ADDRESS

TO THE

GEOLOGICAL SECTION

OF THE

British Association,

AT

CAMBRIDGE, OCTOBER 2ND, 1862.

BY

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My reasons for printing this address, in anticipation of the annual volume of Reports, are, first, that I was asked for a copy of it by several persons at the Meeting of the Association at Cambridge; and, secondly, that the subject of it is one that I wish to see fully discussed and settled as soon as may be, and shall therefore be glad that the views here advocated should be either generally adopted if they be correct, or modified or refuted if they be erroneous, both for my own guidance and that of others.

J. B. J.

Dublin, October 10th, 1862.

ADDRESS.

It is now thirty-two years ago since I first, when a "freshman" of this University, attended the geological lectures of Professor Sedgwick. I had previously had access to a cabinet of fossils, and had been accustomed to seek for specimens in my schoolboy rambles, on the hills near Dudley. It may be imagined, therefore, with what interest I listened to the "winged words" of the Woodwardian Professor, which used day after day to delight an audience composed of all ranks of the University.

Geology and its kindred sciences did not then, indeed, form any part of our regular course of university studies, and many of the college tutors were so far from encouraging our attention to them, that they rather discountenanced it, considering them as at best useless, and probably even dangerous pursuits. With such a man as Professor Sedgwick, however, in the Woodwardian chair, whose wit and humour delighted, while his eloquence aroused and informed his hearers, the love of the science and the knowledge of it could not fail to extend from one year to another.

The natural sciences are now considered as worthy of study, by those who have a taste for them, both in themselves and as a means of mental training and discipline. In my time, however, no other branches of learning were recognised than classics and mathematics, and I have with some shame to confess that I displayed but a "truant disposition" with respect to them, and too often hurried from the tutor's lecture-room to the river or the field, to enable me to add much to the scanty stores of knowledge I had brought up with me. Had it not been, then, for the teaching of Professor Sedgwick in Geology, my time might have been altogether wasted. But it was not only in the lecture-room that I learnt from him. With that kindness of heart and geniality of disposition which make him as much loved, as his powers cause him to be admired, he was good enough to step down from his high place as a Professor of the University, and to take some notice of the young undergraduate whom he saw lingering over the trays of specimens when the lecture was over, to inquire his name, and to invite him to his table. He subsequently allowed me to accompany him on some excursions in different parts of England, and gave me some of those practical lessons in the field, which, as you know, teach more in three days than can be learnt in months or years in the museum or the lecture-room. I look back upon these circumstances as those which gave direction to the whole course of my life, and as the origin of a paternal friendship with which Professor Sedgwick has honoured me for so many years, and which it has been my chief pride to endeavour to deserve. I hope, ladies and gentlemen, I may be pardoned for these few personal allusions; but amid all the gratification which I must necessarily feel at the honour which has now fallen upon me, that, namely, of being called upon to preside, within the walls of my own Alma Mater, over the Geological Section of the British Association, it was impossible for me to neglect the opportunity of acknowledging the debt of gratitude I owe to one of the ruling spirits of both bodies, and of avowing that my chief claim to occupy this chair is that I am an old pupil of Professor Sedgwick.

One of the most obvious difficulties in the way of any person who now undertakes to preside over this section, is the thought of the contrast that will necessarily arise in the minds of many of you between him and his predecessors. That I am now occupying the seat that has been filled by Sedgwick, Buckland, Lyell, Murchison, Hopkins, De la Beche, Forbes, and so many other illustrious men, may well cause me to doubt my own capability of fulfilling its duties. One lesson I must certainly learn, and that is, to endeavour to make up for other deficiencies by attention and assiduity, and, above all, not to take such an advantage of the position, as to bring anything of my own before your notice, to the hindrance of others who may have something to produce that may be more worthy of it. At the end, then, of this Address, which I will endeavour to make as brief as possible, I shall consider my own mouth as almost closed for the remainder of the meeting, and shall endeavour so far to imitate the Speaker of the House of Commons as to say as little as possible.

I propose to take for my subject the external features of the earth's surface. The principal business of Geology is to acquire as accurate a knowledge as we can of the internal structure of the crust of the earth, and to learn as much as possible of all the operations by which that structure was originally formed, or by which it has been subsequently modified. The crust of the earth has always been receiving accessions to its composition, both from within and from without. In like manner it has always been subject to modifying influences proceeding both from within and from without. It is obvious that the external influences act directly upon the actual surface of the time being. It is equally obvious that the internal influences can only reach that surface by penetrating through the thickness of the crust. If, therefore, we ask by what means the present surface of the earth, or, to bring the problem within more narrow limits, by what means the present surface of any of our dry lands, has been produced, we should naturally conclude that it owes its form to the external influences that have been brought to bear directly upon it, rather than to the indirect action of those deep-seated agencies, which can only reach it through an unknown thickness of solid rock.

I believe this conclusion to be the true one. It is, however, by no means the idea which is commonly entertained, even by many geologists, while those who are not geologists are always inclined to refer all the more striking features of the surface of the earth to the direct action of convulsive force proceeding from the interior, rather than to their true source in the gentle, gradual, silent influence of the "weather," continued through an indefinite period of past time.

I have heard even educated men speak of the correspondence in the Chalk cliffs of the opposite sides of the Straits of Dover, as evidence in favour of the notion that England had been separated from France by the tearing open of those straits, by what they called some "great convulsion of nature." There is hardly a description to be found in any book, of any deep and narrow valley or mountain gorge—especially if the precipices on each side of it show entering and re-entering angles, and rocks that were obviously once continuous across the gap,—but what its formation is unhesitatingly attributed to this well-worn idea of a "convulsion of nature." Nay, I have even heard the existence of broad valleys over an anticlinal arch, such, for instance, as the valley of the Weald, attributed to the effect of the gaping of the rocks at the surface, consequent on the upward flexure of the beds. Mythical powers of disturbance are called into existence with as bold a personification as the Βια and Κράτος of the poet, and with even less warrant for their existence.

It seems to me, therefore, that the time is come when geologists should study a little more closely this problem of the mode of production of the surface of the land, and determine what was the exact method of the formation of those variations in the surface of the dry land which we call mountains, hills, table-lands, cliffs, precipices, ravines, glens, valleys, and plains.

Few men, perhaps, ever pause to consider as to the origin of a great plain; nevertheless the question may well be put, and it is one which deserves an answer. Some plains are doubtless the result of original formation. They are level and flat, because the beds beneath the surface are horizontal. Even these, however, have very rarely a surface formed simply by the last deposited beds. The actual surface is one that has been formed by the erosion and removal of more or less of the uppermost beds, and the production of undulations formed by the act of cutting down into the beds below. This erosion or denudation has even in many such cases gone to the length of entirely removing a much greater thickness than we should at first suspect; the present surface being one that has been laid bare by that removal.

In all cases where the beds below the surface are not strictly horizontal, or do not accurately coincide as to their "lie" with the form of the surface, it is obvious that the plain must be one of denudation.

Suppose we take the great plain on which we now are, and which stretches from Cambridge far into Lincolnshire. The hills which rise from it towards the east are formed by the escarpment of the Chalk, the beds of which terminate abruptly at that escarpment, and allow the clays which lie beneath the Chalk to come up to the surface and spread beneath the plain. The hills rising to the west of the plain, on the other hand, are formed of the Oolites, the beds of which lie below these clays and rise gently from beneath the plain, and themselves terminate in an escarpment still farther west.

There can be no reasonable doubt that the whole thickness of the Chalk and the beds below it once spread many miles to the westward of their present boundaries. The little Chalk-capped monticule of the Castle Hill, at the western end of the town of Cambridge, and the hills near Maddingley, show that the Chalk was once continuous that far, at all events, from the Gogmagogs; and had still higher ground been left by the denudation still farther west, that would in like manner have been capped by the bottom beds of the Chalk.

The great plain of the Fens, then, is one of denudation, its surface being one that is now bare in consequence of the removal of a thickness of many hundred feet of Chalk from above it.* But this reasoning may be carried out with respect to the whole of the flat lands of England and the British Islands. The great central plain of Ireland, for instance, stretching from Dublin Bay to Galway Bay, with an average elevation of less than 300 feet above the sea, has immediately beneath it abruptly undulating beds of Carboniferous limestone, rising up at all angles, and dipping in all directions. The most level parts of the surface sometimes cut horizontally across the most contorted and perpendicular beds. The small isolated hills scattered here and there about the plain are formed sometimes of beds that rise up from beneath the bottom of the Limestone, and sometimes of beds which rest upon the top of it. It is here abundantly evident, then, that the internal forces of disturbance which have bent the beds from their original horizontality into so many curves, and broken them by so many dislocations, had nothing at all to do with the production of the present surface, which has been formed across all these bent and broken beds after the disturbances had ceased.

But, in fact, the very first glance at a geological map, if there be two or more colours on it representing conformable groups of stratified rocks, is just as good a proof of this vast denudation as the most elaborate reasoning. The last deposited group of beds would of course conceal all those beneath it; it would be represented by one uniform colour. Let the internal forces bend, or tilt, or break it in any fashion you like, they cannot of themselves remove a particle of it. It will still lie over all those on which it was originally

* In this general statement the few feet of peat, or the little banks of drift gravel and sand, which have been subsequently deposited on or grown over the plain, are of course, disregarded.

deposited, and the map would show the one colour only, unless we go the length of supposing that a piece of the crust of the earth could be tossed over like a pancake, and laid down again with its bottom upwards.

I have taken the case of a plain in the first instance, because it is obvious that if we arrive at the conclusion that many plains are low and level, because mountainous masses of rock have been removed from above their present surface, it will be easy for us to recognise the proofs of denudation in the hills and mountains, on whose flanks the obvious marks of it are still left.

If we except volcanoes or "mountains of ejection," all other hills and mountains are either caused by the removal of the rocks which once surrounded them, or have suffered from the removal of those that once spread over them. The first kind of hills have simply been left high, while the surrounding ground has been worn down to a low level about them. In the second kind, the rocks composing them have, indeed, been thrust up from beneath by internal force to a much greater elevation than those same rocks have in the surrounding area, and their height is due entirely to that upward tilting, vast masses of once superincumbent beds having been removed from above them. These hills are high, not in consequence of, but in spite of, denudation. I have elsewhere proposed to call the first kind, "*hills of circumdenudation;*" and the second, "*hills of uptilting.*" To the latter class belong all the great mountain chains of the world, and most of the smaller ones.

It may be taken as an invariable rule that, as we approach all mountain chains formed by uptilting, the beds rise towards them, and end successively at the surface; lower and lower beds still rising up, until the lowest of all appear in the heart of the mountains, where they are often reared up into the loftiest peaks. True as is this general statement, it is only generally true. The great groups of rocks thus rise successively one from beneath another, but this general rise is often complicated by numerous folds and reduplications, by great longitudinal fractures, or by complex flexures.

The geological axis of a mountain chain runs along the line where the lowest group of beds rises to the surface. The geographical axis may be said to run along that dominant crest which forms the watershed of the chain. But it by no means follows that these two axes are coincident, that the lowest group of beds is always confined to the line of watershed, or even that the loftiest peaks and summits rise from that crest. The geological axes are dependant solely on the internal forces of elevation; if, therefore, the geographical axes do not coincide with them, it shows at once that *they* are independant of those forces; in other words, that the great external features have not been caused by the direct action of internal movement. The position of the geological axes of mountain chains has, however, been often erroneously placed, from the tendency to refer them to any great masses of granite or other plutonic rocks that may show themselves; a reference which is more often erroneous than correct.

All mountain chains of uptilting tell the same story, that if the internal forces of disturbance and elevation had acted alone, without any external action of denudation, and if they had acted without it to the same extent which they have with it (*supposing that possible*), the mountain chains would have been many times more lofty than they are. I say, "*supposing that possible*," because it appears to me that the elevation of the lowest rocks might never have proceeded to the same extent, if the internal force had not been gradually relieved of some of the external weight which it had to lift. However that may be, we see now that the lowest beds which appear at the surface, about the geological axis of a mountain chain, dip on either hand beneath an ever-increasing thickness of superincumbent rock, as we recede from the axis. All the rocks which have been affected by the same action of disturbing force must have stretched unbroken across the disturbed district, before the disturbance commenced; for the lowest rocks appear at the surface now, not in consequence of the flexure or fracture of those that were above them, but in consequence of their removal. That removal could not have taken place prior to the internal disturbance, unless we assume the existence of a deep hole or trough of erosion along the space where the mountain chain was subsequently thrust upwards. The removal of the bent or broken beds, then, must have taken place either during the action of disturbance or subsequently to its termination. In either case it was an external action, the result in fact of moving water, which slowly wore away and carried off so many square miles, or, as in some cases, so many hundreds or thousands of square miles of rock, so many thousands of feet in thickness. The internal forces operated simply by lifting up the rocks to within the region of the denuding influence, and they have only produced that indirect effect upon the features of the surface, which results from their having brought up to different levels, and placed in various positions, masses of rock of various hardness and constitution, on which the forces of erosion and transport have had a corresponding variety of effect, when they reached them.

I believe that all our uptilted mountain chains have thus grown by a very slow and gradual growth, the internal force thrusting upwards what the external agencies always tended to wear down.

The investigation of the nature and effects of the mechanical forces that have acted on the crust of the earth from the interior has been undertaken by many eminent philosophers, by none with more acuteness and profundity than by our present General Secretary, Mr. W. Hopkins, who is so distinguished an ornament of this University. To the correctness of the mathematical reasonings employed in these researches, no exception is of course to be taken, even by those who may withhold their assent from some of the conclusions arrived at. I profess my incapacity to engage in the discussion of mathematical problems. Nevertheless, it has sometimes occurred to me to suppose that, however sound and legitimate may be the conclusions thus drawn from the premises assumed, they may nevertheless be imperfect or inadequate as conceptions of the truth, in consequence of the incompleteness of the assumptions on which they are based. I shall not venture, even by a guess, to attempt to supply this defect. I only wish to regard the question as still an open one, thinking it possible that some condition or some agency may have been hitherto omitted from the speculation, which no one has as yet, perhaps, formed even a conception of. The researches already made may be admirable guides in all future investigations, and most useful in clearing the way for them; but it may nevertheless be dangerous to take the conclusions as so far established as to render future investigation unnecessary.

There is one line of research, however, in pursuing which we may feel sure of the ground on which we tread, and that is the observation of occurrences which take place before our eyes, and of structures which each one may see and examine for himself.

We have in earthquakes and volcanoes the external symptoms of the action of the earth's internal forces. What they do now, we may feel sure they were able to do formerly; and we have no right to assume that they ever did either more or less within a given period than they have done during historic times.

Volcanoes drill holes through the crust of the earth, and eject lava and ashes through these holes. These holes are often arranged in lines, as if they were connected with linear cracks in the earth's crust.

Earthquakes jar and shake the earth's crust, throw its surface into transient waves, and cause sometimes cracks and open fissures to appear at that surface. The largest of these fissures, however, are rarely more than a few miles in length and a few yards in width, and they appear rarely to leave any permanent traces on the surface, or to give rise to any of its more striking features. No one has ever yet pointed to any valley or any glen, still less to any river course, as having been caused by the gaping of the surface during any known earthquake.

Mr. Mallett's researches have given us the means of calculating the depth at which the impulse of an earthquake may originate. This depth seems to be always proportional to the extent of the surface affected, from which it is obvious that in many cases a very considerable thickness of the external envelope of the earth must have been traversed by these movements. Supposing them to have a local origin, and to be caused by, or to be accompanied by, any considerable disturbance either of flexure or fracture, in the solid or quasi-solid rocks, at or about the centre of origin, it seems necessarily to follow that the amount of disturbance must lessen as we recede from that centre, in proportion to the thickness and extent of the matter over which it is diffused. The tremblings and undulations, then, and the surface-cracks and fissures, produced by earthquakes, are probably only the slight external indications of much larger but more local disturbance below. Great open fissures and gapings of the surface could only, as it appears to me, be caused by disturbances originating at a comparatively slight depth, where it is difficult to imagine any cause for them, and where, as a matter of fact, *great* disturbances never do seem to originate.

In addition to the more convulsive movements of the shocks, permanent elevation and depression of the surface take place during earthquakes, and also to an equal if not greater exent by a slow gradual movement, unaccompanied by earthquakes, and therefore not perceptible to our senses. These risings and sinkings of the surface are evidently the result of the upward or downward movement of the whole thickness of the earth's crust, whatever that thickness may be.

Resting on considerations such as these, thus hastily sketched out, I am inclined to be bold enough to dispute the physical possibility, or at all events to deny the actual occurrence at any time, of such surface manifestations of internal force as could give rise to what have been called "*Craters of elevation*," "*Valleys of elevation*," or any other large openings of the surface of the ground. I would go even farther than this, and hesitate to believe that any high inclination or great contortion had ever been imparted to any beds at, or close to, the surface. I believe all such disturbed positions to have been acquired by a slow creeping movement, the result of the combination of great force acting against almost, but not quite, equally great superincumbent pressure, and therefore at a correspondingly great depth, and that, by the very constitution of the interior of the earth, such great force could not be brought to bear upon any mere point or line of the surface.

The rocks thus disturbed ultimately arrive at the surface, because they have been laid bare by the stripping off of veil after veil of covering, by the external erosive forces acting over the upraised area; upraised either during the disturbance or by a subsequent action of elevation of a broader and more equable character. These same combined actions, still further carried out, ultimately bring to the surface the Metamorphosed Schists, which had been deeply buried by the converse actions of depression and deposition, as well as the granitic masses which, proceeding from the interior, slowly worked their way upwards to a certain height, but cooled and consolidated before they were able to approach the surface as it was then.

No one can study a mountainous district, in which the rocks have been greatly bent and broken, with the same care and attention that has been bestowed by the Geological Survey on the mountains of the British Islands, without perceiving that the external features, whether of hill or valley, do not depend on the frangibility of the rocks, but on their relative power of resistance to erosive action. The hard siliceous rocks, or those best adapted to resist the chemical and mechanical action of water, form the prominences, the softer or more soluble rocks form the valleys and low grounds. The upward or anticlinal curves in the beds, over which, if any where, external gaping fissures would be formed, are at least as often marked by the occurrence of hills and ridges over them, as of valleys; the external feature depending altogether on the "weatherable" nature of the rock.

The same reasoning is applicable to great faults and dislocations. We are all familiar with the fact that of faults that have a dislocation of hundreds or even thousands of feet, there is often not the least indication at the surface of the ground, which may be a perfect plain, or may undulate without any regard to the subterranean structure of the rocks. This seems to me to be strong evidence in favour of the supposition that these dislocations never did make any great feature at the surface. The amount of dislocation has been gained foot by foot and inch by inch below, the movement being so slow as to allow of the surface irregularity being always diminished or obliterated as fast as it was formed. If a great dislocation had taken place at once, and an equally great cliff had been formed by it, surely the traces of such a feature would have been more often preserved than they are.

Small cliffs do occur sometimes along the line of a fault, but only when it so happens, that at the present surface of the ground a hard unyielding rock is brought against a soft and more perishable one, and the cliff or bank is always in proportion to the "weatherable" natures of the two rocks, and not to the amount of the dislocation. In like manner, valleys sometimes run along the line of faults and especially of large faults, and there is sometimes a sort of proportion between the magnitude of the dislocation and that of the external feature; but even in these cases the magnitudes are not of the same kind, the width of the fault being very slight indeed, as compared with the width of the valley. The coincidence is one of direction only, the original fracture having determined the direction of the subsequent erosive forces, so as to cause them to excavate the valley along that line rather than any other.

When, moreover, we examine faults below ground, we find no trace of any wide-gaping fissures, the walls of the fault, on the contrary, are jammed tightly against each other, and show frequent evidence of immense grinding force, proving the friction of the sides to have been enormous. In hard massive rocks there doubtless occur open spaces here and there between the walls, "pockets" or "bellies" between their projecting protuberances, or where they have been partly kept asunder by fragments detached from the sides. These are often full of crystalline minerals and form "mineral veins" below, but seldom, if ever, form valleys or ravines at the surface.

If these ideas as to the relative action of the internal and external forces at work upon the crust of the globe be well founded, it follows that none of the present features of the surface of the globe have been produced by the direct action of the internal forces, except volcanic orifices and cones, and that all others have been produced by the process of external erosion, except such as have been formed by external deposition, like hills of blown sand, or alluvial flats and deltas.

The surfaces of our present lands are as much carved and sculptured surfaces as the medallion carved from the slab, or the statue sculptured from the block. They have been gradually reached by the removal of the rock that once covered them, and are themselves but of transient duration, always slowly wasting from decay. Even, then, if the internal forces could produce such external features, it can always be shown that the surface which existed when they operated has long since disappeared, together with, in many cases, vast thicknesses of rock that intervened between it and the present one.

It remains to say a few words on the nature of the erosive agencies which form these surfaces.

The Ocean is the grandest of these. The ceaseless breaking of its waves against the margin of the land constantly gnaws into and undermines it, and the tides and currents carry off the eroded materials and deposit them on some part or other of the ocean bed. This action is that of a great horizontal planing machine, always tending to the production of level surfaces, the cutting power being confined to the sea level, while the matter carried off tends to fill up the hollows of the inequalities that lie below it. The denuding action of the sea, therefore, produces "plains of denudation" on the parts it has passed over, and long lines of cliffs or steep banks along the margin where its influence ceased. It is essential for the energetic action of the sea that it should be the open sea, where a heavy swell can roll in upon the land, and where gales of wind can hurl furious waves against it. In sheltered bays and narrow inlets and fiords its erosive agency becomes comparatively small, and in very protected places sinks perhaps to nothing.

While, then, we look to marine denudation as the cause of wide plains, of long escarpments, of bold headlands, and isolated hills, and of the general outline of mountain chains, and as the remover of the great groups of rock that were continuous over the area of the mountains before their elevation was commenced, I believe we err when we attribute to that cause the lesser features by which these greater ones are themselves modified. The river valleys that traverse the great plains, the gullies that run down the sides of the hills, the valleys, glens, ravines, and gorges that furrow the flanks of the mountain chains, have, I believe, been all caused by atmospheric agency on the land, while standing above the level of the sea.

The only case in which the sea tends to produce anything like a valley is that in which it forms open sounds or straits between islands, where the set of the tides and currents impart to it a river-like action. Those depressions in the crest of a mountain chain which are called "passes" or "gaps" have doubtless been often caused by this action, but it is obvious that this ceases as soon as the summit of the pass once rises above the sea level, and prevents the currents from sweeping through it.

While the ordinary erosive action of the sea is a horizontal one, tending to the production of plains bordered by cliffs, that of the atmospheric agencies is a vertical one, always tending to the production of furrows, or more or less steep-sided channels, on all the land exposed to their influence.

Rain falls vertically, and tends to sink vertically into rocks, producing decomposition in them, both by mechanical and chemical action. A superficial coating of greater or less thickness is always thus kept in a state of decay.

In almost all Granite districts, the rock beneath the hollows and flatter parts of the ground will often be found to be decomposed *in situ* to a mere sand, so that it could be dug out with a spade to a depth of several feet. Roundish lumps are found here and there in this sand, which were the centres of the original blocks; these, as well as the solid rock below, showing every gradation of firmness, from hard crystalline rock to a mere incoherent sand. I have observed this in Granite districts in all parts of the world, and was much struck with it during the past summer in the southern part of Brittany, where the deep narrow lanes often showed both Granite and Gneiss thus rotten and soft, to a depth sometimes of fifteen or twenty feet. On the steeper slopes, the exposed rock was much less decomposed, obviously because the particles had been washed down and carried off as fast as they became completely disintegrated.

Hard limestones, again, exhibit the effects of the action of the rain in the numerous open fissures and caverns that are always found in them, the water here having dissolved the rock and carried it off in solution, as if it were so much salt or sugar. The fantastic forms and honey-combed surfaces of all limestone crags attest the same action. In baring the surface of a limestone quarry, where the beds are inclined at any considerable angle, they are often found to be furrowed by rain channels one or two feet in depth and several inches in width, the hollows being filled with the finest earth. A deep covering of mould and turf is no protection against this action, and perhaps even aids it, by contributing an additional dose of acid to the rain water.

Even where hard siliceous rocks exhibit a weathered coat of a very slight depth, a mere skin perhaps of a quarter of an inch thick, as is the case in some Felstones, still it merely proves that the atmospheric influences cannot affect a great thickness at any one time, and does not render it impossible that many such weathered coats may have been formed outside the present surface, and successively removed altogether by the completion of the process.

The joints of rocks when first formed are doubtless mere planes of separation, without any interstice that would allow the insertion of even the thinnest edge of a knife; they would be quite insensible to the sight, and would perhaps scarcely of themselves be sufficient to cause the separation of the rock into distinct blocks. In working deep mines it is sometimes said that the rocks cease to show any joints at all. The open joints such as we see in all rocks near the surface have been opened by the "weather," acting along these concealed planes of separation.

The action of the Atmosphere, then, (*i. e.* the chemical action of air and water and the various gases mingled with them, and their mechanical action, owing both to their movements of gravity and their expansion and contraction from changes of temperature) is operative in the gradual destruction of rock, to a much greater vertical depth beneath the surface than is commonly recognised. Its superficial action is still greater, and has also, as I believe, generally failed, as yet, in receiving due appreciation. The rain that falls upon the surface and does not sink beneath it runs of course down the shortest and steepest slopes it can find, and is collected first into rills, then into brooks and rivulets, and finally passes by rivers to the sea. This superficial drainage of a country is often augmented and kept up by springs, which are caused by that part of the water that had sunk beneath the surface finding its way back to it.

The natural tendency of running water is to cut its channel deeper, and that at a rate compounded of the rapidity of the current and the nature of the rock below. Let anyone take the basin of drainage of any great river, and trace it up to its source, following all its tributaries to their sources, and he will not fail to perceive that all the varied features of the different channels of this system of running waters are the result of these two circumstances only. In the mountain glens he will see those that traverse Granite commonly with rounded open forms; those that cut through hard slates, or thick horizontal sandstones, are commonly narrow and precipitous, with jagged cliffs and overhanging ledges, perhaps, jutting from the sides of the ravines. He will see the marks of the old cataracts that once fell over these ledges, but which now are removed to other places by the cutting down and cutting back of the streams. Torrs and pinnacles will be left here and there, perhaps, rising up from the bed of the stream, showing the former islets and rocks which resisted the erosive action better than the parts on each side of them. Where a softer and more yielding mass of rock occurred, there the glen widens into an open valley; the narrowest and most jagged and steep-sided glens are just where the rocks are most hard and intractable, and best calculated for resisting the chemical and mechanical action of running water.

The scale upon which these operations have been carried out does not affect the nature of the argument. The action has been the same in the miniature glens of our own mountains, and in the grander and more awful abysses that gash the sides of the Alps, the Andes, and the Hymalayahs.

In all cases when the river comes down now, or has formerly come down, in the form of a glacier, before springing into running water, the ice-mass has of course scooped out and deepened and widened the valley in its own peculiar fashion.

When we leave the mountains, and come down into the lower lands, where the rivers wind with a more gentle stream from side to side of broad open valleys, through wide alluvial flats, still it is to the river that the present form and depth of the valley is due. Whatever may have been the undulation of the original surface of marine denudation which determined the course of the primary stream, the river has long since cut down beneath that surface, and is still occupied in cutting deeper, so long as it retains any sensible current at all. It effects this by undermining the bank now on one side and now on the other side of the valley, shaving off a little corner here and another there, so that a river not a hundred yards broad, perhaps, may eventually form a valley of several miles in width. The obstructions it accumulates from time to time in its own bed constantly deflect its channel, so that ultimately it visits every part of the valley.

In many cases the mere deepening of the valley necessarily widens it also, since the rocks may be of such a composition, or may lie in such a way, as not to be able to form a bank of any steepness, and the materials, therefore, always slip down towards the bottom of the valley as fast as their bases are cut into.

It is true that all these processes are infinitesimally slow; but if carried on through a period of time, indefinitely great, it is obvious that it is impossible to assign a limit to the amount of their results.

I have for several years been studying the origin of the river valleys of the South of Ireland, and have since the last meeting of this Association been compelled to arrive at the conclusion, that the great limestone plain of the centre of Ireland has lost a thickness of 300 or 400 feet at least, by the mere action of the rain that has fallen upon it. As a corollary of this conclusion, I have also been led to perceive that the longitudinal and lateral valleys of the Irish mountains, and if of them, then those of all other mountain chains of the world, are the result of the action of the water or the ice that has been thrown down on them from the atmosphere. I believe that the lateral valleys are those which were first formed by the drainage running directly from the crests of the chains, the longitudinal ones being subsequently elaborated along the strike of the softer or more erodable beds exposed on the flanks of those chains.

If we take any mountain chain and its adjacent lowlands, and suppose no rain to fall upon them for a time, and that all the valleys of whatever description were filled up, and the sides of the mountains smoothed over from their peaks to their bases, I believe the surface thus produced would be one representing the limits of marine denudation; then let rain begin to fall on such a country, and all the elaborate structure of valleys, gorges, glens, and ravines would be produced by it. I, of course, do not intend to say that any country ever existed without valleys, since valleys of some kind must commence as soon as the first peaks of the mountains show themselves above the sea, and must be continued and extended in proportion to the extent of the land which gradually rises into the atmosphere. Atmospheric denudation and marine denudation have always been at work simultaneously upon the different parts of every land in the globe, and their action may be very complex, so that it is often difficult or impossible to separate the results of one from those of the other at any particular place.

Most of you will be aware that the views I have thus endeavoured to place before you are not altogether original; other persons have before now proposed the same method of explanation of the form of ground. M. Charpentier long ago referred the origin of the valleys of the Pyrenees to the action of the rivers which traverse them. Mr. Dana had pointed to the same action as the cause of the wonderful system of ravines that furrows the sides of the Blue Mountain range in New South Wales. I confess, however, that I had, up to the present year, hesitated to accept this explanation without reserve, and therefore, since I am now convinced of its truth, I am anxious to take the earliest opportunity of recording that conviction.

I should not omit to mention that two geologists of the greatest eminence, each pursuing a distinct line of investigation of his own, have lately been led to express the same conviction.

Mr. Prestwich, in his recent papers read before the Royal Society, has adopted the hypothesis of the subaërial deepening of the valleys of the Somme and the Seine, and other river-valleys both in France and England, to account for the formation of the freshwater gravels which he finds on the flanks of those valleys, so high above the present levels of the rivers, or of any possible floods.

Professor Ramsay has in like manner attributed the formation of the hollows in which the lakes of Switzerland lie, to the ploughing action exercised on the subjacent rocks, by the action of the glaciers, when far more extensive than now. The formation of lakes lying in "rock basins," and not formed by the mere stoppage or damming up of a river, had always been a complete puzzle to me until I read Professor Ramsay's paper in the last number of the *Geological Journal*. I believe his explanation of their origin to be the true one.

That he and Mr. Prestwich and myself should all, within the space of the same twelvemonth, have been compelled to appeal to external atmospheric action as the only method of explaining the origin of the different surface phenomena we were studying, is of itself, I think, good evidence that we are all three pursuing the right track in our search after truth.

At the instant of penning this sentence, I see by a newspaper paragraph that Dr. Tyndall follows us in his speculations as to the origin of the valleys of the Alps.

As a concluding observation, allow me to remark how curiously the threefold physical agencies that are in simultaneous operation on the crust of the globe were typified in the old heathen mythology. The atmosphere which envelopes the land and rests upon the sea, the ocean which fills up the deeper hollows of the earth's surface, and the nether-seated source of heat and force that lie beneath the crust of the earth are each personified in it as a great Divinity. If one of the old Greek poets were to revisit the earth, and clothe these ideas in his own imagery, he would tell us in sonorous verse of Zeus (or Jupiter), the God of the air, ruling all things upon the land with his own absolute and pre-eminent power; of Poseidon (or Neptune) governing the depths of the Ocean, but shaking the shores which encircle it; and of Hades (or Pluto) confined to his own dark regions below, tyrannizing with all the sternness of a force irresistible by anything which can there oppose it, but rarely manifesting itself by any open action within the realms of the other Divinities.