The Evolution of Derbyshire Scenery.

EDITED BY GEORGE FLETCHER, F.G.S.

From Notes by Messrs. Ward and Fletcher.

PERHAPS no district exemplifies so well the relation between rock-structure and scenery as a limestone district. This is due to the physical and chemical constitution of the rock, which determine the manner in which the disintegrating agents act upon it. The chief of these agents is water in its several forms. Rain, as soon as condensed from the watery vapour in the air, is pure. In passing through the air it dissolves therefrom a certain amount of carbonic acid gas, and in passing through soil containing decaying vegetable matter, collects a further amount. In considering the action of running water upon rocks the presence of this acid is of great importance, for while pure water can only take up about two grains per gallon of carbonate of lime, it is not uncommon for natural waters (which contain this acid) to be found to contain 25 grains per gallon after running over or through limestone rocks. The waters of Kent's Cavern contain from 13 up to 30 grains per gallon, while two analyses of Knaresboro' Dropping Well water give 23 and 39 grains per gallon. Dr. Thresh, in his analysis of Buxton water in 1882, found some 14 grains of calcium bicarbonate, out of a total of 27·096 grains of solid matter per gallon. Water is capable of dissolving a definite amount of carbonic acid gas, and this enables it to take up a definite amount of carbonate of lime. If, then, water fully saturated is spread out over a surface, as on the roofs of caves, or in drops from projections, evaporation takes place, and the carbonate of lime is deposited, hence the stalactitic and stalagmitic deposits of limestone caves. In a similar manner we may explain the formation of tufa, or of the "fur" deposited from hard water in tea-kettles and hot-water pipes.

This chemical action of water upon limestone, and all rocks in which lime forms a constituent is important, but it is obvious that its action will be modified by the physical structure of the rock itself. No matter what the solvent power of the water, it would be incapable of producing the observed effects were it not for the numerous joints and fissures which allow of the entrance of the solvent. To the fact that these are numerous, and recur with some regularity in limestone, must be ascribed the character of the scenery of many districts in Derbyshire. It is not sufficient, however, to notice this structure on a large scale, but to explain the peculiarities in the disintegration of various kinds of rock, the minute structure must be observed. The capacity of rocks for water varies very considerably owing to this difference in structure. The water absorbed is in part taken in between the constituent particles of the rock, and is retained until evaporated or driven off by heat. This is termed the "water of saturation." Other water passes more or less freely through the rock, and is termed the "water of imbibition." Experiments have been made by Prestwich, Wethered, Delesse and others, in order to determine the quantity of water of saturation held by various rocks. From these it is seen that while such rocks as slate and limestone will absorb only a very small quantity of water, sands and soft sandstones will absorb a large quantity, amounting in some cases in sands to as much as three gallons per cubic foot. Mr. Wethered, in the course of a series of observations, found that millstone-grit from Sheffield absorbed over ten times as much water as carboniferous limestone from Clifton. It is not difficult to deduce the effects of freezing upon such rocks. During a sharp frost the water contained between the particles of a sandstone freezes. In freezing it expands, and the cohesion between the particles being overcome, they are thrust asunder, and when a thaw occurs the rock crumbles. This may be noticed in a ploughed field after a frost, or upon wet sand. Sometimes during, or shortly after a frost, long fibres of ice may be seen projecting from such a sand, some of them bearing upon their ends pebbles or fragments of earth. Hence the tendency is for a soft sandstone to crumble into sand. Limestones (excepting oolites and magnesian), however, usually absorb but little water, and so the amount of this action is exceedingly small. What happens in the case of limestone is that water contained in the cracks of the rock expands in freezing, and rends it into blocks and fragments. One effect of the solvent action of water upon the surface of limestone is to bring out their fossiliferous character. The crystalline structure in the fossils causes them to resist more successfully the weathering to which the more or less impure calcareous matrix yields, and this gives rise to the beautiful weathered surfaces from which stand crinoids, corals, and shells in relief. An interesting instance occurs in the carboniferous limestone of Durham and Northumberland. The face of the unaltered rock shows no signs of certain little grains which make their appearance as the rock weathers. As decomposition proceeds, a disintegrated mass is formed, consisting of a small foraminifer—*Saccammina Carteri.*

The effect of a landscape depends largely upon the nature and amount of the vegetation present, and the close connection between geology and vegetable growth is frequently overlooked. The physical and chemical character of the soil depends upon the underlying rock, from which it has mainly been derived; thus we get sandy, clayey, or calcareous soils, and they determine to a very large extent the kind of tree or grain which shall thrive upon them. One soil frequently lacks something which another possesses, so that often at a junction between a limestone and sandstone, or clay, where the products of decomposition mix together, we get a fertile strip which indicates—too often in vain—the kind of treatment necessary to render the adjacent land equally productive. It is an interesting and instructive thing to take a walk across the strata which crop out on the east or west flanks of the Derbyshire anticlinal, say from Matlock to Stretton, noting the changes in the rock scenery, the vegetation, and the industries on the way; from the romantic scenery of Matlock Dale, over the millstone moors, with their scanty herbage and straggling population, right to the coal measure country over which, looking from the grit slope, we can see fertile fields and the kindling fires of the coal and iron industries, surrounded by the busy hives of workers. Much light has been thrown upon the comparative fertility of soils by chemical and physical examinations, for we must not only consider them in regard to the plant foods which they contain, but also with regard to their capacity for absorbing and retaining moisture. The subject is, however, too complex to be dealt with in a few words, it is mentioned here as bearing in an important degree on the relation between geology and scenery.

In an article on "The Origin of Derbyshire Scenery," in last year's *Journal*, I pointed out the effect of jointing and stratification planes upon scenery. It is my intention in the present article to give further local examples of this,* and to deal with underground drainage and the formation of caves. This subject was dealt with by me in a paper on "Valleys and Caves," read at the annual meeting of the Society last year;† but further additional facts have been observed by Mr. Ward in caves and elsewhere in the Peak, which should be placed on record.

The variety met with in the scenery of Derbyshire is due to the association of strata of differing hardness and structure. Over lying the Mountain Limestone, the lowest of the series in

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* My attention has been called to the fact that this subject has been previously dealt with in the Society's Journal, although very briefly: "On the Geology of some of the River Scenery of Derbyshire." A. T. Metcalfe, F.G.S. Vol. VIII., 1886. The diagram there given, however, of the erosive action of a stream upon rocks, is misleading, taking no account of the modifying effect of the divisional planes.

† I should here acknowledge the remarks on the formation of caves contained in Mr. Ward's article "On Rains Cave, Longcliffe, Derbyshire."—*Journal* of the Derbyshire Archæological and Natural History Society, 1889.

Derbyshire, we have the Yoredale Rocks, consisting of sandstones and shales; and above these, the Millstone Rocks. The Yoredale shales present characteristics of great importance, giving rise to peculiarities of scenery worthy of note. These shales are peculiarly friable, breaking up readily in most cases into small and somewhat lenticular fragments, and in other cases being finely laminated, breaking up in the hand into laminæ scarcely thicker than paper. Such shales, although undergoing no marked chemical change under the action of water, are readily disintegrated.

We have also another fact to take into consideration. Owing to the structure of these shales, they readily undergo change of form, due to the pressure of the overlying Millstone rocks, giving rise, where the Millstone rocks have been cut through, forming valleys in the shale, to interesting local phenomena, of which one is mentioned hereafter. The succession of grits and shales in the Millstone series gives rise to the long lines of escarpments or "edges" of grit, which form so marked a characteristic of Derbyshire scenery. Where fully developed, as along the east side of the Derwent Valley north of Baslow, the three grits give rise to three escarpments overlooking the river, *viz.*, Derwent Edge, overlooking the village of Derwent (Kinderscout Grit); Strines Edge, a mile behind it (Rivelin Grit); and a mile and a half still further behind is Sugworth Edge (Rough Grit). Nearer Hathersage are Bamford, Stanage, and White Edges, respectively of the above rocks. In section, and, of course, when looked at in the direction in which these edges run, the contour takes the form shown in Figure 1.

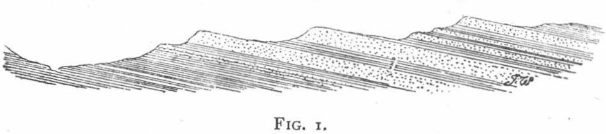

FIG. 1.

A, *Derwent.* B, *Derwent Edge.* C, *Strines Edge.* D, *Sugworth Edge.*

The production of these edges are of interest. Their formation would be readily accounted for if streams ran at their bases, but this is not the case. Their origin must be referred to two causes. (1) The rapid disintegration and undercutting of the underlying shales, and (2) the regular recurrence of joints in the grit by which it is divided into more or less rectangular blocks, having little or no cohesion. As the shale is worn away the blocks of Millstone grit slide down as shown in Figure 2. The dislodged blocks, having no stream to remove them, strew the slope for a considerable distance below the edge, as may be seen along the Derwent Valley north of Baslow, and near the railway cuttings at Padley.

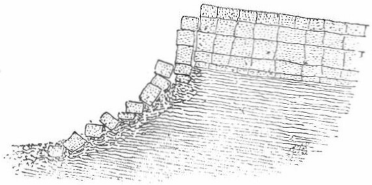

FIG. 2.

Reverting to the denudation of limestone areas, it has been pointed out that the shape, and possibly in many cases the direction of valleys in limestone strata, depend upon the natural divisional planes, *viz.*, the planes of jointing and stratification. In many cases these joints give rise to other phenomena than the production of valleys. Surface waters finding their way into joints and crevasses gradually enlarge them by dissolving away the rock, percolating further and further, until they at last find, perhaps, an outlet at a lower level, often at a considerable distance from the point of entrance. By-and-bye this subterranean channel becomes widened by the constant trickling of the solvent water, and one of the many springs with which our limestone district abounds, is formed. Undoubtedly large areas in Derbyshire must be perfectly honeycombed in this way, large underground cavities being full to overflowing with the waters derived from the surface. A consideration of the phenomena of some of the better known springs would serve to make this clear.

Take the case of the springs which supply the Fountain Baths at Matlock Bath. Here many thousands of gallons pass through the baths and run into the river every day, the supply being scarcely affected by a long spell of dry weather. Sometimes the water of a river will in this way find its way to an outlet at a lower level, leaving its old channel high and dry. As the volume of water poured into the subterranean conduit increases, the work of dissolution proceeds apace, and where the water enters, a "swallow hole," sometimes deep, and with precipitous sides, is produced, and in its further journey "eats out" in the course of its wanderings huge chambers, which constitute the "natural wonder" of a future age. While the erosive action of the water is mainly chemical, it must not be forgotten that, especially in periods of heavy rain, it is supplemented by the mechanical action of suspended particles. It was once the writer's good fortune (in the company of Messrs. Arnold-Bemrose and John Ward) to explore a portion of such an underground watercourse, into which, by accident, the workings of a lead mine (the Bagshawe Cavern, at Bradwell, near Castleton) had penetrated. Here and there upon the floor lay huge tabular masses of limestone which had been detached from the roof, and in other places the floor was thickly covered with a sandy deposit, brought down during storms by the surface waters. The action of these sandy particles, carried by a rapid torrent in a tortuous underground channel, cannot be overlooked. At the time of our visit there had been a long dry season, during part of which this portion of the underground channel had been temporarily deserted, although the rush of waters could be heard in the neighbourhood. During times of storm even large fragments of rock may be taken up in the current and used as battering-rams for the destruction of opposing obstacles, and Professor McKenny Hughes* has well described from personal observation the progress and action of a sudden and violent storm upon the cave and slopes of Ingleborough—a somewhat similar district. Here the action of

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* "On Caves." Trans. Victoria Institute, 1887.

boulders carried by the torrent was particularly noticeable, especially in widening out the swallow hole. Fig. 3 illustrates the above; part of the water of a higher valley is diverted by a short underground passage to a valley on a lower level.

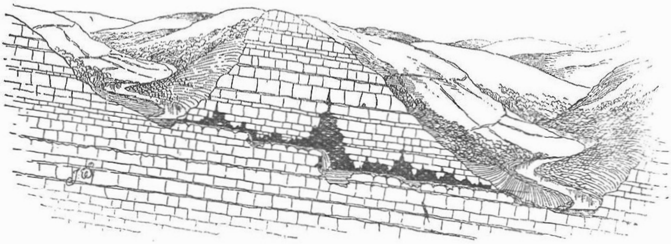

FIG. 3.

We have several most interesting local examples of this action, one of the best known being that of the Peak Cavern at Castleton. We must regard this magnificent cavern as having been produced by the erosive action of the water derived from the district lying to the west and south-west of Castleton. The surface water finds its way into the limestone mainly along the junction of the Yoredale Shale from Windy Knoll to at least as far as Perry Foot. The trough-shaped valley mainly constituting this area was previously drained by a stream, the bed of which may now be seen, dry and deserted, running in the direction of the Mersey, in whose watershed the area in question lies. Along the bed of the valley are a number of "swallow holes," into which the water disappears, finding its way into the Derwent through its subterranean channel. The outlet was previously through Peak Cavern entirely, and it is to the erosive action of this water that the cavern owes its existence. At the present time, however, but little water finds its way through the mouth of the cavern except in flood-time, a lower course having been cut finding its outlet at the spring near the mouth of the cavern, known as Russet Well. A section of the cavern, roughly indicating the course of the underground water, is shewn in Figure 4. As illustrating the manner in which river gorges are sometimes formed, it may be pointed out that the ravine which runs for some distance from the entrance of Peak Cavern is due to the same cause, the roof of the cavern having here fallen in, and the *débris* in the course of time removed. It will readily be seen that with a further lowering of the general surface, a larger portion of the cavern will be opened out, forming an overground stream with precipitous banks. This further step in the evolution of Derbyshire scenery will, however, doubtless require some thousands of years for its completion, unless the present rate of erosion is greatly increased. A portion of the water which issues from the Peak Cavern is possibly derived from the limestone hills a little further south. It is very probable that the huge chasm known as Eldon Hole communicates with Peak Cavern; and there is an old story to the effect that a goose, which fell down this hole emerged at Castleton.

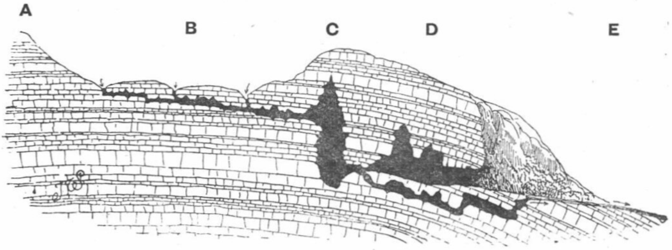

FIG. 4.

A, *Sparrow Pit.* **B**, *Trough-shaped valley west of Castleton.* **C**, *Windy Knoll, and below, the 'Bottomless Pit' of the Speedwell Mine.* **D**, *Peak Cavern.* **E**, *Hope Dale.*

Another good example is to be seen in the Waterfall near Foolow, of which a section, giving a view of the interior, is shewn in Fig. 5, the arrows indicating the direction of the flow. An examination of the district shows that there is a dry valley, representing the old watercourse, extending from the great open chasm which gives rise to the waterfall, to the end of Middleton Dale. Part of this old channel is known as Linen Dale. At present the stream pours into the chasm and disappears, to find its way, together with the waters from neighbouring "swallows," to the valley of the Derwent by way of Middleton Dale. Various causes determine the spot at which the stream takes to its underground course. There are, for example, numerous "swallows" along the junction of the Yoredales with the limestone. Again, an open fissure is sufficient to determine the commencement of the subterranean course, and, bearing in mind the relationship between fissures and mineral lodes, it would be remarkable if the latter were not closely connected with swallows. A case in point is the Waterfall. The chasm occurs at the intersection of the Cross Low and the Black Hole Veins; and there are numerous instances which point to the fact that these underground streams frequently follow the course of the lodes.*

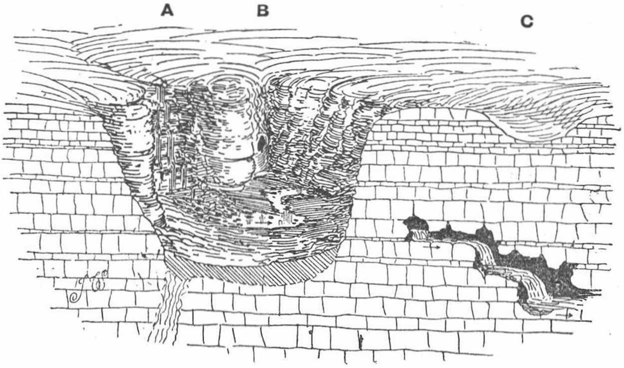

FIG. 5.

A, *The Waterfall.* B, *Mineral lode and small cave.* C, *Old valley-route, with present underground route below.*

Many of the Derbyshire caverns consist in part of worked-out mines and in part of natural chambers encountered in following up the mineral vein. The huge underground chasm intersected in working the Speedwell Level near Castleton is a good example; while Mr. Ward notes that Deepdale Cave illustrates this. On the north-easterly side of this cave is a longitudinal fissure, doubtless connected with the lode which runs by here. This, together with the direction of the plane of stratification, has determined the shape of the cave.

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* Pippin Swallow, near the waterfall referred to, is a good example. It is produced in a lode, indeed the longer axis of the chasm is in a line with it.

Large roughly rectangular blocks detached from the roof occupy the floor, and thus the level of a cave is sometimes slowly raised. This is also illustrated by Rains Cave, and by the underground watercourse previously referred to as occurring in the Bagshawe Cavern. It will thus be seen, without quoting further examples, that the limestone is perforated with numerous conduits, opening now and again into large cavernous spaces, due to the solvent action of natural waters. In studying the scenery of limestone districts, the presence of these must be taken into account, for at some time or other these underground streams will be converted into overground streams. The general erosion taking place at the surface will at last convert these spaces into river gorges, brought about partly by the recession of the mouth of the cavern—as is well seen in the ravine extending from the mouth of the Peak Cavern—and partly by the collapse of the roof, when this has become too thin to keep in position. This will take place gradually, and the fallen *débris* will gradually be removed by the water. This will most probably account for the phenomena presented by some transverse valleys, as may be seen by reference to Fig. 4. An interesting example occurs in Wensley Dale, where a steep-sided ravine carries the drainage through the middle of a hill of smooth contour into Wensley Dale. The rounded contour must probably be referred to the action of ice during that period known to geologists as the Glacial Epoch. The ravine referred to abruptly interrupts the contour of this hill. Now there is nothing in the geological structure of the ground which affords any other explanation of a stream cutting its way straight through an opposing hill, than that it first made its way underground into Wensley Dale, and that at some period since the Glacial Epoch the roof collapsed. There are cases where a river suddenly passes from a broad alluvial valley into a wall-like cliff of limestone rising right in its path. We may note, for example, the case of the Derwent, which passes from the broad shale valley of Darley Dale to cut its way through the limestone which rises abruptly right across its path, on to Cromford. Here, it might be thought, is surely a case where the river found its way in the first place *through* the limestone, and that the collapse of the roof converted the underground watercourse into the Matlock Valley. There is not the slightest necessity for such an assumption. The river course was determined before the broad valley of Darley Dale had been formed, and the cutting out of the valley in the shale and in the limestone must of necessity have proceeded *pari passu*, for it is obvious that material worn from the former must be removed through the valley cut in the latter, and hence the rate of vertical erosion in the shale would be controlled by the rate of erosion in the limestone. At the same time, owing to the widely different physical nature of the shale and the limestone, the valley cut in the former is broad, while that in the latter has that peculiar shape described and explained in my paper in last year's *Journal.* In the case of the ravine cut through the hill on the south-west of Wensley Dale, however, the case is quite otherwise, for the rock is limestone on both sides of the hill, which was obviously rounded before the ravine had any existence, and so its origin must be referred to the causes cited above.

I have already mentioned landslips, which are really so numerous locally as to form an important factor in the evolution of scenery. We have the well-known cases of the slips of limestone which have taken place at Crich, and Hob's House in Monsal Dale. A phenomenon of a somewhat similar nature but more difficult of explanation, is to be seen near Abney, and another at Alport. These are rock-movements of a somewhat different nature to landslips of the Crich type. Let us consider the example near Abney. A hasty survey of the district of the Highlow Brook shows that the valley is cut through a plateau of thinly-bedded shales (Shale Grit) resting upon the black Yoredale shales previously described. The sides of the valley are normally rather gentle and grass clad; but in the section of the valley (about a mile long) where the slips have occurred, the southern side is usually precipitous, naked, and separated from the brook, which here flows at the foot of the northern side, by a gradually descending shelf, or "undercliff," varying from a few hundred feet to nearly a quarter of a mile in breadth. In this part of the valley the sides are about 200 feet high, and the bottom cuts into the black shale. Upon this undercliff are a series of long hillocks running some four or five abreast in the direction of the valley. These hillocks give a peculiar and rather weird character to the scenery (Fig. 6) as they range up to some fifty feet in height, and, although generally grass-clad, possess few trees, and these, being of a stunted character, greatly enhance their apparent magnitude. It must here be remarked that those hillocks near the brook are well rounded, and, almost invariably, lower than those further south towards the cliff. Further those near the brook are well covered with verdure, while the masses towards the cliff show their "ribs" in a marked manner. From this fact, and from the steepness of their sides, which in certain cases exceed an angle of 45°, it would seem that the hillocks near the brook are older than those near the cliff. An important point to notice is that the bedding of the hillocks is very regular, and corresponds, as fairly as can be expected in such material, with the bedding in the cliff to the south.

FIG. 6.

In consonance with the method adopted here, we are now to enquire into the origin of these hillocks, and trace our way back carefully to the causes which have brought about their existence. In the first place it is obvious that these are outliers of the plateau to the south, and which I shall hereafter speak of as the parent rock. The problem to be solved is this: How have they become detached and isolated from the parent rock? The answer which would glibly be vouchsafed by the embryo student of Geology is, that the action of the weather had carved out the spaces between the hillocks, in the manner in which most other hills have been formed. Such an answer would be found to be unsatisfactory, for it is found that the appearances of the hillocks as regards contour and verdure point to the fact that they are of different ages, the grass-clad mounds near the brook being distinctly older than those near the parent rock. An astute geologist would conclude that these hillocks had slipped down from the parent rock over the oleaginous shales which underlie them. Indeed, the officers of the Geological Survey offer this explanation in the analogous case of the peaked hillock known as Alport Tower, and the surrounding hummocks.* Mr. Ward is, however, of the opinion that this explanation does not satisfy the facts of the case either in the Alport instance or the one at Abney, and he suggests a theory which is presented below. He argues that the isolation of the hillocks cannot be due to slipping simply, for the detachment of the masses has proceeded with some regularity, and that such slipping could not have proceeded without considerable disturbance of the bedding of the detached masses, which certainly does not appear to has taken place. Further, the dip is very gentle, not exceeding 3° to the north, which, in our opinion, would not be competent to produce such slipping. The explanation is to be found in the physical structure of the underlying shales, which has been previously referred to. Above these shales lie a thickness of about 200 feet of shale grit. So long as this superincumbent mass is continuous it will be well supported by the shales below. But suppose, as in the present case, that the cutting tools of nature carve out a strip of this overlying plateau. Were there a considerable amount of cohesion between the shales, no marked effect would follow; but, as has been pointed out before, the

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* Memoir of the Geological Survey: "The Geology of the Carboniferous Limestone, Yoredale Rocks, and Millstone Grit of North Derbyshire," p. 42.

cohesion is very slight, the shales being remarkably friable, and the flaky fragments slipping over each other with readiness. It was explained in last year's *Journal*[*] how the pressure of overlying gritstones had produced flexures in the Yoredales of the Amber Valley. In the present cases a somewhat different effect has been produced. The shales have resembled in their behaviour a viscous substance. The pressure of the overlying mass has caused them to be squeezed out towards the valley, where there is but slight resistance laterally, and no overlying mass. If it is difficult to conceive how this could be brought about; let it be borne in mind that much of the water falling on to the plateau would find its way down to the Yoredale shale, permeating and lubricating the upper laminæ. Now the overlying rocks are of a broken character, being thinly bedded and divided vertically by joints. Accordingly, as the shales are squeezed out from below, they will tend to carry with them—float out, as it were—portions of the overlying strata. But the separation from the parent rock depends also upon another process. It must not be overlooked that the slight dip would tend to direct the water sinking through the plateau south of the valley, northwards into the latter, in preference to the lower valleys to the south. Hence the shale, as it approaches the valley, would be more mobile, and hence more susceptible to being squeezed out. But, where this squeezing out takes place, the shale will become correspondingly thinner, and, as a consequence, the overlying rocks will unequally sink those portions next the valley at a greater rate than those behind them. This unequal subsidence will obviously aid the fracturing. The process would be accelerated when once begun by the lateral thrust exerted by the "creep" produced on the shale between the detached mass and the parent rock, and by the talus falling into the crevasse from the sides; also by the increased action of water finding its way in large quantities behind the detached mass and thus soaking the semi-solid mass

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[*] "On Some Contorted Strata in the Yoredale Rocks, near Ashover." By John Ward.

on which the *berg* is being floated out. This mass being thus detached, and its lateral support withdrawn from the parent rock, the compression proceeds apace, and another block parts and floats off at the rate of probably only a few feet per century, to be followed by other blocks, whose downward path, though by no means rapid, is certainly sure, and does not cease until the hillock is brought to the brookside, and there exposed to the rapid disintegration of the stream. But so slow are these movements—so apparently earth-fixed are the hillocks—that upon one of these slipped masses lower down the valley is an old cottage with its outbuildings and gardens. It will be seen that the earliest removed masses will have been for a longer period subjected to the wear and tear of sub-aerial denudation; hence we find such more disintegrated, possessing gentler slopes, and more completely clad with the verdure which only time can bestow. The newer ones—near the mainland, so to speak—are steeper and barer; while right back on the slope of the parent mass higher up the valley, can be perceived—particularly from a distance—peculiar Λ shaped *depressions marking the lines along which further separation is taking place. There is no actual fissure in these cases, for it would be filled up as formed with material from above and below, but they are interesting as marking the line of parting for the next mass. Sufficient has been said to shew that this ingenious theory is fully borne out by the observed facts, and certainly has, so far as the writer is aware, the merit of novelty.

And here must end the present article; not because the subject is exhausted but because the space is limited. One word may be said in conclusion. It is sometimes thought that the scientific investigation and explanation of these natural phenomena will detract from the pleasure to be derived from them. One friendly critic wrote as much in reference to my article bearing a similar title in last year's *Journal*. Surely the opposite is the case. To the geologist every detail in the outline of hill and valley conveys

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* This refers not to the *section* of the depression, but to its *outline* on the hill side.

a meaning, and carries the imagination back to a period when things were not as they are now, but when the present forces were at work slowly bringing about the present state of things. It is frequently said that science takes the poetry out of physical phenomena by explaining them, the romance being, therefore, rooted in ignorance. On the contrary, science infuses new interest and the highest poetry into everything—her explanations can never be ultimate, they simply lead on to fresh discoveries, ever opening out fresh vistas of enquiry, and at every step strengthening the reason and stimulating the imagination. To the unlearned the river gorge and gaping chasm are evidence only of some huge convulsion which rent the rocks asunder—and there the matter ends. The geologist perceives in them evidence of the prolonged action of water, and thence spreads out a series of questions. How did the water get there? in what way did it manage to remove the solid rock? and why should it have carved out the rock in just that shape? And to answer these questions, he has to ask others—of Nature, who, in answering one, invariably suggests others, so that, although he is infinitely wiser and nearer the solution of the problem, yet he sees stretched before him an interminable vista of questions to be asked and secrets to be revealed, which, after it has been traversed, will still find him face to face with mystery. Yet the glimpse that he gets of the relations of things, of the interdependence and immutability of nature's laws, is spiritual food and drink, providing that energy and stimulus from which alone proceeds worthy and fruitful scientific investigation.