibrium of the elements of rocks, and tends to reduce into powder, and to render fit for soils, even the hardest aggregates belonging to our globe *. And as it is well known that almost every thing affected by rapid combustion may also be affected gradually by the slow absorption of oxygen, the surface of the hardest rocks exposed to the air may be said to be slowly burning away.

When earthy matter has once been intermixed with running

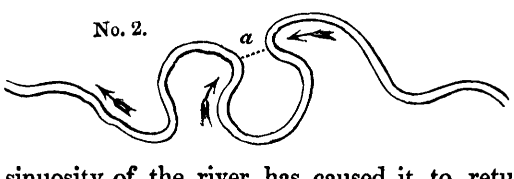
* Sir H. Davy, Consolations in Travel, p. 271.

water, a new mechanical power is obtained by the attrition of sand and pebbles, borne along with violence by a stream. Running water charged with foreign ingredients being thrown against a rock, excavates it by mechanical force, sapping and undermining till the superincumbent portion is at length precipitated into the stream. The obstruction causes a temporary increase of the water, which then sweeps down the barrier. By a repetition of these land-slips, the ravine is widened into a small, narrow valley, in which sinuosities are caused by the deflexion of the stream first to one side and then to the other. The unequal hardness of the materials through which the channel is eroded, tends also to give new directions to the lateral force of excavation. When by these, or by accidental shiftings of the alluvial matter in the channel, and numerous other causes, the current is made to cross its general line of descent, it eats out a curve in the opposite bank, or the side of the hill bounding the valley, from which curve it is turned back again at an equal angle, and recrossing the line of descent, it gradually hollows out another curve lower down, in the opposite bank, till the whole sides of the valley, or river-bed, present a succession of salient and retiring angles.

Among the causes of deviation from a straight course by which torrents and rivers tend to widen the valleys through which they flow, may be mentioned the confluence of lateral torrents, swoln irregularly at different seasons in mountainous regions by partial storms, and discharging at different times unequal quantities of debris into the main channel.

When the tortuous flexures of a river are extremely great, the aberration from the direct line of descent is often restored by the river cutting through the isthmus which separates two neighbouring curves. Thus, in the annexed diagram, the

No. 2.



extreme sinuosity of the river has caused it to return for a brief space in a contrary direction to its main course, so that a peninsula is formed, and the isthmus (at *a*) is consumed on both sides by currents flowing in opposite directions. In this case an island is soon formed,—on either side of which a portion of the stream usually remains*. These windings occur not only in the channels of rivers flowing through flat alluvial plains, but large valleys also are excavated to a great depth through solid rocks in this serpentine form. In the valley of the Moselle, between Berncastle and Roarn, which is sunk to a depth of from six to eight hundred feet through an elevated platform of transition rocks, the curves are so considerable that the river returns, after a course of seventeen miles in one instance, and nearly as much in two others, to within a distance of a few hundred yards of the spot it passed before †. The valley of the Meuse, near Givet, and many others in different countries, offer similar windings. Mr. Scrope has remarked, that these tortuous flexures are decisively opposed to the hypothesis, that any violent and transient rush of water suddenly swept out such valleys; for great floods would produce straight channels in the direction of the current, not sinuous excavations, wherein rivers flow back again in an opposite direction to their general line of descent.

Our present purpose, however, relates to the force of aqueous erosion, and the transportation of materials by running water, considered separately, and not to the question so much controverted respecting the formation of valleys in general. This subject cannot be fully discussed without referring to all the powers to which the inequalities of the earth's surface, and the very existence of land above the level of the sea, are due. Nor even when we have described the influence of all the chemical and mechanical agents which operate at one period in effecting changes in the external form of the land, shall we be enabled to present the reader with a comprehensive theory of the origin of the present valleys. It will be necessary to consider the complicated effects of all these causes at distinct geological epochs, and to inquire how particular regions, after having remained for ages in a state of comparative tranquillity, and under the influence of a certain state of the atmosphere, may be subsequently remodelled by another series of subterranean movements,—how

* See a paper on the Excavation of Valleys, &c., by G. Poulett Scrope, Esq. Proceedings of Geol. Soc., No. 14, 1830.

† Ibid.

the new direction, volume, and velocity acquired by rivers and torrents may modify the former surface,—what effects an important difference in the mean temperature of the climate, or the greater intensity of heat and cold at different seasons, may produce,—what pre-existing valleys, under a new configuration of the land, may cease to give passage to large bodies of water, or may become entirely dried up,—how far the relative level of certain districts in the more modern period may become precisely the reverse of those which prevailed at the more ancient era. When these and other essential elements of the problem are all duly appreciated, the reader will not be surprised to learn, that amongst geologists who have neglected them there has prevailed a great contrariety of opinion on these topics. Some writers of distinguished talent have gone so far as to contend, that the origin of the greater number of existing valleys was simply due to the agency of one cause, and that it was consummated in a brief period of time. But without discussing the merits of the general question, we may observe that we agree with the author before cited, that the sinuosity of deep valleys is one among many proofs that they have been shaped out progressively, and not by the simultaneous action of one or many causes; and when we consider other agents of change, we shall have opportunities of pointing out a multitude of striking facts in confirmation of the gradual nature of the process to which the inequalities of hill and valley owe their origin.

In regard to the transporting power of water, we are often surprised at the facility wherewith streams of a small size, and which descend a slight declivity, bear along coarse sand and gravel; for we usually estimate the weight of rocks in air, and do not reflect sufficiently on their comparative buoyancy when submerged in a denser fluid. The specific gravity of many rocks is not more than twice that of water, and very rarely more than thrice, so that almost all the fragments propelled by a stream have lost a third, and many of them half of what we usually term their weight.

It has been proved by experiment, in contradiction to the theories of the early writers on hydrostatics, to be a universal law, regulating the motion of running water, that the velocity at the bottom of the stream is everywhere less than in any part above it, and is greatest at the surface. Also that the superficial particles in the middle of the stream move swifter than those at the sides. This retardation of the lowest and lateral currents is produced by friction, and when the velocity is sufficiently great, the soil composing the sides and bottom gives way. A velocity of three inches per second is ascertained to be sufficient to tear up fine clay,—six inches per second, fine sand,—twelve inches per second, fine gravel,—and three feet per second, stones of the size of an egg *.

When this mechanical power of running water is considered, we are prepared for the transportation of large quantities of gravel, sand, and mud, by the torrents and rivers which descend with great velocity from the mountainous regions. But a question naturally arises, how the more tranquil rivers of the valleys and plains, flowing on comparatively level ground, can remove the prodigious burden which is discharged into them by their numerous tributaries, and by what means they are enabled to convey the whole mass to the sea. If they had not this power, their channels would be annually choked up, and the lower valleys and districts adjoining mountain-chains would be continually strewed over with fragments of rock and sterile sand. But this evil is prevented by a general law regulating the conduct of running water, that two equal streams do not occupy a bed of double surface. In proportion, therefore, as the whole fluid mass increases, the space which it occupies decreases relatively to the volume of water; and hence there is a smaller proportion of the whole retarded by friction against the bottom and sides of the channel. The portion thus unimpeded moves with great velocity, so that the main current is often accelerated in the lower country, notwithstanding that the slope of the channel is lessened. It not unfrequently happens, as we shall afterwards demonstrate by examples, that two large rivers, after their junction, have only the surface which one of them had previously; and even in some cases their united waters are confined in a narrower bed than each of them filled before. By this beautiful adjustment, the water which drains the interior country is made continually to occupy less room as it approaches the sea; and thus the most valuable part of our continents, the rich deltas,

* Encycl. Brit.—Art. Rivers.

and great alluvial plains, are prevented from being constantly under water *.

Many remarkable illustrations of the power of running water in moving stones and heavy materials were afforded by the late storm and flood which occurred on the 3rd and 4th of August 1829, in Aberdeenshire and other counties, in Scotland. The floods extended almost simultaneously and in equal violence over a space of about five thousand square miles, being that part of the north-east of Scotland which would be cut off by two lines drawn from the head of Lochrannoch, one towards Inverness, and another to Stonehaven. All the rivers within that space were flooded, and the destruction of roads, lands, buildings, and crops along the courses of the streams was very great. The elements during this storm assumed all the characters which mark the tropical hurricanes: the wind blowing in sudden gusts and whirlwinds, the lightning and thunder being such as is rarely witnessed in that climate, and heavy rain falling without intermission. The bridge over the Dee at Ballatu consisted of five arches, having upon the whole a water-way of two hundred and sixty feet. The bed of the river on which the piers rested, was composed of rolled pieces of granite and gneiss. The bridge was built of granite, and had stood uninjured for twenty years, but the different parts were swept away in succession by the flood, and the whole mass of masonry disappeared in the bed of the river †. "The river Don," observes Mr. Farquharson, in his account of the inundations, "has upon my own premises forced a mass of four or five hundred tons of stones, many of them two or three hundred pounds weight, up an inclined plane, rising six feet in eight or ten yards; and left them in a rectangular heap, about three feet deep on a flat ground; and, singularly enough, the heap ends abruptly at its lower extremity. A large stone, of three or four tons which I have known for many years in a deep pool of the river, has been moved about one hundred yards from its place ‡."

The power even of a small rivulet, when swoln by rain, in removing heavy bodies, was lately exemplified in the College, a

* See Article Rivers, Ency. Brit.

† From the account given by the Rev. James Farquharson, in the Quarterly Journ. of Sci., &c., No. 12, new series, p. 328.

‡ Ibid., p. 331.

small stream which flows at a moderate declivity from the eastern water-shed of the Cheviot-Hills. Several thousand tons weight of gravel and sand were transported to the plain of the Till, and a bridge then in progress of building was carried away, some of the arch-stones of which, weighing from half to three-quarters of a ton each, were propelled two miles down the rivulet. On the same occasion, the current tore away from the abutment of a mill-dam a large block of greenstone-porphyry, weighing nearly two tons, and transported the same to the distance of a quarter of a mile. Instances are related as occurring repeatedly, in which from one to three thousand tons of gravel are in like manner removed to great distances in one day *.

In the cases above adverted to, the waters of the river and torrent were dammed back by the bridges which acted as partial barriers, and illustrate the irresistible force of a current when obstructed. Bridges are also liable to be destroyed by the tendency of rivers to shift their course, whereby the pier, or the rock on which the foundation stands, is undermined.

When we consider how insignificant are the volume and velocity of the rivers and streams in our island, when compared to those of the Alps and other lofty chains, and how, during the various changes which the levels of different districts have undergone, the various contingencies which give rise to floods, must in the lapse of ages be multiplied, we may easily conceive that the quantity of loose superficial matter distributed over Europe must be very considerable. That the position also of a great portion of these travelled materials should now appear most irregular, and should often bear no relation to the existing water-drainage of the country, is a necessary consequence, as we shall afterwards see, of the combined operations of running water and subterranean movements.

In mountainous regions and high northern latitudes, the moving of heavy stones by water is greatly assisted by the ice which adheres to them, and which forming together with the rock a mass of less specific gravity †, is readily borne along. The glaciers also of alpine regions, formed of consolidated snow,

* See a paper by Mr. Culley, F.G.S., Proceedings of Geol. Soc., No. 12, 1829.

† Silliman's Journal, No. 30, p. 303.

bear down upon their surface a prodigious burden of rock and sand mixed with ice. These materials are generally arranged in long ridges, which sometimes in the Alps are thirty or forty feet high, running parallel to the borders of the glacier, like so many lines of intrenchment. These mounds of debris are sometimes three or more deep, and have generally been brought in by lateral glaciers: the whole accumulation is slowly conveyed to the lower valleys, where, on the melting of the glacier, it is swept away by rivers *.

The rapidity with which even the smallest streams hollow out deep channels in soft and destructible soils is remarkably exemplified in volcanic countries, where the sand and half-consolidated tuffs oppose but a slight resistance to the torrents which descend the mountain side. After the heavy rains which followed the eruption of Vesuvius is 1822, the water flowing from the Atrio del Cavallo, cut in three days a new chasm through strata of tuff and volcanic ejected matter to the depth of twenty-five feet. The old mule road was seen, in 1828, intersected by this new ravine. But such facts are trifling when compared to the great gorges which are excavated in somewhat similar materials in the great plateau of Mexico, where an ancient system of valleys, originally worn out of granite and secondary rocks, has been subsequently filled with strata of tuff, pumice, lava, and trachytic conglomerate, to the thickness of several thousand feet. The rivers and torrents annually swoln by tropical rains, are now actively employed in removing these more recent deposits, and in re-excavating the ancient water-courses †.

The gradual erosion of deep chasms through some of the hardest rocks, by the constant passage of running water charged with foreign matter, is another phenomenon of which striking examples may be adduced. Some of the clearest illustrations of this excavating power are presented by many valleys in Central France, where the channels of rivers have been barred up by solid currents of lava, through which the streams have re-excavated a passage to the depth of from twenty to seventy feet and upwards, and often of great width. In these cases

* Saussure, Voyage dans les Alpes, tom. i.

† I am indebted to Captain Vetch for this information, whose researches in Mexico will, it is hoped, be soon communicated to the scientific world.

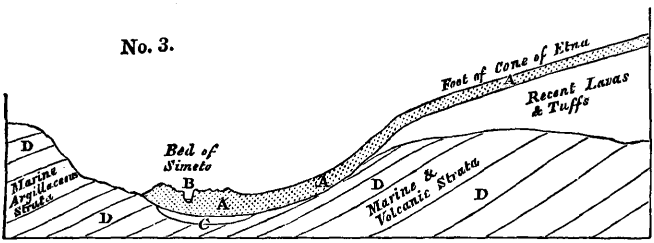
there are decisive proofs that neither the sea nor any denuding wave, or extraordinary body of water, have passed over the spot since the melted lava was consolidated. Every hypothesis of the intervention of sudden and violent agency is entirely excluded, because the cones of *loose* scoriæ, out of which the lavas flowed, are oftentimes at no great elevation above the rivers, and have remained undisturbed during the whole period which has been sufficient for the hollowing out of such enormous ravines. But we shall reserve a more detailed account of the volcanic district of Central France for another part of this work, and at present confine ourselves to examples derived from events which have happened since the time of history.

Some lavas of Etna, produced by eruptions of which the date is known, have flowed across two of the principal rivers in Sicily; and in both cases the streams, dispossessed of their ancient beds, have opened for themselves new channels. An eruption from Mount Mojo, an insulated cone at the northern base of Etna, sent forth, in the year 396, B.C., in the reign of Dionysius I., a great lava-stream, which crossed the river Caltabianca in two places. The lowermost point of obstruction is seen on the eastern side of Etna, on the high road from Giardini to Catania, where one pier of the bridge on either bank is based upon a remnant of the solid lava, which has been breached by the river to the depth of fourteen feet. But the Caltabianca, although it has been at work for more than two and twenty centuries, has not worn through the igneous rock so as to lay open the gravel of its ancient bed. The declivity, however, of the alluvial plain is very slight; and as the extent of excavation in a given time depends on the volume and velocity of the stream, and the destructibility of the rock, we must carefully ascertain all these circumstances before we attempt to deduce from such examples a measure of the force of running water in a given period *.

* I omitted to visit the higher point near the village of Mojo, where the Caltabianca has cut through the lava. Some future traveller would probably derive much instruction from inspecting that spot, which is laid down in Gemmellaro's Quadro Istorico, &c. dell' Etna, 1824.

Recent Excavation of the Simeto.—The power of running water to hollow out compact rock is exhibited, on a larger scale, at the western base of Etna, where a great current of lava (A A, diagram 3), descending from near the summit

No. 3.



of the great volcano, has flowed to the distance of five or six miles, and then reached the alluvial plain of the Simeto, the largest of the Sicilian rivers which skirts the base of Etna, and falls into the sea a few miles south of Catania. The lava entered the river about three miles above the town of Adernò, and not only occupied its channel for some distance, but, crossing to the opposite side of the valley, accumulated there in a rocky mass. Gemmellaro gives the year 1603 as the date of the eruption *. The appearance of the current clearly proves that it is one of the most modern of those of Etna, for it has not been covered or crossed by subsequent streams or ejections, and the olives on its surface are all of small size, yet older than the natural wood on the same lava. In the course, therefore, of about two centuries the Simeto has eroded a passage from fifty to several hundred feet wide, and in some parts from forty to fifty feet deep.

The portion of lava cut through is in no part porous or scoriaceous, but consists of a compact homogeneous mass of hard blue rock, somewhat lighter than ordinary basalt, containing crystals of olivine and glassy felspar. The general declivity of this part of the bed of the Simeto is not considerable, but, in consequence of the unequal waste of the lava, two waterfalls occur at Passo Manzanelli, each about six feet in height. Here the chasm (B, diagram No. 3.) is about forty feet deep, and only fifty broad.

* Quadro Istorico dell' Etna, 1824. Some doubts are entertained as to the exact date of this current by others, but all agree that it is not one of the older streams even of the historical era.

The sand and pebbles in the river bed consist chiefly of a brown quartzose sandstone, derived from the upper country; but the matter derived from the volcanic rock itself must have greatly assisted the attrition. This river, like the Caltabianca, has not yet cut down to the ancient bed of which it was dispossessed, and of which we have indicated the probable position in the annexed diagram (c, No. 3.)

On entering the narrow ravine where the water foams down the two cataracts, we are entirely shut out from all view of the surrounding country; and a geologist who is accustomed to associate the characteristic features of the landscape with the relative age of certain rocks, can scarcely dissuade himself from the belief that he is contemplating a scene in some rocky gorge of a primary district. The external forms of the hard blue lava are as massive as any of the most ancient trap-rocks of Scotland. The solid surface is in some parts smoothed and almost polished by attrition, and covered in others with a white lichen, which imparts to it an air of extreme antiquity, so as greatly to heighten the delusion. But the moment we reascend the cliff, the spell is broken; for we scarcely recede a few paces, before the ravine and river disappear, and we stand on the black and rugged surface of a vast current of lava, which seems unbroken, and which we can trace up nearly to the distant summit of that majestic cone which Pindar called "the pillar of heaven," and which still continues to send forth a fleecy wreath of vapour, reminding us that its fires are not extinct, and that it may again give out a rocky stream, wherein other scenes like that now described may present themselves to future observers.

Falls of Niagara.—The falls of Niagara afford a magnificent example of the progressive excavation of a deep valley in solid rock. That river flows from Lake Erie to Lake Ontario, the former lake being three hundred and thirty feet above the latter, and the distance between them being thirty-two miles. On flowing out of the upper lake, the river is almost on a level with its banks; so that, if it should rise perpendicularly eight or ten feet, it would lay under water the adjacent flat country of Upper Canada on the West, and of the State of New York on the

East*. The river, where it issues, is about three quarters of a mile in width. Before reaching the falls, it is propelled with great rapidity, being a mile broad, about twenty-five feet deep, and having a descent of fifty feet in half a mile. An island at the very verge of the cataract divides it into two sheets of water; one of these, called the Horse-shoe Fall, is six hundred yards wide, and one hundred and fifty-eight feet perpendicular; the other, called the American Falls, is about two hundred yards in width, and one hundred and sixty-four feet in height. The breadth of the island is about five hundred yards. This great sheet of water is precipitated over a ledge of hard limestone, in horizontal strata, below which is a somewhat greater thickness of soft shale, which decays and crumbles away more rapidly, so that the calcareous rock forms an overhanging mass, projecting forty feet or more above the hollow space below. The blasts of wind, charged with spray, which rise out of the pool into which this enormous cascade is projected, strike against the shale beds, so that their disintegration is constant; and the superincumbent limestone, being left without a foundation, falls from time to time in rocky masses. When these enormous fragments descend, a shock is felt at some distance, accompanied by a noise like a distant clap of thunder. After the river has passed over the falls, its character, observes Captain Hall, is immediately and completely changed. It then runs furiously along the bottom of a deep wall-sided valley, or huge trench, which has been cut into the horizontal strata by the continued action of the stream during the lapse of ages. The cliffs on both sides are in most places perpendicular, and the ravine is only perceived on approaching the edge of the precipice †.

The waters which expand at the falls, where they are divided by the island, are contracted again, after their union, into a stream not more than one hundred and sixty yards broad. In the narrow channel, immediately below this immense rush of water, a boat can pass across the stream with ease. The pool, it is said, into which the cataract is precipitated, being one hundred and seventy feet deep, the descending water sinks down

* Captain Hall's Travels in North America, vol. i., p. 179.

† Ibid., pp. 195, 196, 216.

and forms an under-current, while a superficial eddy carries the upper stratum back *towards* the main fall *. This is not improbable; and we must also suppose, that the confluence of two streams, which meet at a considerable angle, tends mutually to neutralize their forces. The bed of the river below the falls is strewed over with huge fragments which have been hurled down into the abyss. By the continued destruction of the rocks, the falls have, within the last forty years, receded nearly fifty yards, or, in other words, the ravine has been prolonged to that extent. Through this deep chasm the Niagara flows for about seven miles; and then the table-land, which is almost on a level with Lake Erie, suddenly sinks down at a town called Queenstown, and the river emerges from the ravine into a plain which continues to the shores of Lake Ontario †.

There seems good foundation for the general opinion, that the falls were once at Queenstown, and that they have gradually retrograded from that place to their present position, about seven miles distant. If the ratio of recession had never exceeded fifty yards in forty years, it must have required nearly ten thousand years for the excavation of the whole ravine; but no probable conjecture can be offered as to the quantity of time consumed in such an operation, because the retrograde movement may have been much more rapid when the whole current was confined within a space not exceeding a fourth or fifth of that which the falls now occupy. Should the erosive action not be accelerated in future, it will require upwards of thirty thousand years for the falls to reach Lake Erie (twenty-five miles distant), to which they seem destined to arrive in the course of time, unless some earthquake changes the relative levels of the district. The table-land, extending from Lake Erie, consists uniformly of the same geological formations as are now exposed to view at the falls. The upper stratum is an ancient alluvial sand, varying in thickness from ten to one hundred and forty feet; below which is a bed

* See Mr. Bakewell, jun., on Falls of Niagara. Loudon's Magazine, No. 12, March, 1830.

† The Memoir of Mr. Bakewell, jun. above referred to, contains two very illustrative sketches of the physical geography of the country between Lakes Erie and Ontario, including the Falls.

of hard limestone, about ninety feet in thickness, stretching nearly in a horizontal direction over the whole country, and forming the bed of the river *above* the falls, as do the inferior shales *below*. The lower shale is nearly of the same thickness as the limestone. Should Lake Erie remain in its present state until the period when the ravine recedes to its shores, the sudden escape of that great body of water would cause a tremendous deluge; for the ravine would be much more than sufficient to drain the whole lake, of which the average depth was found, during the late survey, to be only ten or twelve fathoms. But, in consequence of its shallowness, Lake Erie is fast filling up with sediment, and the annual growth of the deltas of many rivers and torrents which flow into it is remarkable. Long Point, for example, near the influx of Big Creek River, was observed, during the late survey, to advance three miles in as many years. A question therefore arises, whether Lake Erie may not be converted into dry land before the Falls of Niagara recede so far. In speculating on this contingency, we must not omit one important condition of the problem. As the surface of the lake is contracted in size, the loss of water by evaporation will diminish; and unless the supply shall decrease in the same ratio (which seems scarcely probable), Niagara must augment continually in volume, and by this means its retrograde movement may hereafter be much accelerated.