PROBLEMS IN THE STUDY OF COAL, WITH A SKETCH OF RECENT PROGRESS IN GEOLOGY.[1]

WE have again assembled in our annual council, to renew and extend our acquaintance with each other, to maintain and strengthen the *esprit de corps* which ought to characterize the workers in a common field, to share with each other the new facts and new conclusions that we have reached by the labors of the last year, *mente et malleo*, and especially to aid each other in securing larger and more symmetrical views of the truths we hold, by fraternal discussion, criticism, and correction.

To review the record of the last year, and gather up its most significant advances, would be appropriate to the occasion; but various limitations forbid me to undertake such a task in any formal way. Before entering, however, upon the discussion of the subject which I wish to present to you, I beg leave to call your attention to a few facts that seem to me of special interest; and also to point out, in like cursory manner, some of the special directions and subjects in which American geology seems to me to be showing the most activity and progress at the present time.

The history of the vertebrate life of the globe, as far as it is now written, indisputably owes some of its most interesting and important chapters to American geology; but up to the last year we were still obliged to recognize the Ludlow rocks of Great Britain as the depositories of its earliest known forms. The recent fortunate discovery of the pteraspidian type of fishes in the Onondaga group of central Pennsylvania, by our associate, Prof. E. W. Claypole, has, however, granted us an equal date, at least, with the Scaphaspis of the lower Ludlow; and a fair argument can be made as to the somewhat greater antiquity of the Pennsylvania forms. This argument it is not necessary to press; for it loses its point and interest in the light of Professor Claypole's subsequent discovery of well-marked scales and spines of fishes in the iron sandstone of the middle Clinton group of central Pennsylvania. Onchus Clintoni of Claypole must enjoy the distinction, at least for a little time, of being recorded as the earliest representative of the vertebrate life of the globe.

But the 'earliest vertebrate' always sits on a precarious throne. At any moment the title is liable to lapse. To see its horizon suddenly descend several thousand feet in the scale, scarcely awakens our surprise. The abrupt appearance, the great numbers and the comparatively high organization of the earliest American fishes heretofore known, all demand a long antecedent history; and it is therefore no unwelcome labor to erase the old boundaries, and to draw the new ones, in such a way as to gain protracted ages for the unfolding and development of the type.

Another fact in the history of vertebrate life, acquired during the past year, deserves special mention here. Mr. Samuel Garman has recently published a description of a living shark that proves to be a cladodont, and so nearly allied to the genus Cladodus of carboniferous time, that it might with little violence be referred thereto. According to present knowledge, the family of cladodonts originated in the middle Devonian; and the genus Cladodus, as we have hitherto been obliged to hold, became extinct in the same age that gave it birth: but the chance-catch of a Japanese fisherman gives us an unmistakable cladodont, if not a true Cladodus, to-day; and in it we find 'the oldest living type of vertebrates.' The gap is far wider than any that has been heretofore bridged.

The discovery during the last year of fossil scorpions in three quite widely separated portions of the world at horizons approximately identical, and at the same time vastly lower than any in which they had been found hitherto, is a fact of much geological interest and significance. These three specimens from the upper Silurian effect an immense extension of the history of the tribe to which they belong, but each of them still falls short of the title of the 'earliest known land-animal.' That distinction is, for the present, held by the representative of an allied division. From well-characterized strata of middle Silurian age in central France, there was obtained during the past year the fragment of a cockroach's wing. It is a surprise to find Blatta, for the time being, at the head of the line of the inhabitants of the dry land.

Within the last year our associate, Mr. C. D. Walcott, has published a description of two species of pulmoniferous mollusks from the lower portion of the carboniferous rocks of Nevada. Both belong to the aquatic section of the Pulmonifera, and constitute the sole known representatives of that group in paleozoic time. One of them is a true Physa, and thus gives to this humble form a vast antiquity.

But leaving, without further notice, these very suggestive facts, let us barely glance, in passing, at some of the chief features in the advance of geological knowledge among us at the present time.

In the first place, stratigraphical geology appears to me to be attaining a somewhat juster recognition than has hitherto prevailed. It has been made very clear, that the work of the paleontologist is still too incomplete to allow any off-hand settlement of many of the questions that arise, by his determinations. There has been, in my judgment, an undue tendency to settle all questions as to the age and order of the several strata of any considerable series by the testimony of a few fossils. In the second place, the growing use of the microscope in geology is to be noted as one of the directions in which progress is apparent and marked. There is scarcely a field of research in which the service of the thin section is not now acknowledged and invoked. By it most of the varied claimants to the early life of the globe must be tried; and by it, as well, the minerals of the igneous and metamorphic rocks must be finally determined. Let us glance next with equal brevity at two

[1] Abstract of an address delivered before the section of geology and geography of the American association for the advancement of science, at Ann Arbor, Aug. 26, by Professor EDWARD ORTON, State geologist of Ohio, vice-president of the section.

or three of the fields of American geology in which special activity now prevails.

I have already called your attention to the beginnings of vertebrate life on this continent, but it is not in this fact that the chief interest of our vertebrate geology is found. It is in the later stages and higher forms of vertebrate life that American geology holds an easy and undisputed pre-eminence. Along the eastern slopes of the Rocky Mountains, there are being disentombed the remnants of great faunas of cretaceous and tertiary time that are quite without parallel in the history of geology. While these faunas are remarkable for the great number and variety of the species and individuals, and also for the enormous size of some of their forms, it is in other directions that their highest interest lies. By their anomalous and altogether unexpected characters, by their strange combination and dissociation of peculiarities of structure, they throw a flood of light on the question of evolution, and give us a key to the development of the existing creation that, before their discovery, it was too much to expect that we should ever possess. Here are birds with teeth, here are reptiles without them. Here are animals in which the characters of both birds and reptiles are so blended that it is hard to tell on which side of the line they belong, or whether there is any line. Here are horses with four toes, and hogs that chew the cud.

The activity in the investigation of the so-called archaean rocks is 'known and read of all men;' but as to the progress to be reported I dare not affirm, for the smoke of battle still covers the field, and the clash of arms still fills the air. In no previous year has there been so large and varied an amount of publication upon all of the problems involved as in this; and the topics discussed cover the whole range, from the igneous fusion of the earth, to the formation of a recent volcanic cone. The discussions are characterized by great ability, but the conclusions reached are wide apart and irreconcilable. Eozoön still maintains the struggle for existence, but with apparently lessening chances of survival.

Glacial geology is still a field of decided activity and progress. The most recent of geological formations, the drift, is still the most anomalous and perplexing. We have less experience and direct observation that can be brought to bear on its mode of formation, than we have on oceanic deposits, or even on the outflows of igneous vents. But, little by little, we seem to be coming into substantial accord in regard to the general sequence of the events that constituted the glacial period. The luminous and fruitful theories of Croll, like Darwinism in biology, are permeating all our modern glacial literature.

The most important service that has been rendered in the American field is the recent mapping of the great moraine from the Atlantic border to Dakota. And in view of the facts which have thus been brought out, scepticism in regard to the former occupation of the northern portions of the continent by a sheet of land-ice moving southward would seem to be impossible to the candid mind. It is coming to appear that the glacial record of North America is, like the rest of its geological history, incomparably simpler and clearer than that of Europe; and both the order of events of the last ice-age, and the nature and mode of operation of the forces employed, can be studied to better advantage here than elsewhere in the world.

I wish now to bring before you a few of the *Unfinished problems relating to the geology and chemistry of coal.*

For the last fifty years, there has been no reasonable ground for doubt that coal is more or less metamorphosed vegetation, and that the plants which formed the coal grew where they are now found. Nearly every seam of coal is underlaid by a stratum of clay containing the well-known stigmaria, which have been proved to be the roots, or underground stems, of the lepidodendrid and sigillarid trees composing the coal; and hence it may be truly said that the rootlets of the stigmaria bind the coal-seams fast to the surface of the land. Most of the well-matured and more elaborate theories of coal agree still farther in holding that this vegetation grew on low lands, and not only near the sea-level, but near the sea itself. But as we advance beyond these generally accepted positions, we seem to find ourselves at once among the unsettled questions; for the particular conditions and modes of growth of the great sheets of coal vegetation are variously conceived and represented.

1°. Forests growing on swampy tracts, finally submerged, and buried under sheets of sand and clay, the forest trees themselves constituting the bulk of the coal: this is one of the earlier and cruder theories which it is somewhat surprising to find still surviving. 2°. An accumulation of vegetation, quite after the manner of the mangrove swamps of sub-tropical lands at the present time, makes another theory. Geikie adopts this as the best picture of the conditions of coal formation that we can find in the existing order of things. 3°. By Sir Charles Lyell, the cypress swamps of the lower Mississippi were made to do like service. 4°. Fifty years ago Brongniart made the suggestion, in an almost incidental way, that we should find in the peat-bogs of to-day the analogue and representative of the coal-seams. This suggestion has been living and growing ever since. A young Swiss naturalist was perhaps the first to expand it into a definite theory. He saw that the laws of the peat-bog could be applied to the coal-seam; that the only key to the history of the latter was to be found in the beds of fuel that are growing now, but whose roots go back into past millenniums. We should have had a glacier theory of the drift without Agassiz, a scientific geography without Guyot, and, in like manner, the peat-bog theory of coal would have found its way here without Lesquereux; but, historically, it fell to these three illustrious compatriots, fellow-students, and life-long friends, to lead the way, each in his own field, to these several great advances.

I have glanced at the problem of the coal-swamp, and the accumulation of a single seam; but these seams are combined in great systems with beds of

sandstone, conglomerate, shale, limestone, and iron-ore, to a thickness of hundreds and thousands of feet. We are confronted, then, with the problem of a *coal-field*, and bring to our interpretation of it the points already made; viz., that every seam was formed by vegetable growth in a swamp or bog near the sea-level. Subsidence of the coal-forming area must be invoked, and the swamps successively buried under marine sediments.

To see what some of the problems of a coal-field are, let us take a concrete case. The coal-field of eastern Ohio is by far the most orderly field that has ever been described. The regularity and simplicity of its structure make it the type for this whole class of formations. What, then, do we find in this, the simplest and most symmetrical, the least disturbed and complicated, of all known coal-fields? We find a maximum of two thousand feet of strata covering ten thousand square miles. There is a well marked rhythmical order of arrangement of these strata. The three kinds that represent the agency of life are always found in close proximity. Coal standing for the life of the land, limestone for the life of the sea, iron-ore, equally dependent on life for its separation and concentration, but blended with both limestone and coal, these form vital nodes in the series, relatively of small amount, but containing all the economic interest and value. The nodes are separated by the sandstone and shale, which are barren of life, and owe their accumulation to inorganic forces. Measured against the products of life, these inorganic sediments have a thickness of five or ten feet to one. But note, the intervals between the vital nodes are approximately equal. Turning now to the problems presented by this typical field, how can we explain the regularity of these intervals? One suggestion of an explanation is found in that unique contribution to modern science, Croll's 'Climate and time;' viz., that the carboniferous age was a period of high eccentricity, and that the coal-seams were formed during interglacial stages, — an astronomical cause for the recurrence of these cycles of life, that exhibit an almost astronomical rhythm and order, this is a light in a dark place, albeit the light is thus far but a feeble one.

But more important questions yet remain, involving the extent and reach of the several seams, and the laws of growth of the field as a whole. Were the lowest coal-seams formed over the entire area? and may we expect their presence in the central portions of the basin, if we descend deep enough? These questions, and others of like import, must be classed as open, although certain general propositions which it would be a pleasure to expand compel me to believe that they should not be answered in the affirmative.

On the chemical side, there are various unsettled questions pertaining to coal, some of which possess both theoretical and practical interest. But, although they are probably not insoluble, science must sink its roots deeper before it can give us full answers. The microscopic structure of coal is another field in which much remains to be done. It is what has been already done in this direction that gives us our grounds of confidence in regard to the vegetable origin of coal. But the relative importance and distinguishing characters of coals formed of carbonized vegetable tissue, of spores, and of hydrocarbons, are still undetermined.

In conclusion, we may be sure that the problems relating to coal which now rise before us as unfinished, will, sooner or later, find their solution. But when they are solved, will all be known? Nay, verily. Out of these old carboniferous swamps, new questions, larger, deeper, than any we now see, will perpetually arise to stimulate by their discovery, and to reward by their solution, that *love of knowledge for its own sake* which makes us men.

PROCEEDINGS OF THE SECTION OF GEOLOGY AND GEOGRAPHY.

THE section opened with the *éclat* of a masterly address by its chairman, and was continued with lively interest, and a fair attendance, which abated only on the last day of the session. Twenty-seven papers were read, and nearly all of those elicited appreciative and profitable discussion. Debate was never unduly warm, and, though full, rarely wandered from the text. The proper functions of the association were evenly exercised; all ideas were freely criticised; the isolated and retiring student was encouraged; the chronic talker was merciful; and the philosopher, who had evolved from his consciousness a perfect theory of the universe, was persuaded to defer its promulgation. In the distribution of the communications by topics, stratigraphy received the lion's share, rejoicing not only in the leading number of contributions, but in the most important paper of the session. The age of ice claimed less attention than usual, and the mysteries of the archaean were unassayed. The following summary of the proceedings, abandoning the order of sequence of the meeting, gives first place to the earth's crust as a whole, follows with its successive layers from lowest to highest, and closes with volcanism and mineralogy. Geography made no contribution to the programme of the section; but it furnished the only paper accepted by the association for presentation to the general meeting, — a lecture by Capt. E. L. Corthell, on the inter-oceanic problem, the substance of which has already appeared in *Science*.

When, in his celebrated essay, George Darwin deduced from the tidal retardation of the earth's rotation the theorem, that the ellipticity of the terrestrial figure has been diminished throughout geologic time, he omitted to make certain deductions in regard to