SCIENCE

FRIDAY, DECEMBER 24, 1897.

CONTENTS:

MSS. intended for publication and books, etc., intended for review should be sent to the responsible editor, Prof. J. McKeen Cattell, Garrison-on-Hudson, N Y.

THE FOUNDERS OF GEOLOGY.

THE geologists of America in April of the present year welcomed to this country Sir Archibald Geikie, the distinguished Director-General of the Geological Survey of Great Britain and Ireland, on the occasion of his coming to give the opening course of lectures upon the George Huntington Williams memorial foundation at the Johns Hopkins University. The many representative men from all portions of America who went to Baltimore to listen to him shows the high position of authority which he holds in geological science and the desire which was universally felt to do honor to the man. Those who met him and listened to his carefully prepared words gained an inspiration which will be long felt in geology on this side of the Atlantic.

The lectures, which have been recently printed, appear in an attractive form from the Macmillan press.* In the introduction to the *first* lecture of the course the author states that the searcher after truth is liable to lose sight of the paths already trodden, and that it is, therefore, "eminently useful now and then to pause in the race, and to look backward over the ground that has been traversed, to mark the errors as well as the successes of the journey, to note the hindrances and the helps which we and our

* *The Founders of Geology*, by Sir Archibald Geikie, X. 297 pp. 1897. Macmillan & Co., London. The Macmillan Company, New York.

predecessors have encountered, and to realize what have been the influences that have more especially tended to retard or quicken the progress of research." For that purpose the epoch which extends from the middle of the last century to the earlier decades of this is especially selected as the period when the real foundations of geology were laid, although it is freely recognized that many honored names in the domain of the science antedated this time.

After referring to the curious coincidence of the appearance of the writings of the two last and most eminent of the cosmogonists, Leibnitz and Buffon, in the same year during the middle of the last century, the author proceeds in most interesting manner to describe the life and work of the hitherto little recognized Guettard (1715–1786), who, by his brilliant researches in many lines, may be truly called one of the founders of modern geology. To Guettard we owe the first practical attempt to construct geological maps by depicting the superficial distribution of mineral substances. It is doubtful, however, if he had very definite ideas regarding the sequence of formations or of geological structure. His map of western Europe, so far as it relates to the areas of his own observations in France, coincides in a broad way with the modern conception of the distribution of the stratigraphical series, although often erroneously grouping younger with older deposits in his 'bands.' Guettard's contributions in the field of paleontology are also of much significance. He recognized the importance of fossils in geological research, and published many large and elaborate memoirs in which numerous forms are figured and described. He was the first to recognize *trilobites*. The excellence of his descriptions and drawings entitle him to rank according to the author as 'the first great leader of the paleontological school of France.' His memoir 'On the Accidents that have befallen Fossil Shells compared with those which are found to happen to Shells now living in the Sea,' which appeared in 1765, is regarded as unquestionably one of the most illustrious in the literature of geology, as it introduces a natural explanation for the phenomena of organic remains entombed in the rocks.

To the field of physiographic geology his memoir 'On the Degradation of Mountains effected in Our Time by Heavy Rains, Rivers and the Sea' contributed much and must be regarded as one of the classics of that department of the science. No one had elaborated the subject so fully as he at that period.

The recognition by Guettard of the volcanic origin of the mountains of the Auvergne affords one of the most interesting chapters in the whole book. It is one of the curious facts connected with his remarkable career that these views "practically started the Vulcanist camp, and his promulgated tenets regarding basalt became the watchword of the Neptunists." It seems that he was "an indefatigable and accurate observer who, gifted with a keen eye, well-trained powers of observation, and much originality of mind, opened up new paths in a number of fields which have since been fruitfully cultivated, but who rigidly abstained from theory or speculation."

In the *second* lecture the author discusses the rise of volcanic geology as shown by the work of Desmarest, and also the beginning of geological travel by Pallas and de Saussure. To Desmarest (1725–1815), a public official and astute scientific observer, we owe a further elucidation of the geology of the classic volcanic district of the Auvergne, which had been the scene of so much of Guettard's labors. Although Guettard had observed the general volcanic character of the district, it was Desmarest who, in great detail, traced out the disposition of these various rocks and others, unrecognized by his predecessors, and who endeavored to establish a system of succession among them. This led him to a study of the denudation which the several lava streams had suffered, and thus to the most comprehensive statement of the effects of erosive action based upon concrete examples which had up to that time appeared. One of the most important conclusions of Desmarest's investigations in the Auvergne was the recognition that basalt was of eruptive origin, although he found few supporters for his views and did not enter later into the prolonged discussion which arose upon the subject. His map of the Auvergne elaborated in great detail, although unpublished at the time of his death, may still be regarded as his greatest contribution to geology, and was certainly far in advance of any other attempt at the cartographic representation of geological phenomena of its day.

Desmarest also contributed four massive volumes upon Géographie Physique in the famous Encyclopédie Méthodique, and had not completed the last at the time of his death in his ninetieth year. Cuvier, in his biographical sketch of him, says: "The Academy of Sciences saw in him, as it were, the monument of a bygone age, one of those old philosophers, now too few, who, occupied only with science, did not waste themselves in the ambitions of the world, nor in rambling through too wide a range of study, men more envied than imitated."

A factor which added much to the advance in scientific thought of last century was the rise of the spirit of scientific travel. To Pallas (1741–1811), who spent six years, from 1768 on, at the head of a scientific expedition commissioned by Empress Catherine II., we owe much important geological information regarding a portion of the world then but little known. His study of the Ural chain led to his attempt to classify the rocks of mountain areas, the chief value of his observations lying "in his clear recognition of a geological sequence in passing from the center to the outside of a mountain chain. He saw that the oldest portions were to be found along the axis of the chain, and the youngest on the lower ground on either side." One of the geological questions which especially occupied his attention was the occurrence of the remains of the fossil elephant, rhinoceros and buffalo throughout the whole vast basin of Siberia, between the Ural and Altai mountains.

Few men have better claim to be regarded among the founders of geology than de Saussure (1740–1799), who was the first to arouse the modern spirit of mountaineering, and whose indefatigable travels throughout the high Alps contributed so largely to the stock of ascertained fact which was so useful as a basis for theoretical speculation. To de Saussure we owe the first use of the terms geology and geologist, while his experiments upon the fusion of rocks, although only negative results were obtained, are especially interesting, as they mark the earliest beginnings of experimental geology.

The *third* lecture deals with the history of the doctrine of geological succession, and the influence of Wernerianism upon the geological thought of the day. Lehmann, Fuchsel and Werner more than any others during the latter half of the last century advanced the ideas of geological succession. Lehmann (died 1767) published, in 1756, the first treatise in which a definite attempt is made at a chronological classification of the rocks of the earth's crust. He recognized, from a study of the rocks of the Harz and Erzgebirge, three major orders which became the Primitive, Secondary and Alluvial divisions of the proposed classification. His profiles of the succession of strata showed, according to the author, 'a remarkable grasp of some of the essential features of tectonic geology.' Contemporary with Lehmann was Fuchsel (1722–1773), who in 1762 published one of the most remarkable works, with map and sections, which had 'up to that time been devoted to the description of the actual structure and history of the earth.' 'He recognized as clearly as Lehmann, and with more accuracy of detail, the sequence of stratified rocks,' and considered that 'the changes which the earth had undergone were of no abnormal kind.' In divining with singular sagacity 'that a continuous series of strata of the same composition constitutes a formation, or the record of a certain epoch in the history of the globe,' he anticipated, according to the author, 'a doctrine which afterward took a prominent place in the system of Werner.'

The most notable figure in the mineralogical and geological arena during the last quarter of the last century and the early years of this was Werner (1749–1817), who, chiefly by the vast influence of 'his personal gifts and character,' wielded an overmastering power upon the geological opinions of the time. Appointed professor at twenty-five in the Mining Academy of Freiberg, he gradually, by the brilliancy of his teaching, drew about him an enthusiastic body of pupils from all portions of the civilized world, and raised the local mining school into the position of a great university. "No teacher of geological science," says Geikie, "either before or since has approached Werner in the extent of his personal influence or in the breadth of his contemporary fame." His most distinguishing quality, he states further, was 'his overmastering sense of orderliness and method,' which made his contributions to the then half chaotic science of mineralogy of vast significance, although he wholly ignored crystalline form in his classification. In the study of the earth, for which he and his adherents used the term geognosy, he endeavored to apply the same precision, and laid down doctrines which he dogmatically applied, although there was generally no basis for them in observed fact. He adopted the idea that "the whole globe had once been surrounded with an ocean of water, at least as deep as the mountains are high, and he believed that from this ocean there were deposited by chemical precipitation the solid rocks which now form most of the dry land." His order of sequence, taken to a considerable extent from Lehmann and Fuchsel, was developed into a system of his own. He believed basalt and other eruptive rocks to be of aqueous origin, and all volcanic activity modern phenomena, produced by vast repositories of inflammable matter.

The greatest service which Werner rendered to the cause of geological science, according to the author, was the enthusiasm he inspired in so many capable men. Among the most distinguished of Werner's pupils were d'Aubuisson (1769–1819) and von Buch (1774–1853), who, although loyal to their master, gradually became convinced of the fallacy of many of his views, and finally practically abandoned them altogether. Curiously, they were led to these conclusions largely from a study of the district of the Auvergne, where in previous years Guettard and Desmarest had done such valuable work for the cause of geological science. Von Buch especially became one of the most prominent figures in European geology. He traveled widely, and the result of his investigations greatly enriched geological literature. In 1824 he brought out a geological map of Germany in forty-two sheets, while his contributions to the science covered nearly every branch of geological research.

The *fourth* lecture is devoted to the consideration of a very different school of geology than that described in the previous chapter. It had for a time far fewer supporters than the Neptunist System of

Werner, although in the end largely supplanting the latter. This opposing school had as its chief representative the Scotch scientist Hutton (1726–1797), who, although never wielding the personal influence of Werner, slowly developed, by actual observation, a system of geological thought that forms the basis of much of modern geology. Hutton himself published but little regarding his ideas. His chief work, entitled 'Theory of the Earth, with Proofs and Illustrations,' appeared in 1795; but Playfair (1748–1819), his friend, has given us, in his 'Illustrations of the Huttonian Theory of the Earth,' an admirable exposition of his views. Hutton, unlike Werner, had 'no preconceived theory about the origin of rocks,' but considered that 'the past theory of our globe must be explained by what can be seen to be happening now.' He observed that the greater part of the land consists 'of compacted sediment which had been worn away from some pre-existing continent, and had been spread out in strata over the bed of the sea,' and that the strata had often become 'inclined, sometimes placed on end or even stupendously contorted and ruptured.' Recognizing as of fundamental importance the internal high temperature of the globe, of which volcanoes are one of the proofs, he distinguished three types of eruptive rock—whinstone, porphyry and granite—which he considered had been intruded from below among the rocks with which they are now found associated. Hutton, to be sure, drew no distinction between mineral veins and dykes, referring them all to intrusive origin and even regarded the flint concretions of the Chalk to be of similar origin.

We find also in the Huttonian theory practically 'the whole of the modern doctrine of earth sculpture,' while there is also 'the germ of the Lyellian theory of metamorphism.' Even the modern conception of glacial action is foreshadowed in the recognition of the potency of glaciers in the transport of detritus. Hutton 'rigorously guarded himself against the admission of any principle which could not be founded on observation,' and never permitted himself to make any assumptions. It is said of him that 'he was a man absorbed in the investigation of nature to whom personal renown was a matter of utter indifference.'

Among Hutton's friends was Hall (1761–1830), to whom we owe 'the establishment of experimental research as a branch of geological investigation.' His experiments upon the fusion of rocks, in which he showed the effects of the rate of cooling upon texture, are of much interest in the history of volcanic geology. Other experiments upon the effect of pressure in modifying the influence of heat, and his machine for contorting layers of clay, are hardly less significant.

For a time the Huttonian views in Scotland received a setback by the appointment of Jameson (1774–1854), a pupil of Werner, to the professorship of geology at Edinburgh, but upon the death of the great master, in 1817, his views, already opposed openly even by some of his pupils, rapidly declined in favor, and the old controversy between the Neptunist and Vulcanist gradually disappeared.

The *fifth* lecture is devoted to a consideration of the rise of stratigraphical geology, as shown by the work of Giraud-Soulavie, Cuvier, Brongniart and D'Omalius d'Halloy in France, and Michell and William Smith in England. To Giraud-Soulavie (1752–1813) 'the merit must be assigned,' according to the author, 'of having planted the first seeds from which the magnificent growth of stratigraphical geology in France has sprung.' In a series of volumes upon the natural history of southern France, of which the first two appeared in 1780, he described the calcareous mountains of the Vivarais and divided the limestones into five epochs or ages, the strata in each of which are marked by a distinct assemblage of fossil shells. He thought, however, "that the most ancient deposits had been accumulated at the highest levels, when the sea covered the whole region, and that, as the waters sank, successively younger formations were laid down at lower and lower levels," and "he felt confident that if the facts observed by him in the Vivarais were confirmed in other regions a historical chronology of fossil and living organisms would be established on a basis of incontestable truth."

Cuvier (1769–1832) and Brongniart (1770–1847) together studied in much detail the Tertiary formations of the Paris basin. They demonstrated in this area 'the use of fossils for the determination of geological chronology and they paved the way for the enormous advances which have since been made in that department of our science.' They brought forward clearly the evidence for 'a definite succession among the strata and the distinction of the organic remains contained in them.' Cuvier had already shown that the fossil elephant found near Paris belonged to a different species from either of the living forms, and by further research reconstructed the skeletons of other types, which enabled him to announce 'the important conclusion that the globe was once peopled by invertebrate animals which, in the course of the revolutions of its surface, have entirely disappeared.' The work of Cuvier and Brongniart upon the Tertiary formations has been but little altered, although greatly elaborated. The broad outlines sketched by them remain as true now as they were when first traced by them early in the century.

D'Omalius d'Halloy extended the work of his predecessors among the Tertiary formations, but, what is of more interest, 'recognized the leading subdivisions of the Cretaceous series and actually showed the extent of the system upon a map. This map is regarded as the first attempt to construct a true geological map of a large tract of France,' which was something more than 'a mere chart of the surface rocks.' It was provided with a horizontal section showing the structural relations of the formations.

In England, Michell is regarded as the first to present anything like a clear idea of stratigraphical sequence, a table giving the broad features of the succession of strata from the Coal Measures of Yorkshire up to the Chalk, having been drawn up by him about 1788 or 1789. Geikie very clearly points out, however, that "the establishment of stratigraphy in England, and of the stratigraphical sequence of the Secondary, or at least of the Jurassic, rocks for all the rest of Europe, was the work of William Smith,'' a land surveyor, usually known as the 'Father of English Geology.' "No more interesting chapter in scientific annals can be found," according to the author, "than that which traces the progress of this remarkable man, who, amidst endless obstacles and hindrances, clung to the idea which had early taken shape in his mind, and who lived to see that idea universally accepted as the guiding principle in the investigation of the geological structure, not of England only, but of Europe and of the globe." Smith made no attempt to publish his results, although he accumulated a vast store of notes upon his observations during his journeys in the pursuit of his profession. His ideas gradually became widely known, and a card of English strata from the Coal to the Chalk, drawn up in 1799, though not actually published, obtained wide publicity. His geological map of England and Wales with part of Scotland, in fifteen sheets, regarded as one of the great classics of geological cartography, and upon which he had been at work for many years, was not published until 1815. The appearance of this map marked 'a distinct epoch in stratigraphical geology, for from that time some of what are now the most familiar terms in geological nomenclature passed into common use.' Smith also published geological maps, on a larger scale, of the English counties and a series of horizontal sections across different parts of England.

The *sixth* and last lecture deals with the further development of stratigraphical geology along lines laid down by Smith and his distinguished contemporaries, who had applied the criteria derived from fossils with such success. Smith's researches, as we have seen, did not include rocks older than the Coal Measures. The great mass of earlier strata known in the old classification as Greywacke, or Transition, rocks were regarded in their generally disturbed and poorly fossiliferous condition to be beyond interpretation by the principles of Cuvier, Brongniart and Smith, until Murchison and Sedgwick, for the most part, 'working independently of each other in Wales and in the border counties of England,' succeeded in establishing a definite order among the oldest fossiliferous formations, thus adding the Devonian, Silurian and Cambrian chapters to the geological record.

Murchison (1792–1871), after several years of investigation of the Secondary rocks of England and the Continent, and some preliminary work with Sedgwick upon the old rocks of the northern counties of England, began in 1831 in Wales and the adjoining counties of England his epoch-making study of the strata below the Old Red Sandstone. Starting with that already known and easily recognizable horizon he established a series of underlying divisions which he found to be characterized by peculiar fossils. To this assemblage of formations, which he divided into an Upper and a Lower series, he gave the name of Silurian System. He recognized its conformity to the Old Red Sandstone, but wrongly thought it to rest unconformably upon the older series of greywacke. Murchison also worked out the lithological character of these old rocks, observing eruptive materials among them, some of which he clearly saw were intrusives, while others he recognized to be lavas and ashes. His first communication upon this subject was made to the Geological Society of London in 1831, his great book, 'The Silurian System,' appearing in 1838. The author tells us that even before the advent of this volume his remarkable results had become widely known and 'within a few years the Silurian System was found to be developed in all parts of the world,' Murchison's work furnishing the key to its interpretation.

Sedgwick (1785–1873), almost from the very beginning of his career, devoted his energies to the ancient rocks, his earlier publications, however, showing strong leanings to the Wernerian school. He soon parted with these views and early came to a true perception of geological principles which he applied in a study of the older formations of northern England. The author tells us that though fossils had been found in the rocks Sedgwick did not at first make use of them for purposes of stratigraphical classification, but ascertained the succession of the great groups of strata upon lithological grounds alone. He, as well as Murchison, recognized volcanic rocks to form part of the greywacke rocks of North Wales and soon 'succeeded in disentangling their structure and ascertained the general sequence of their principal subdivisions.' At this period, however, his investigations were of far less significance in the field of general stratigraphy than Murchison's, since he had not determined the relation of his rocks to any well recognized horizon and had made no use of fossils for correlative purposes. Later investigations showed that the upper part of what Sedgwick termed the Cambrian system contained the same organic remains as the Lower Silurian formations defined by Murchison, and thus arose a permanent misunderstanding between these two old friends and leaders in English geological thought.

While this dispute was in progress Barrande made his remarkable investigations in the Bohemian basin, where he not only recognized the equivalents of Murchison's Upper and Lower Silurian, but also found a still older group of strata containing forms similar to those occurring in Sedgwick's Cambrian system. To the latter fauna he gave the name of First or Primordial fauna. The consensus of geological opinion, on the grounds of priority, to-day regards as Lower Silurian the Upper Cambrian of Sedgwick. Sedgwick's classification, however, in these old and disturbed rocks has proved of vast importance in the elucidation of the ancient sediments, and the succession of strata observed by him has continued with hardly a modification to the present day.

A no less important work pursued by Sedgwick and Murchison together in the days before their estrangement was the determination of the Devonian. Its reference in the absence of stratigraphical data to a position between the Silurian and Cambrian was based mainly upon the paleontological work of Lonsdale, who pointed out that the fossils in its lower portions showed an affinity to the Silurian while those in its upper parts were closely allied to the Carboniferous faunas.

The pre-Cambrian rocks now remained to be studied and deciphered. The paleontological criteria were no longer available and many difficulties presented themselves. "The first memorable onward step," according to Geikie, "was taken in North America by Logan (1798–1875)." Some study had already been given to these old rocks, but Logan was the first to attempt to establish a chronological sequence among them. To him we owe the names Laurentian and Huronian, and although his results have been much modified by subsequent observers his work marks a distinct advance in this field of stratigraphical geology.

The first recognition of the wide significance of glaciers as geological factors of more than local importance must be accorded to Agassiz (1807–1873). He was the first to offer a satisfactory explanation for the so-called erratics, which were found distributed over the Swiss plain and the flanks of the Jura mountains. Contrary to the preconceived notions of the day, he held that the Alpine ice once extended over the area and that it was an explanation of a former period of extreme cold. His further researches in England, where he found similar phenomena, convinced him that the great extension of ice was connected with the last great geological change on the surface of the globe. These teachings of Agassiz, which to-day, in all their essential elements, have been generally accepted, place his name, according to the author, as that of 'the true founder of glacial geology.'

The attempts at geological classification upon lithological grounds, which had been pushed to such an extreme by Werner and his followers, greatly declined after the marvelous impetus which the study of organic remains brought to the science of geology. But the investigation of rocks in their mineralogical aspects was not to be permanently abandoned. The invention of the famous prisms of Iceland spar by Nicol and the cutting of thin sections introduced a new element into geological investigation, but it was not until Sorley extended this method by the more systematic examination of thin sections that microscopical petrography became recognized in the field of geological research. The publication, in 1858, of his memoir 'On the Microscopic Structure of Crystals' marks one of the most prominent epochs in modern geology. There was at first much opposition to this method of investigation, but it soon had many devoted followers who have done much to advance the science, among the more important being Zirkel, Rosenbusch, Fouqué and Michel Levy.

There yet remain two illustrious names to be mentioned among the founders of geology. They are Charles Lyell and Charles Darwin. Lyell (1792–1875), who exercised a profound influence on the geology of his time, adopted the principles of Hutton, and with marvelous industry collected a vast store of facts in support of the doctrine that 'the present is the key to the past.' He pushed the Huttonian doctrine to its logical conclusion and became the great leader of uniformitarianism, a creed which, according to the author, 'grew to be almost universal in England during his life, but which never made much way in the rest of Europe.' Lyell's 'Principles of Geology' must certainly be regarded as one of the classics of our science. To Lyell, in conjunction with Deshayes, we owe the classification of the Tertiary into Eocene, Miocene and Pliocene, upon the basis of the proportion of living species of shells. Lyell was not so much an investigator as 'a critic and exponent of the researches of his contemporaries.' Ramsey said of him, "We collect the data, and Lyell teaches us to comprehend the meaning of them."

Darwin (1809–1882) did much, not only by his contributions to the literature of geology, but in the introduction of the doctrine with which his name is associated, to revolutionize the geological thought of his time. His demonstration of the imperfection of the geological record and the great antiquity of the earth's crust came, according to the author, 'as a kind of surprise and awakening.'

In concluding the lectures the author calls attention to three prominent facts: first, that but three of the men considered, Werner, Sedgwick and Logan, could be called professional geologists, the others being either men of leisure, as Hutton, Hall, de Saussure, von Buch, Lyell and Darwin, or professionally engaged in other pursuits, as was the case of the great majority; second, that geology affords 'some conspicuous example of the length of time that may elapse before a fecund idea comes to germinate and bear fruit,' as, for instance, the length of time taken for the true principles of stratigraphical geology to become recognized; and third, that 'one important lesson to be learnt from a review of the early history of geology is the absolute necessity of avoiding dogmatism' the examples of the Wernerian catastrophist and uniformitarian schools being cited.

In endeavoring to give a somewhat comprehensive review of this latest important work of Sir Archibald Geikie it has been impossible to bring out clearly the delightful biographical and personal touches which so charm the reader. In the summary of the work which I have given it has been my endeavor to use, so far as possible, the phrases and happy expressions with which the book so richly abounds. The volume is one of much significance to the student of geology, as it for the first time presents to English readers anything like a satisfactory statement of the development of geology. Many of the men to whom we owe so much regarding our modern views of the science, and whose work has been but little considered by recent writers, are brought before us in their true proportions. The book must take high rank among the many other masterpieces of the distinguished author.

W. B. CLARK.
JOHNS HOPKINS UNIVERSITY.

CHARACTERS, CONGENITAL AND ACQUIRED.
II.

ACQUIRED physical characters (properly so termed) may involve not only quantitative changes, which alone we have as yet considered, but qualitative changes also.