CLASSICS OF SCIENCE: Theory of Strata

Geology

The arrangement of strata in your neighborhood and the kinds of rock which compose them will afford an illustration of Hutton's theory of their formation.

ILLUSTRATIONS OF THE HUTTONIAN THEORY, 1802, in The works of John Playfair, Esq., Vol. 1. Edinburgh, 1822.

Strata Have Moved

Now, it is certain, that many of the strata have been moved angularly, because that, in their original position, they must have been all nearly horizontal. Loose materials, such as sand and gravel subsiding at the bottom of the sea, and having their interstices filled with water, possess a kind of fluidity: they are disposed to yield on the side opposite to that where the pressure is greatest, and are therefore, in some degree, subject to the laws of hydrostatics. On this account they will arrange themselves in horizontal layers; and the vibrations of the incumbent fluid, by impressing a slight motion backward, and forward, on the materials of these layers, will very much assist the accuracy of their level.

It is not, however, meant to deny, that the form of the bottom might influence, in a certain degree, the stratification of the substances deposited on it. The figure of the lower beds deposited on an uneven surface, would necessarily be affected by two causes; the inclination of that surface, on the one hand, and the tendency to horizontality, on the other; but, as the former cause would grow less powerful as the distance from the bottom increased, the latter cause would finally prevail, so that the upper beds would approach to horizontality, and the lower would neither be exactly parallel to them, nor to one another. Whenever, therefore, we meet with rocks, disposed in layers quite parallel to one another, we may rest assured, that the inequalities of the bottom have had no effect, and that no cause has interrupted the statical tendency above explained.

Layers Originally Horizontal

Now, rocks having their layers exactly parallel, are very common, and prove their original horizontality to have been more precise than we could venture to conclude from analogy alone. In beds of sandstone, for instance, nothing is more frequent than to see the thin layers of sand, separated from one another by layers still finer of coaly, or micaceous mat-

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ter, that are almost exactly parallel, and continue so to a great extent without any sensible deviation. These planes can have acquired their parallelism only in consequence of the property of water just stated, by which it renders the surfaces of the layers, which it deposits, parallel to its own surface, and therefore parallel to one another. Though such strata, therefore, may not now be horizontal, they must have been so originally; otherwise it is impossible to discover any cause for their parallelism, or any rule by which it can have been produced.

This argument for the original horizontality of the strata, is applicable to those that are now farthest removed from that position. Among such, for instance, as are highly inclined, or even quite vertical, and among those that are bent and incurvated in the most fantastical manner, as happens more especially in the primary schisti, we observe, through all their sinuosities and inflections, an equality of thickness and of distance among their component laminæ. This equality could only be produced by those laminæ having been originally spread out on a flat and level surface, from which situation, therefore, they must afterwards have been lifted up by the action of some powerful cause, and must have suffered this disturbance while they were yet in a certain degree flexible and ductile. Though the primary direction of the force which thus elevated them must have been from below upwards, yet it has been so combined with the gravity and resistance of the mass to which it was applied, as to create a lateral and oblique thrust, and to produce those contortions of the strata, which, when on the great scale, are among the most striking and instructive phenomena of geology. . . . It is plain, that if they remained now in the situation in which they were at first deposited, they would never appear to be suddenly broken off. No stratum would terminate abruptly; but, however, its nature and properties might change, it would constitute an entire and continued rock, at least where the effects of waste and *detritus* had not produced a separation. This, however, is very far from being the actual condition of stratified bodies. Those that are much inclined, or that make considerable angles with the horizontal plane, must terminate abruptly where they come up to the surface. Their doing so is a necessary consequence of their position, and furnishes no argument, it may be said, for their having been disturbed, different from that which has been already deduced from their inclination. There are, however, instances of a breach of continuity in the strata, under the surface, that afford a proof of the violence with which they have been displaced, different from any hitherto mentioned. Of this nature are the *slips* or *shifts,* that so often perplex the miner in his subterraneous journey, and which change at once all those lines and bearings that had hitherto directed his course. . . . These *shifts* are often of great extent, and must be measured by the quantity of the rock moved, taken in conjunction with the distance to which it has been carried. In some instances, a vein is formed at the plane of the shift or slip, filled with materials of the kinds which will be hereafter mentioned; in other instances, the opposite sides of the rock remain contiguous, or have the interval between them filled with soft and unconsolidated earth. All these are the undeniable effects of some great convulsion, which has shaken the very foundations of the earth; but which, far from being a disorder in nature, is part of a regular system, essential to the constitution and economy of the globe. . . .

Great Unconformities

Though such marks of violence as have been now enumerated are common in some degree to all the strata, they abound (*Turn to next page*)

Theory of Strata—*Continued*

most among the primary, and point out these as the part of our globe which has been exposed to the greatest vicissitudes. At their junction with the secondary, or where they emerge, as it were, from under the latter, phenomena occur, which mark some of those vicissitudes with astonishing precision; phenomena of which the nature was first accurately explored, and the consequences fully deduced, by the geologist whose system I am endeavouring to explain. He observed, in several instances, that where the primary schistus rises in beds almost vertical, it is covered by horizontal layers of secondary sandstone, which last are penetrated by the irregular tops of the schistus, and also involve fragments of that rock, some angular, others round and smooth, as if worn by attrition. From this he concluded, that the primary strata, after being formed at the bottom of the sea, in planes nearly horizontal, were raised, so as to become almost vertical, while they were yet covered by the ocean, and before the secondary strata had begun to be deposited on them. He also argued, that, as the fragments of the primary rock, included in the secondary, are many of them rounded and worn, the deposition of the latter must have been separated from the elevation of the former by such an interval of time, as gave room for the action of waste and decay, allowing those fragments first to be detached, and afterwards wrought into a round figure.

Indeed, the interposition of a breccia between the primary and secondary strata, in which the fragments, whether round or angular, are always of the primary rock, is a fact so general, and the quantity of this breccia is often so great, that it leads to a conclusion more paradoxical than any of the preceding, but from which, nevertheless, it seems very difficult to withhold assent. Round gravel, when in great abundance, agreeably to a remark already made, must necessarily be considered as a production peculiar to the beds of rivers, or the shores of continents, and as hardly ever formed at great depths under the surface of the sea. It should seem, then, that the primary schistus, after attaining its erect position, had been raised up to the surface, where this gravel was formed; and from thence had been let down again to the depths of the ocean, where the secondary strata were deposited on it. Such alternate elevations and depressions of the bottom of the sea, however extraordinary they may seem, will appear to make a part of the system of the mineral kingdom, from other phenomena hereafter to be described.

On the whole, therefore, by comparing the actual position of the strata, their erectness, their curvature, the interruptions of their continuity, and the transverse stratification of the secondary in respect of the primary, with the regular and level situation which the same strata must have originally possessed, we have a complete demonstration of their having been disturbed, torn asunder, and moved angularly, by a force that has, in general, been directed from below upwards. In establishing this conclusion, we have reasoned more from the facts which relate to the *angular elevation* of the strata, than from those which relate to their *absolute elevation,* or their translation to a greater distance from the centre of the earth. This has been done, because the appearances, which respect the absolute lifting up of the strata are more ambiguous than those, which respect the change of their angular position. The former might be accounted for, could they be separated from the latter, in two ways, viz. either by the retreat of the sea, or the raising up of the land; but the latter can be explained only in one way, and force us of necessity to acknowledge the existence of an expanding power, which has acted on the strata with incredible energy, and has been directed from the centre toward the circumference. . . .

From all, therefore, that relates to the position of the strata, I think I am justified in affirming, that their disturbance and removal from the place of their original formation, by a force directed from below upwards, is a fact in the natural history of the earth, as perfectly ascertained as any thing which is not the subject of immediate observation. As to the power by which this great effect has been produced, we cannot expect to decide with equal evidence, but must be contented to pass from what is certain to what is probable. We may, then, remark, that of the forces in nature to which our experience does in any degree extend, none seems so capable of the effect we would ascribe to it, as the expansive power of heat; a power to which no limits can be set, and one, which, on grounds quite independent of the elevation of the strata, has been already concluded to act with great energy in the subterraneous regions. We have, indeed, no other alternative, but either to adopt this explanation, or to ascribe the facts in question to some secret and unknown cause, though we are ignorant of its nature, and have no evidence of its existence.

James Hutton was born in Edinburgh, Scotland, June 3, 1726, and died in the same city March 26, 1797. He attended the schools and the university in Edinburgh, and became greatly interested in the scientific method of thought. He studied medicine, as the only profession which satisfied his scientific leanings, and spent several years in Paris and Holland, taking his M. D. at Leyden in 1749, at the age of 23. But the practice of medicine did not appeal to him, and at the age of 28 he took up scientific farming in Berwickshire. By 1768, the farm was running so smoothly that its problems no longer interested its owner, and he returned to Edinburgh. There Hutton enjoyed the friendship of scientific companions, and spent the rest of his life in working out his theories of the cause of rain, published in 1784, and of the formation of the earth. The latter was read before the Royal Society of Edinburgh in 1785, with the title: "Theory of the Earth, or an Investigation of the Laws Observable in the Composition, Dissolution and Restoration of Land upon the Globe." Although it marked a great advance in the very new science of geology, the paper was written in so difficult a style that it was not appreciated at its true value until explained by Hutton's friend Playfair five years after the author's death.

John Playfair was born in Benvie, Forfarshire, Scotland, March 10, 1748, and died in Edinburgh July 20, 1819. His higher education was at the University of St. Andrews, where he studied for the ministry but became interested in science. At the age of 18 he was considered for the position of professor of mathematics at Marischal College, Aberdeen, but was not appointed. At 24 he again applied unsuccessfully for professorship of natural philosophy at St. Andrews. The next year, upon his father's death, he succeeded him as minister at Liff and Benvie, where he remained for nine years, but kept up his interest in scientific study. In 1782 he resigned to become tutor of Ferguson of Raith, and thereafter remained in his preferred work. He became professor of mathematics at Edinburgh University in 1785, and during his residence in that city he became the friend of the geologist Hutton. Playfair published his "Illustrations of the Huttonian Theory of the Earth" in 1802, five years after the death of the older scientist, and by his clear exposition made Hutton one of the shapers of the new science of geology. Playfair, after teaching mathematics for 20 years, became professor of natural philosophy at Edinburgh in 1805, and continued in that position for the rest of his life.