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JAMES HUTTON, THE PIONEER OF MODERN GEOLOGY[1]

GEOLOGY had its beginnings in ambitious attempts to solve by a single system of philosophy all the secrets of the physical universe, at a time when little was known and when it was the custom to evolve conceptions out of the workings of the inner consciousness rather than by reasoning from the facts of observation. It is, therefore, of the greatest significance that our civilization grew up within the most unstable belts upon the earth's surface, within which the awe-inspiring and catastrophic phenomena of nature draw attention to man's impotence in the face of these destructive manifestations.

From the outset religious beliefs have strongly colored the conceptions of natural phenomena. Earthquakes and volcanic eruptions, devastating floods of waters and plagues of insects have one and all been looked upon as indications of the displeasure of some deity. The Christian era inherited both from the pagan world and from the Hebrew conceptions of the Old Testament the idea of punishment through the infliction of destructive geological phenomena.

Under these circumstances it was but natural that the church should have been looked upon as the fountain of all wisdom in matters scientific as well as spiritual, the more so since the intellectual class of the middle ages was restricted to the churchmen and to the physicians, who were usually closely attached to the persons of powerful Christian princes on whom they were dependent for their support. The records of ideas were, moreover, treasured in the monasteries of the church. Little wonder is it, therefore, that reasoning from the facts of observation was so long in usurping the place of the inherited conceptions over which the church had spread the protecting cloak of divine revelation.

Science has been inclined to ascribe an emancipation from church dictation to the controversy which developed near the middle of the last century over Darwin's "Origin of Species," but evidence is not wanting that within large sections of our own country its shackles are still upon the popular beliefs.

There were certain fundamental problems of geology on which the church had made no very definite pronouncement, and it was in this supposedly safe quarter where no affront would be offered to church

[1] Read at the Memorial Meeting of the University of Michigan Research Club on April 21, 1926.

dogmas that modern geology grew up and obtained a certain amount of support before its more independent leaders were called upon to measure swords with the champions of the church. The problem of the origin of rocks it was at first sought to solve in such a manner as to cover by a single process all rocks of whatever sort. Two schools soon grew up—the Neptunists, who ascribed all to the action of water, and the Vulcanists, who made the action of fire explain everything.

The leader of the Neptunists was a very remarkable personality, Abraham Gotlob Werner, teacher of mining and mineralogy at the Mining Academy of Freiberg in Saxony during the last quarter of the eighteenth century and the first quarter of the nineteenth. The recognized head of the rival school, though he did not really ascribe the origin of all rocks to the action of fire, was James Hutton, of Edinburgh. In the controversy for which Werner was so largely responsible, neither he nor Hutton took a very active part, the fight having been waged with great bitterness by the disciples or the admirers of these leaders. To evaluate the service to science of James Hutton it is necessary at the outset to study the personality of his rival. Werner was in no sense an observer and he had never been outside the little province of Saxony in which he was born. His quite remarkable influence upon the thought of his time must be ascribed to his engaging but dominating personality and to his quite remarkable power as a lecturer. Not only the young men, but those also who had already arrived at distinction, traveled to Freiberg and learned the German language in order that they might listen to the lectures of this great expounder of popular doctrines. Captivated by his personality and power they went to their homes as his apostles fired with all the zeal of Jesuit missionaries to propagate the faith of their idolized master.

Werner's lectures traversed every field of human interest. His mineral specimens he would connect up in his lectures with the migrations of races, with the development of the arts, with campaigns, battles and military strategy. The artist, politician, historian, physician and soldier were each shown how mineralogy was altogether indispensable to them in their professions. Sir Archibald Geikie has said of Werner: "It seemed as if the most efficient training for the affairs of life were obtainable only at the Mining School of Freiberg. . . . No teacher of geological science either before or since has approached Werner in the extent of his personal influence or in the breadth of his contemporary fame."

Of the great geologists of the day who received their inspiration from Werner were von Humboldt, von Buch, Cuvier, d'Aubuisson, Freisleben, Karsten and Jameson. Yet it was from among this distinguished group of his students who had fallen under the master's spell that many of Werner's doctrines were destined later to be completely repudiated; for there can be no doubt whatever that the evolution of scientific thought was set back by decades through the influence of Werner's hypnotic teachings. "Never," says Sir Archibald Geikie, "was a system devised in which theory was more rampant; and theory, too, unsupported by observations, and, as we now know, utterly erroneous. From beginning to end of Werner's method and its applications, assumptions were made for which there was no ground, and these assumptions were treated as demonstrable facts. The very point to be proved was taken for granted, and the geognosts, who boasted of their avoidance of speculation, were in reality among the most hopelessly speculative of all the generations that had tried to solve the problem of the theory of the earth."

In Great Britain the Wernerian School gained headway because the doctrine of a universal ocean within which the rocks had been precipitated from solution was made to fit to the dogmas of the church through connecting up the latest inundation with the Noachian deluge. This rallied the church to its support at a time when heresy-hunting had been greatly stimulated by the French Revolution, and nowhere more than in Scotland, where Robert Jameson, one of the most distinguished of Werner's British pupils, was the professor of natural history in the University of Edinburgh. Jameson in his writings asked the pertinent question, "What has since become of the immense volume of water that once covered and stood so high over the whole earth?" And with true Wernerian faith he answered it himself. "Although," he said, "we cannot give any very satisfactory answer to this question, it is evident that the theory of diminution of the water remains equally probable. We may be fully convinced of its truth, and are so, although we may not be able to explain it. To know from observation that a great phenomenon took place is a very different thing from ascertaining how it happened." Commenting upon this, Geikie remarks: "I do not suppose that in the whole literature of science a better illustration could be found of the advice—'When you meet with an insuperable difficulty, look it squarely in the face—and pass on.'"

The Wernerian doctrines did not alone hold sway at the great Scottish university; Sedgwick, at Cambridge, and Buckland, at Oxford, were Church of England clergymen, as were other prominent naturalists of the day, such as Conybeare, Whewell and Henslow. The Geological Society of London, which was founded at this time, was so dominated by the Neptunists that it was in effect a second Wernerian

institution, a so-called Wernerian Society having already been started at Edinburgh for the purpose of propagating the Neptunist doctrines.

Specifically, the battle came to rage most bitterly over the origin of basalt, which according to the Wernerian dogma was, in common with all rocks, a chemical precipitate from the ocean; though it is now known to be always formed by cooling and consequent consolidation of a molten mass.

It is against this background of authority by dogma that the figure of James Hutton is projected late in the eighteenth century. Born at Edinburgh on June 3, 1826, the son of a worthy citizen who had held the office of city treasurer, Hutton received a high-school education, and though already interested in chemistry, at the age of seventeen he chose the profession of the law. After a year of drudgery as apprentice in a lawyer's office, he shifted to medicine, and for three years he prosecuted his medical studies at Edinburgh. As was then the custom, he completed his studies upon the continent, remaining nearly two years in Paris, where he studied chemistry and anatomy. At Leyden in Holland he received the degree of doctor of medicine in 1749.

Having already abandoned the law, his first choice of a profession, he now lost his interest in medicine so soon as he came to enter upon its practice. This appears to have been due at least in part to the success of some chemical researches of a practical sort begun with a friend on the manufacture of sal ammoniac. However, before these studies had reached the stage of commercial success, Hutton had resolved to apply himself to farming. In 1752 he went to Norfolk in East Anglia to live with and study the methods of a farmer, and now in the rural sports and in the little adventures of his host, he entered with great zeal. It was on excursions in and about Norfolk that his mind first turned to mineralogy, as geology was then called. He entered with great interest also into his farming studies, and after two years at it made a tour to Flanders to study farming methods there, after which he settled down upon his own family inheritance in Berwickshire. For fourteen years beginning in 1754 he was buried in his rural pursuits at this homestead, only occasionally visiting Edinburgh. The sal ammoniac process had by this time proved a success and he became in 1765 a regular copartner in the manufacture of it so as to become fairly independent. Having now his farm well regulated, in 1768 at the age of forty-two he removed to Edinburgh to devote himself entirely to scientific studies.

In the Scottish capital he found many friends and was at once received into the most select society. One of his most intimate friends was Dr. Joseph Black, the great chemist who had made the discovery of carbonic acid. Another of his closest friends was John Clerk, of Eldin, known as the author of a work on naval tactics and as the inventor of the method for breaking the enemy's line at sea which led to so many naval victories by Great Britain. Other intimate friends were Sir James Hall, the pioneer in experimentation in geology, and John Playfair, the well-known mathematician and philosopher.

Playfair's relation to Hutton came to be very much the same as that which later developed between Huxley and Darwin. Hutton, like Darwin, was without the gift of a clear and forceful literary expression; Playfair, like Huxley, possessed this gift in a high degree, though he lacked the trenchant quality which belonged to Huxley's style, and he was without the aggressive, not to say pugnacious, manner which was so effective in Huxley. Like Huxley, however, Playfair essayed to be the interpreter for his heavy but profound colleague and friend. Playfair's remarkable book, "Illustrations of the Huttonian Theory of the Earth," which was written after Hutton's death, is delightful reading even to-day, in spite of the antique s's.

The doctrines alluringly set forth by Playfair were first presented by Hutton in 1785 before the Royal Society of Edinburgh at one of its early meetings, and the paper was printed in the initial volume of the Society's "Transactions." In expanded form, but still incomplete, it was published in 1795 in two octavo volumes under the title, "Theory of the Earth, with Proofs and Illustrations," and a third volume was left in manuscript when Hutton died. There is some doubt whether a fourth volume was in part written and has been lost. The manuscript of the third volume, which has been preserved in the library of the Geological Society of London, was in 1899 edited with great skill by the late Sir Archibald Geikie and published in that year. Like the "Origin of Species," Hutton's work was a vast storehouse of careful observations, but it lacked good summaries to set forth the principles which were derived. The third volume of the work and the "Illustrations" by Playfair constitute the material on the basis of which Hutton is best known to geologists to-day.

Though he antedated Darwin by almost three quarters of a century, Hutton's work is characterized by the same painstaking care and thoroughness of observation. It would thus be diffcult to conceive of a greater contrast than Hutton supplied to the brilliant Werner, whose fame had drawn disciples from every country of Europe, but whose views have one after the other been repudiated as their fallacy has been proven by the facts of observation. It was Hutton's practice to go direct to nature in order to discover

the facts. On the basis of these facts he then sought to lay down the principles of a science which was soon to become known as geology, though Werner had already promulgated the name geognosy and referred to his disciples as geognosts.

By many observations Hutton was able to prove conclusively that granite and basalt were not precipitated, as Werner supposed, from the ocean, but were both formed as the result of the cooling of a molten mass. Sir Charles Lyell has said of Hutton's "Theory of the Earth":

> This treatise was the first in which geology was declared to be in no way concerned about questions as to the origin of things, the first in which an attempt was made to dispense entirely with all hypothetical causes, and to explain the former changes of the earth's crust by reference exclusively to natural agents.

Elsewhere he wrote, "Hutton laboured to give fixed principles to geology as Newton had succeeded in doing for astronomy."

Hutton was not actually the first to derive all the ideas which he promulgated. Guettard, a French contemporary of Hutton, who completed his geological studies somewhat earlier, proved conclusively that most of what we now know as the volcanic rocks of Central France had been produced by the cooling of a molten mass. Of the basalt of the region the relations were not by any means so clearly indicated, and this rock Guettard erroneously explained as a precipitate from water, a view in harmony with the later Wernerian doctrine. Guettard may therefore be regarded as in the anomalous position of being the founder of both the rival schools of the Vulcanists and Neptunists. Like Hutton he was not gifted with powers of exposition, but wrote ponderous technical volumes. It has even been said of him that he buried his reputation under the weight of material which he left to support it. Guettard's error concerning the origin of the French basalt was corrected by his contemporary, Desmarest, who, quite as much as Guettard and Hutton, went to nature for his facts.

But to return to Hutton, his "Theory of the Earth" in spite of all its defects of exposition has been declared by von Zittel, the distinguished paleontologist and historian of geology, to be "one of the masterpieces in the history of geology." Notwithstanding this, there is no fact more certain than that it failed utterly to recommend itself in his own day for general acceptance, and the scientific world was forced to wait another half century until much the same ideas alluringly and tactfully set forth by Sir Charles Lyell brought a revolution in the science and laid the cornerstones of the modern edifice.

Both in his study of the rocks themselves and of the shaping of the surface features of the earth, Hutton proved that processes like those still in operation were entirely competent to account for all the facts of observation. This he expressed in the now oft-quoted sentence, "In the economy of the world I can find no traces of a beginning, no prospect of an end," which was coupled with the doctrine that all past changes on the earth have been brought about by the slow action of existing causes. Here we find the fundamental idea of the doctrine of evolution—continuity as opposed to interruptions—a doctrine now often described for the inorganic world as uniformitarianism. "Consistent uniformitarianism," wrote Huxley in 1887, "postulates evolution as much in the organic as the inorganic world."

The conception of evolution thus arrived for the inorganic world a full three quarters of a century before it was promulgated by Darwin for the realm of the organic. Lyell's motto paraphrasing Hutton's slogan above cited was "the present is the key to the past," and this he had extracted from Playfair's "Illustrations."

The *idea* of continuity or evolution in nature was, of course, much older than either Hutton or Darwin, for it is to be found well expressed in Lucretius and it was revived by Generelli, an Italian Carmelite friar of the sixteenth century; but it was Hutton who first found the proof of the doctrine in the facts of observation. Professor Judd has related that in 1871 Matthew Arnold laughingly remarked to him, "I can not understand why you scientific people make such a fuss about Darwin. Why, it's all in Lucretius!" "Yes," retorted Judd, "Lucretius guessed what Darwin proved."

But the first chapter of Genesis, which sets forth in allegory the creation of the inorganic and organic worlds, recites sudden creations at definite times, not a continuous growth by slowly operating forces, and on the continent of Europe the authority of the great Cuvier was given to the idea of great catastrophes which had punctuated earth-history, bringing with them destruction of organic forms and creation of new species. Hutton was soon charged with heresy for bringing out ideas which were contrary to the Scriptures. Kirwan, de Luc and Williams, all zealous geologists of the Wernerian School, declared Hutton to be an enemy of religion. Sedgwick, at Cambridge, eloquently declaimed against the unscriptural tenets of the Huttonians. Conybeare, in his "Outlines of the Geology of England and Wales," speaks of the wildness of Hutton's views, and adds: "He who could perceive in geology nothing but the ordinary operation of actual causes, carried on in the same manner through infinite ages, without the trace of a beginning or the prospect of an end, must have surveyed them through the medium of a preconceived hypothesis alone."

The city of Edinburgh, where Hutton made his home, was the stronghold of the Presbyterians and Calvinists, and it was in such an atmosphere a simple matter to blacken Hutton's reputation. "Britain," says Judd, "which had produced the great philosopher, Hutton, had now become the center of the bitterest opposition to his teachings."

Hutton died in 1797 without having been able to convince his contemporaries of the truth of the principles he had laid down; but in the very year of his death two men were born, Paulett Scrope and Charles Lyell, who were destined to establish the Huttonian doctrines as the foundation stones of modern geology. The greater of them, Sir Charles Lyell, possessed just those gifts which Hutton lacked. By a forceful and lucid literary expression and a diplomacy and tactfulness in dealing with those questions which were in conflict with church dogma, he succeeded completely where Hutton had utterly failed. Somewhat unfairly, Lyell wrote of Hutton—and throughout he has given less than due credit to his distinguished predecessor—"I think he ran unnecessarily counter to the feelings and prejudices of the age. This is not courage or manliness in the cause of Truth, nor does it promote progress. It is an unfeeling disregard for the weakness of human nature, for it *is* our nature (for what reason heaven knows) . . ." Lyell himself was most careful to avoid a frontal attack upon the citadel of the church. He preferred unobtrusively to sap and mine, and he did this with a success of which geologists are now well aware, and by so doing he reaped rewards which might have come to the pioneer, Hutton.

Those who are intimately familiar with the fierce controversy which raged in England over the appearance of the "Origin of Species" will remember that though Lyell was on terms of intimacy with the great figures in the controversy on the Darwin side—Darwin himself, Huxley, Wallace, Hooker and Spencer—he yet was careful to refrain from any public expression likely to bring himself into conflict with the church.

It has generally been supposed that Lyell derived his views as expressed in his "Principles" directly from Hutton's writings, though this has been disputed by Judd, who claims they were developed from Lyell's own studies and that later when he read Hutton's book and the Playfair "Illustrations" he was greatly impressed by the proofs of genius in the great Scottish philosopher.

To-day the place of James Hutton is secure among the great founders of geology, and he stands out from the others as the hardy pioneer who endured the hardships and took the hard knocks and thereby paved the way for the new era in geological science. He was the first to prove the truth of the doctrine of continuity or evolution within the inorganic realm of nature, as Darwin was in the organic. That Hutton was not acclaimed for his work while he lived probably caused him little concern. He seemed to be content to have the good opinion of the great men associated with him—those who knew his work intimately and whose esteem was, therefore, precious to him. Their opinion is shared to-day by all geologists who have carefully studied the history of their science.

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COOPERATIVE RESEARCH—THE PLAN OF THE NATIONAL TUBERCULOSIS ASSOCIATION

I

THE necessity for progress in medical research in tuberculosis has been recognized since the first presidential address by the great American pioneer, Edward L. Trudeau. In the natural course of events the urgency for organization and education held research work in abeyance during the first fifteen years of the association's existence, even though its importance was emphasized from time to time. This abeyance of activity was justified by the fact that there had been devised no sure method for the expenditure of money for the development of research. Methods had been tried by foundations and other interested bodies, but had not proved sufficient in production to merit the expenditure.

While the association was anxious to increase its knowledge through research work, its funds were so limited that it was not warranted in making use of them for research unless a way was offered which insured a certain measure of success.

II

In 1920, at the suggestion of Dr. Charles J. Hatfield, at that time managing director, the president, Dr. Gerald Webb, appointed a small committee to study the question of research in tuberculosis and, if possible, to offer to the executive committee of the association a plan for its development that promised success and that would require only the limited sums of money available. This committee was composed of Dr. William Charles White (chairman), Dr. Paul A. Lewis and Dr. Allen K. Krause.

III

One year was spent by the committee in the study of this problem. Surveys were made (1) of research facilities in the tuberculosis hospitals and their labo-