On the Geology of some of the River-scenery of Derbyshire.

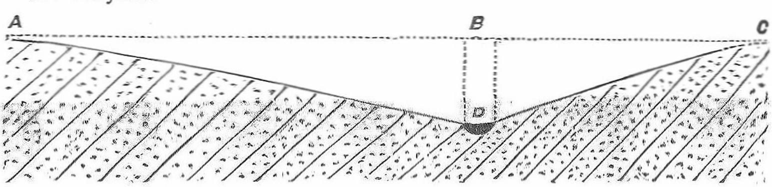
By A. T. Metcalfe, F.G.S.

OF the numerous agencies which modify the surface of the globe, probably the most universal, unceasing, and remarkable in its effects is Water. To it, in its varied forms of action, are largely due not only vast changes in the distribution of sea and land, but also minor diversities of hill, valley, and plain. Our estimate, however, of the magnitude of its operations will be altogether inadequate if regulated by what we witness in our own country. Changes take place, indeed, in Britain, but only the more observant can perceive their extent and importance. Every shower of rain that falls tends to loosen the cohesion of rocks and soils on which it falls: raindrops coalesce to form rills that carry with them loose particles of sand and mud which lie in their paths; rills give their burdens of sediment to the runnels, the runnels to the brooks, the brooks to the rivers, and the rivers to the ocean. Observe the muddy state of a river after heavy rain; obtain a gallon of the water and allow it to settle. The quantity of sediment will be found to be considerable. Could this quantity be multiplied by the number of such gallons rolled down by all the rivers in the country in a year, and then again in a century, one would arrive at some faint idea of the vast amount of solid matter worn from the land by water and deposited in the sea.

It is to regions nearer the equator, however, that we must look for manifestations of the same forces too striking to pass unnoticed, and too stupendous in their results to be ignored. The Mississippi carries into the sea 7,459,267,200 cubic feet of sediment every year—a quantity sufficient to cover a square mile of ground to a depth of 268 feet. The deltas of the Ganges, Amazon, and other large rivers, are accumulations of sediment hundreds of feet deep and thousands of square miles in extent, and have been formed out of the mud, sand, and gravel worn away and transported from the surrounding countries by the action of rain and streams. Yet these vast accumulations represent but a portion of the waste suffered by the land. Beyond the deltas, or estuaries, enormous quantities also are deposited on the ocean floor. The turbid waters of the Ganges reach far into the Bay of Bengal, and the mud of the Amazon is observable for hundreds of miles out in the Atlantic.

It has been calculated that water running with a velocity of 6 inches per second will move fine sand; with a velocity of 12 inches per second will transport fine gravel, and with a velocity of 36 inches will sweep along angular stones of the size of a hen's egg. The transporting and cutting power of rivers therefore depends largely upon the rapidity of their currents; it must not, however, be supposed that running water *of itself* has much power to abrade rocks; the real strength of the denuding and cutting power of a river lies in the sediment with which it is more or less charged. Even when none is visible in the surface-waters, sand and gravel are being hurried along the bottom, and *their never-ceasing friction* wears away the bed, and is for ever deepening the channel. So long as a river has a fall it will continue to deepen its bed. To compare nature with art and to show the cutting power of grains of sand, one may instance the method of cutting large slabs of stone to be seen in a stoneyard. The instrument used is a "saw-plate," or saw with a blunt edge. During the sawing process, however, a constant stream of water and loose sand is kept flowing below the saw-plate, and upon this the cutting action practically depends. Again, to turn to Æolian agencies, it is well known that in the western territories of the United States, and indeed in our own country, there are numerous instances of enormous masses of rocks being almost completely worn away in their lower parts by the incessant friction of grains of sand driven against them by the prevalent winds.

The action of a river when unaided by any other agency, is to cut an ever-deepening narrow trench into the rocks, over which it flows, just as the saw mentioned above, cuts into a block of stone, leaving the sides or banks perfectly steep and vertical. If this be so, it may be asked, how is it that many of the streams of our own country do not flow through deep trenches but through flat open river-valleys, or at least gorges of considerable width? The answer is simple, because the rivers have not been the only factors in producing the landscape. Where the action of the weather has play it rounds off the edges and breaks down the sides of the "trench" cut by the river, and thus what would have otherwise remained a steep-sided trench becomes gradually opened out. One shower of rain disintegrates the material forming the river bank, the next washes it into the stream, which carries it away. This process is continued year after year, century after century, until instead of a plain with a river flowing in a deep trench, we have at length a valley, more or less wide and open, rising gently from either side of the stream. The woodcut below illustrates the subject:



A, B, C, original level of ground.
B, original level of river.
D, present river.
The strata between the points AB, BC, CD, and DA, have been, particle by particle, washed down into the stream and carried away.

It follows from this that the width of a river-valley should vary according to the rapidity or difficulty with which the rocks on its flanks yield to atmospheric agencies. This is just what we find in nature. If we follow the course of rivers in Derbyshire we find them flowing for miles, perhaps, through broad and open valleys, and then through comparatively narrow and steep-sided gorges. It will be invariably found that where the valley is broad and open the river is flowing through soft and easily denuded strata, and that where it is narrow and steep-sided, the rocks are hard and unyielding.

In the Colorado River of the west, which empties itself into the Gulf of California, we have the rare instance of a river which has been allowed to carry on the process of cutting its "trench" without the interference of any other denuding agency. This river flows for over 200 miles through a rainless district. There has, therefore, been no rain or other atmospheric agency, to round off the edges of the trench, to wear away its walls, and to scoop out a valley. We find in consequence that the river flows through a narrow gorge, the walls of which are quite vertical, and vary in height from 3,000 to 6,000 feet; in other words, in many parts the "trench" is more than a mile deep. At various points between the river and the top of the trench may be seen, on protruding pieces of rock, small isolated patches of river-gravel, similar to the gravel in the bed of the river, marking former levels of the stream. A river with banks quite vertical and a mile high is of course only possible in an area free from atmospheric agencies. Here an enormous thickness of solid rock, flanking the stream on each side, has escaped denudation owing to there being no rain or other denuding force to supplement the action of the river.

In Derbyshire we frequently find rivers behaving in what at first sight seems to be a most eccentric manner. They appear to have intentionally gone out of their way to discover and encounter difficulties, and to have deliberately chosen to cut through hard rocks, when it was open to them to find an easy channel through soft strata. Take for instance the course of the Derwent near Matlock. This river flows from Rowsley in a broad open valley of Yoredale shales. About a mile from Matlock Bath it leaves these soft shales and has cut a deep and comparatively narrow gorge into the carboniferous limestone, giving us the beautiful scenery of "the Vale" between the High Tor and Masson. Near Cromford the river quits the limestone and again enters the Yoredale shales. A glance at a geological map of the district will show that it was, so to speak, wholly unnecessary for the river to cut through the limestone at all. When it reached the limestone, had it turned but the slightest distance to one side (the east), it could have *continued* to flow through soft shales to Cromford. It is recorded that originally the gorge where the river enters the limestone was only just broad enough to admit the river, and that it had to be widened by blasting when the highway was made along the valley. Strange as these facts may appear, all difficulty vanishes in a moment if we suppose that the birth of the Derwent dates back to a time before the Yoredale shales, in the direction of Rowsley and the carboniferous limestone of Matlock presented to view the difference of altitude which we now observe. Doubtless at one time the surface of the whole country was a plain as high as the highest portion of the carboniferous limestone at Matlock. It was at this period that the Derwent began to flow. The Yoredale shales of Rowsley being then as high as the now towering carboniferous limestone of Matlock, when the river had flowed across the one, the other presented no such rocky wall as we now behold. Without any necessity for turning aside to escape obstructions, the river then ran on its even course, the only change being in the character of the strata forming the river-bed. As, however, the river deepened its channel the atmospheric agencies would act with unequal rapidity on the strata flanking the river at various parts of its course. The soft Yoredale shales would rapidly suffer disintegration, and allow a wide open river valley to be scooped out of them, as shown in the woodcut. The degraded materials would be washed down to the stream, and carried away by it—thus the "area of drainage" would ever be increasing. In short, as rapidly as the river deepened its channel in the Yoredale shales, atmospheric agencies would wear away and lower the general surface of the country on each side. The carboniferous limestone on the other hand, being harder and more unyielding, would much more effectually resist the denuding forces of the atmosphere, and only suffer a comparatively narrow gorge to be carved out of it; or in other words, the denuding agencies of the atmosphere were unable to affect the carboniferous limestone bordering the river in such a manner as to keep pace with the deepening of the river channel.

Although the surface disintegration of the country at large flanking the river would, as we have seen, proceed at greatly varying rates in different parts of its course, yet the deepening of the river channel itself must have proceeded at the same rate over Yoredale shales and carboniferous limestone alike. The carboniferous limestone of Matlock being lower down the stream than the Yoredale shales of Rowsley, the bed of the channel in the latter could only be deepened by its disintegrated materials being carried away down the stream over the river bed at Matlock. The river bed of the Yoredale shales would therefore, so to speak, be compelled to wait for or keep time with the bed of carboniferous limestone lower down in the matter of cutting the channel.

What has been said with reference to the Derwent at Matlock applies to the Dove at Beresford Hall. The lovely vale known as Dovedale is nothing more or less than a gorge cut in hard and unyielding rocks by the river Dove. Doubless, going back into far antiquity, the soft Yoredale shales which fringe the river prior to its entry into the "dale," and which now lie at a much lower altitude than the top of the carboniferous limestone of Dovedale, were once as high as the latter and have been denuded by atmospheric agencies.

Perhaps, however, the most striking instance is that of the river Manifold, which, after flowing for a long distance in a low lying Yoredale valley, suddenly breaches a wall of limestone at Apes Tor, near Ecton. The contrast here between the levels of the tracts of country, formed respectively of "Yoredales" and carboniferous limestone, is most marked.

In the "rough and ready" or "cataclysmal" days of Geology, the theory that all river gorges, such as we have described, were torn open by some terrible convulsion of nature was adopted without hesitation, and, we may say, without much consideration. Instances without number could be given in which this theory was accepted in spite of the fact that the strata on the opposite sides of a river-gorge did not exhibit the faintest trace of disturbance, and although the river was manifestly flowing over a massive bed of rock in which there was not the slightest rupture. In the affairs of everyday life, no man appeals to the supernatural for an explanation of any circumstance until all natural causes are proved inadequate. So in the interpretation of nature it is now, happily, no longer considered scientific or reasonable to appeal to the "cataclysmal" and "abnormal," until it is manifest that ordinary and regular operations can afford no solution. The Astronomer demands Space; the Geologist postulates Time. Let there be given a sufficient length of time and all the features we have described can be fully explained by agencies which we see every moment at work around us. Scenery is as much the result of law and law-directed forces as the original formation of the rocks, out of which scenery is carved. The Catastrophic Geology of the early part of this century no longer exists; in the words of one of the most thoughtful and striking of modern works*—"Its fallacy was soon and thoroughly exposed. The advent of modified uniformitarian principles all but banished the word catastrophe from science, and marked the birth of Geology as we know it now. Geology, that is to say, had fallen at last into the great scheme of Law."

* "Natural Law in the Spiritual World," by Henry Drummond, F.R.S.E., F.G.S.