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THE

CANADIAN NATURALIST

AND

Quarterly Journal of Science.

THE PROGRESS OF AMERICAN MINERALOGY.

BY G. J. BRUSH,

(Address of retiring President before American Association for the Advancement of Science. Montreal, August 25th, 1882).

The change in the constitution effected at our last meeting, extending the scope of the Association and dividing it into nine sections, each with a Vice-President, whose duty it is to deliver an an address to the section over which he presides, has relieved the retiring President from attempting a general review of the progress of science during the past year. I turn, therefore, to a more special subject, and invite your attention this evening to a sketch of the progress of American Mineralogy since the commencement of this century, with particular reference to the labors of some of the early workers in the science on this continent. During the last quarter of the eighteenth century, while great activity existed and rapid advance was made in the study of chemistry and mineralogy in Europe, almost nothing was accomplished in this new country. It is true that students in other departments of science, especially members of the medical profession in the cities of Philadelphia, New York and Boston, attempted to arouse an interest in mineralogy, believing that the diffusion of a knowledge of this science would be of the utmost importance in the material development of the country. There were, however, no text-books to aid the inquirer. There were no collections of minerals to stimulate the student. In the absence of these it was almost impossible that an interest in this science should be fostered, or that a spirit of investigation should be awakened. As the first distinct beginning of the science, I may mention an association formed in 1798 in the city of New York, which assumed, as they expressed it, "the name and style of the American Mineralogical Society." It announced as its object "the investigation of the mineral and fossil bodies which compose the fabric of the globe, and more especially for the natural and chemical history of the minerals and fossils of the United States." The distinguished Dr. Samuel Latham Mitchill, who seems to have been a man of universal genius, was at once its first President, its librarian and its cabinet-keeper. The committee of the society issued a circular in which, while expressing themselves, "desirous of obtaining and diffusing by every means in their power a correct and extensive knowledge of the mineral treasures of their country, they earnestly solicited their fellow-citizens to communicate to them on all mineralogical subjects, but especially on the following, viz.:—

"Concerning the stones suitable to be manufactured into gun-flints: where are they found? and in what quantity? 2. Concerning native brimstone or sulphur or the waters or minerals whence it may be extracted? 3. Concerning saltpetre: where (if at all) found native? or the soils which produce it in the United States? 4. Concerning mines and ores of lead: in what places? the situation? how wide the vein? in what kind of rock it is bedded."

This warlike demand seems to call more for the discovery of the materials for national defence than for the advancement of science, and besides being a commentary on the spirit of the times, gives a rather humorous impression of their strangely inadequate conception of the science of mineralogy, and its possible bearings on practical life, but in justice to them I should add that it is further announced that "specimens of ores, metals, coals, spars, gypsums, crystals, petrifications, stones, earths, slates, clays, chalks, limestones, marbles and every fossil substances that may be discovered or fall in the way of a traveller, which can throw light on the mineralogical history of America, will be examined and analyzed without cost, sufficient pieces, with the owner's leave, being reserved for placing in the Society's collection." I have quoted the circular almost verbatim to give you some idea of the genuine though crude longings for knowledge felt by our early mineralogists, and also of the generous spirit in which they worked. A still more forcible picture of the ignorance of the time is given by the elder Professor Silliman in 1818, "Notwithstanding the laudable efforts of a few gentlemen," he says, "to excite some taste for mineralogy, so little had been effected in forming collections, in kindling curiosity and diffusing information, that only fifteen years since (1803), it was a matter of extreme difficulty to obtain among ourselves even the names of the most common stones and minerals; and one might inquire earnestly and long before he could find any one to identify even quartz, feldspar or hornblende among the simple minerals, or granite, porphyry or trap among the rocks. We speak from experience, and well remember with what impatient, but almost despairing curiosity we eyed the bleak, naked ridges which impended over the valleys and plains that were the scenes of our youthful excursions. In vain did we doubt that the glittering spangles of mica, and the still more alluring brilliancy of pyrites, gave assurance of the existence of the precious metals in those substances, or that the cutting of glass by the garnet and by quartz proved that these minerals were the diamond; but if they were not precious metals, and if they were not diamonds, we in vain inquired of our companions, and even of our teachers, what they were." Such, then, was the state of knowledge in mineralogy here at the commencement of the century. A few American minerals, collected by travellers from time to time, had before this been taken to Europe for identification, but among these were discovered only two minerals new to science. The Moravian missionaries found at St. Paul, in Labrador, the beautiful species of feldspar called by Werner *Labradorstein*, which in more modern times we know under the name of *Labradorite*. Klaporth, the most eminent analytical chemist of his time, discovered that the so-called fibrous barytes from Pennsylvania was the sulphate of the then newly discovered earth strontia. He thus, for the first time, identified the mineral species *celestite* which was subsequently found in various localities in Europe. Although little had been accomplished in America previous to 1800, the first quarter of the new century was destined to show great development here in the study of mineralogy. During the early years of this quarter several collections of European minerals were brought to this country by American gentlemen, who had availed themselves during a residence in Europe of the best opportunities for acquiring a knowledge of the science from the great masters of the subject in Germany and France. About this time also several colleges in the country had instituted chairs of chemistry and mineralogy, and a commencement was thus made in teaching these sciences in the higher schools. As the result of these influences the number of persons interested in mineralogy was largely increased, and an active search for minerals was initiated throughout all of the older United States and to a considerable extent also in Canada. So energetically were these explorations followed up that in 1825 a Catalogue of American minerals was published by Dr. Samuel Robinson, with their localities arranged geographically, and giving only such as were known to exist in the United States and the British Provinces. It formed an octavo volume of over three hundred pages. That much credit was due to many workers during this period, both in the field and in the laboratory, there can be no question, but among them all I find four men standing forth so prominently as leaders that I have thought that it would be well for us to recall briefly something of the character of these men and their labors for the advancement of mineralogy in this country. First among these I will mention Dr. Archibald Bruce. He was the son of Dr. William Bruce, a surgeon in the British army, and was born in New York in 1777. He was graduated at Columbia College, subsequently studied medicine, and in 1798 went to Edinburgh, where, in 1800, he obtained his doctor's degree from that University. He was early interested in natural science, and while still in college found, his biographer says, "the collection and examination of minerals—a pursuit not then at all attended to in this country—was his particular relief from other studies; for even during his recreation he was ever on the lookout for something new or instructing in mineralogy."

When he went to Europe he took with him a large number of American minerals, and through exchanges with institutions and prominent mineralogists abroad, he established friendly relations with those most interested in his favorite science. After the completion of his medical studies, he travelled for two years on the continent of Europe, making the acquaintance of the Abbé Haüy, and other eminent mineralogists, and collecting an extensive cabinet of valuable minerals, which on his return to this country in 1803, he brought with him to New York. This collection, with another brought to New York about the same time by Mr. B. D. Perkins—both being made fully accessible to all interested in seeing them—contributed, it was said, more than any agencies had ever done before, to excite in the public an active interest in the science of mineralogy. Besides this Dr. Bruce entered into extensive correspondence with others interested in the subject, was active in visiting and discovering new mineral localities, and in advising, encouraging and inspiring young mineralogists. Finally, after well considering the matter, he established the first purely scientific periodical ever published in America. This was called the *American Mineralogical Journal*, and the first number of it was published in 1810. It contained original contributions, chiefly on mineralogy, from a number of investigators. "It was received," says the elder Silliman, "in this country and in Europe in a flattering manner; it excited at home great zeal and effort in support of the sciences which it fostered, and abroad it was hailed as the harbinger of our future exertions." But alas! it was in advance of the age, and after struggling for several years was given up on the publication of the fourth number. Possibly it would have continued longer had it not been for the failing health of its founder. This journal contained several important papers by Dr. Bruce, among them the investigation and description of two new mineral species, the native magnesia of Hoboken and the red zinc oxide of Sussex Co., New Jersey. These are the first American specimens described by an American mineralogist. So thoroughly was the work done by Bruce, that three species remain to-day essentially as he described them, and his papers may well be studied by mineralogists now as models of accuracy and clearness of statement. Dr. Bruce did much also for the elevation of the medical profession, was one of the founders of the New York Medical Society, and was largely influential in obtaining the charter of the College of Physicans and Surgeons, in which he was subsequently the Professor of Materia Medica and Mineralogy. He is described as a successful teacher, a man of wide acquirements and of great integrity, which qualities with abounding generosity and hospitality, commanded the respect and regard of all who knew him. It was a great loss to science and to his country that so able an investigator should have been cut off at the early age of 42. He died in New York, Feb. 24, 1818.

I have mentioned that the importation and exhibition of collections of minerals from Europe had contributed much to excite an interest in the study of mineralogy. It was necessary to have known minerals for study and comparison in order properly to determine those obtained by exploration here. In 1805, Colonel

George Gibbs, of Rhode Island, for many years a resident of Europe, returned from his travels with a collection of minerals, the most extensive and valuable ever brought to America. Colonel Gibbs was a zealous cultivator of mineralogy, and, fortunately for science, a young man of wealth. He used his money freely for the purchase of whole cabinets, as well as in personal explorations in search for minerals. The larger part of his collection was made by the purchase of two famous European cabinets, one from the heirs of Gigot d'Orcy, a noted French collector, and said to be the result of forty years' labor, the other from Count Gregoire de Razamowsky, a Russian nobleman, long resident in Switzerland. D'Orcy's cabinet numbered over 4,000 specimens, chiefly from France, Germany, Italy, and Great Britain; Razamowsky's contained about 6,000 specimens from the Russian empire and the remainder principally from Germany and Switzerland; in all, with the other collections made by Colonel Gibbs, it is said that more than 20,000 specimens were brought by him to this country. In 1807, a portion of the collection was opened in Newport, and many interested in mineralogy made pilgrimages there, to view the treasures it contained. Among others was Professor Silliman, who states in his diary that he spent many weeks in studying the minerals with Colonel Gibbs, finding in the latter "a scientific friend and a professional instructor and guide." That Colonel Gibbs reciprocated Professor Silliman's feelings of friendship there can be no doubt, for after various offers to deposit his collection for exhibition in Boston, New York and elsewhere, to the great surprise of Professor Silliman he proposed to open the cabinet at Yale College, provided rooms should be fitted up for its reception. The proposition was promptly responded to by the authorities of the college, and in 1810, 1811 and 1812, under the personal supervision of Colonel Gibbs, it was opened and arranged, and generously placed at the disposition of the institution and the public. The opening of this collection in New Haven formed an important epoch in the history of the college, and gave a powerful impetus to science throughout the country. It was not only studied by the pupils of the college, but it was visited by travellers from all parts of the United States. In 1825, the collection had for fifteen years been exhibited without any advantage to the owner, other than the satisfaction of observing the great amount of good which was effected by the knowledge it disseminated, and the enthusiasm with which it inspired students. Colonel Gibbs then offered the whole for sale, giving the college the preference as purchaser. Fortunately and mainly through the influence of Professor Silliman, the institution succeeded in raising the funds ($20,000) necessary for its purchase, and the ownership of this collection has exercised a most important influence in the development of natural science at New Haven. Colonel Gibbs, however, did not confine himself to the collection of minerals in Europe. On his return to this country he made extensive journeys and opened up new mineral localities, giving his time and specimens freely to aid others who were interested in this special study. At Yale, as an incentive to students, he for many years offered prizes for superiority of attainments in mineralogical knowledge and for services rendered to the science by useful discoveries and observations. He published valuable papers both in the *American Mineralogical Journal* and the *American Journal of Science*, and did much by his counsel and co-operation to support these publications. Indeed, it was from Colonel Gibbs that Professor Silliman first received the suggestion that he should institute a new journal of science, in order that the advantages already gained by the short-lived mineralogical journal might be secured and further progress for science might be made. In every way Colonel Gibbs proved himself a liberal patron of science, and it was most fortunate for the promotion of mineralogy in this country that he should so unselfishly have devoted his wealth and his personal influence to its advancement. He died August 5th, 1833, aged 57.

Much as had been accomplished by the free exhibition of cabinets and the explorations and investigations of enthusiastic workers in mineralogy during the years from 1805 to 1815, a great drawback was now felt to the progress of the science from the want of text-books. Most of the literature of the subject was in German and French, but the works of the German and French authors had not then been translated and consequently were accessible only to the few who were acquainted with these languages. In English there were not many treatises on the subject. That by Richard Kirwan, the eminent Irish mineralogist of the last century, was a renowned work in its day, but, as the last edition of it had been published in 1794, it was already too old to be of much service to the student. Jameson's treatise was more recent (1804), but its great fullness and exclusive devotion to the Wernerian system made it an undesirable book for beginners, aside from the fact that its price was such that few students in those days could afford to buy it. So much progress had been made at home and abroad, that a work was needed here which should include the modern discoveries, and one also which should gather up the scattered facts already published in regard to American minerals. Fortunately for the further progress of science in this country this was done by Professor Parker Cleaveland. His work was published in 1816, and was entitled "An Elementary Treatise on Mineralogy and Geology." Professor Cleaveland was professor of mathematics and natural philosophy in Bowdoin College, and like many other professors of science in the early history of American colleges was charged by the trustees to lecture also on mineralogy and chemistry. He was an enthusiatic student of mineralogy, was well acquainted with the literature of the science in various languages, had been a successful teacher of the subject for many years, and withal was both an explorer and investigator, and held intimate relations with the leading mineralogists of the day. The work was modelled on the general plan of Brongniart, combining the excellencies of both the French and German schools, and gave in detail almost everything then known in regard to American minerals. It supplied the pressing need for a thorough, systematic and American treatise on mineralogy, well suited to all classes of students, and it was written in such a masterly style that it won for its author the highest praise from the leading mineralogists of the world. "It brought," says Professor Silliman, "within the reach of the American student, the excellencies of Kirwan, Jameson, Haüy, Brochant, Brongniart and Werner, and we are not ashamed," he says, "to have this work compared with those of these celebrated authors." His biographer states that "he received letters of respect and congratulation from Sir David Brewster, Sir Humphrey Davy and Dr. McCulloch, in England; from Berzelius in Stockholm; German of Halle; from Brongniart, Baron Cuvier and the Abbé Haüy, in Paris." The work at once took rank as one of the leading authorities on the science, and was introduced as a class-book in the principal schools and colleges in America. The first edition was soon exhausted and a new and revised edition with more than a hundred pages of new matter was published in 1822. The demand was so great that this likewise was soon out of print and a third edition was called for by the public, but Professor Cleaveland had about this time become so engrossed in the administration of the affairs of the new medical school at Brunswick that he was unable to respond to the call, having turned his thoughts and efforts in new directions. Unfortunately for the science of mineralogy, in which he had obtained such eminence as an author and teacher, he no longer contributed actively to its progress, although he continued his work as lecturer on the science so long as he lived. He died October 16th, 1859, in the 79th year of his age.

The last to be mentioned of these early leaders is Professor Benjamin Silliman. His name is so intimately associated with the progress of science on this continent during the first half of the present century, that his life-work is more or less familiar to all. But the important service he rendered in the early history of mineralogy deserves especial recognition here, not only for the work he himself did in the laboratory and the field, but because his enthusiasm and zeal were a constant inspiration to others. Commencing with the historic "candle box" of unlabelled stones which he took to Dr. Adam Seybert, of Philadelphia, to be named, he began with enthusiasm the acquisition of knowledge and the gathering of material to illustrate the mineral kingdom. During a residence in England and Scotland in 1805-6 he had opportunities to add to this information and collect many specimens, chiefly from the mines of Derbyshire and Cornwall. On his return to America he at once applied the knowledge he had acquired in making an exploration of the mineral structure of the environs of New Haven, and read a paper on this subject to the Connecticut Academy of Arts and Sciences in September, 1806. In the following year he induced the corporation of the college to purchase the mineral collection of Mr. B. D. Perkins, of New York (already referred to), for one thousand dollars, thus placing the institution in possession of means for illustrating the science of mineralogy far in advance of anything it had before enjoyed. The occurrence of the fall of the Western Meteorite in December, 1807, offered an opportunity for Professor Silliman to undertake, in connection with his colleague, Professor Kingsley, an investigation into the circumstances of the phenomena, and the character of the stones which fell at that time. The results of this investigation were presented to the American Philosophical Society and published in the *American Philosophical Transactions* in 1809. The diligence employed in obtaining all the facts possible from eye-witnesses of the occurrence, and the care and skill shown in the chemical and mineralogical examination of the meteorite made this paper one of the most remarkable memoirs of the time, and attracted the attention of philosophers throughout the world. As already stated, it was the personal enthusiasm and magnetic influence of Professor Silliman which led Colonel Gibbs to deposit his great cabinet of minerals in New Haven, under the care of his friend. It was due to the same qualities in Professor Silliman that the college secured the permanent possession of this invaluable collection, which probably has done more to create an interest in and disseminate a knowledge of mineralogy in this country than any other single agency. The establishment of the *American Journal of Science* in 1818, now everywhere recognized as of inestimable value to all departments of science, was peculiarly helpful to mineralogy, and the early volumes are rich in articles on this subject. Professor Silliman's original contributions to science were more in chemistry and geology, but he also is the author of several important papers on mineralogy, and was the discoverer of the occurence of native tungstic acid as a mineral species. For more than fifty years he continued as a teacher in Yale college, and when he resigned his professorship, in 1853, he had the satisfaction to have as his successor in the department of mineralogy and geology Professor James D. Dana, who was already among the foremost mineralogists of the day, and whose published works, before and since his accession to this professorship, have done so much for the advancement of mineralogy. Professor Silliman retired from his active labors in his seventy-fourth year, still in full possession of his remarkable physical and mental powers, and lived honored and revered until November 24, 1864, when he passed to his rest.

It will be inferred from what has been said of these pioneers that the developments and discoveries of minerals, during the first twenty-five years of the century, were due entirely to individual enthusiasm and private enterprise. Up to this time no aid had been received from either State or National Governments, and in looking over the work accomplished during this period we are filled with wonder and admiration at the energy and rare devotion to science exhibited. The larger portion of the continent was an unbroken wilderness, and the facilities of communication even in the settled parts of the country were of the most primitive character. Yet at the present day with our means of rapid transportation, many naturalists would hesitate to undertake the long journeys then made for purely scientific purposes. Geologists as well as mineralogists will recall how much science is indebted to such men as William Maclure, James Pierce, Thomas Nuttall (the botanist), and others who made extensive trips through the whole territory east, and in some instances, to the west of the Mississippi river. Maclure not only devoted his time and money to making and publishing a geological survey of the United States and Canada, the first report of which was made in 1809, but to him the Academy of Natural Sciences, in Philadelphia, owes its first endowment. I shall be pardoned, I trust, if I mention still another signal instance of private liberality in this connection. General Stephen Van Rensselaer, of New York, a generous patron of science, defrayed all the expenses of a geological survey of the country adjacent to the Erie canal, including the making of a geological section from Lake Erie to the eastern coast of Massachusetts. This survey was under the charge of Professor Amos Eaton, with a competent corps of assistants, and was continued for four years, from 1820 to 1824, at a cost of many thousands of dollars. Gen. Van Rensselaer was also the founder of the first school of technical science in this country—the Rensselaer Polytechnic Institute, at Troy, which was placed under the charge of Professor Eaton. It may be interesting here, in these days of Summer Schools, to recall, although parenthetically, that what was probably the first Summer School of Science in the United States was established more than fifty years ago in connection with this institution. The school consisted of a flotilla of towed canal boats, and the route was from Troy to Lake Erie. It took two months for the trip, and visited all important points on the way. Instruction by lectures and examinations was given in mineralogy, geology, botany, zoology, chemistry, experimental philosophy and practical mathematics, particularly land surveying, harbor surveying and engineering. One of the largest boats in the flotilla was fitted up as a laboratory, with cabinets in mineralogy and geology, and also scientific books for reference. Students were taught the method of procuring specimens, and were required to make collections of whatever was interesting on the route. The public mind was finally awakened to the importance of the work which these explorers and investigators had carried on single-handed. Government now came to the aid of science. In 1824 one State legislature, that of North Carolina, authorized a geological survey to be made. This example was followed in 1830 by Massachusetts, and soon after by New York, Pennsylvania, Virginia and other States, and also by the national government, until, as is now well known, the whole territory of the United States and Canada either has been or is in the process of being surveyed. Several of the State surveys published independent volumes on the mineralogy of their respective States, and these surveys have been a powerful auxiliary in extending our knowledge of the occurrence of minerals on this continent. The opening of mines and quarries throughout the country has also furnished abundant material for study. The large number of original contributions which have been published in the volumes of State surveys, the treatises by American authors, and the still larger number of memoirs and papers communicated to our academies of science and scientific journals cannot be even enumerated in this place, neither is it my purpose to attempt to give here a list of the names of those who have been actively engaged in making researches on American minerals. Still less can I attempt to give an account of the work that has been and is being done by living mineralogists. The sketch which I have presented of the four typical workers has in a measure shown the character of our early mineralogists, the earnest spirit in which they labored, and what they accomplished in the first quarter of the century. The point to which the science has reached in the last quarter of the century cannot be unfamiliar to you all. In the time that remains I desire to call your attention to some of the developments made in the field in which our mineralogists have worked. It was thought by many scientists in the first half of this century that our rocks seemed likely to afford less variety of mineral contents than the rocks of Europe. Further study, however, and more careful and extended observations encourage us to believe that our mineral riches, even in variety of species, will compare favorably with those of other continents. Already fully one-half of the known mineral species have been found here. The present number of known minerals is variously estimated to be from seven hundred to one thousand. There have been described, as occurring here, nearly three hundred supposed new American minerals. Of these, perhaps one quarter are new to science and the remainder have either been proved to be identical with species already described, or their characters are so imperfectly given that further investigation is needed to ascertain what they are. Among these new minerals are some of great interest to science. Time, however, will not allow, even if your patience would permit me, to give the facts in detail; but in justice to the describers of those announced to be new, I will print, as an appendix to this address, as complete a list as I have been able to make of the names of the proposed new American mineral species, with the names of their sponsors. The list will, I trust, be instructive both as a warning and an encouragement to investigators. The ambition to make new species is recognized as a drawback in every department of science, and mineralogy has probably not suffered in this respect more than other sciences. Nor do I believe that American mineralogists have, as a class, been less careful in describing new species than their European confrères. There have been flagrant examples of carelessness in both hemispheres, and the growing tendency during the last ten or fifteen years to call things new which have been only imperfectly investigated cannot be too strongly censured. "If two very simple rules," says a recent writer, "could be conscientiously followed by those investigating supposed new mineral species, the science of mineralogy would be vastly benefitted. These are: first, that the material analyzed, should in every case be proved by a careful microscopical and chemical examination to be homogenous; and second, that the thorough investigation which is to establish the position of a 'new species' should precede, not follow, the giving of a new name. A mineral which can be only partially described does not deserve a name." In comparing the minerals found in America with those of Europe, although interesting minor variations are observed, it can hardly be expected that very marked differences should exist. This is, of course, due to the fact, that in the inorganic kingdom, nature has everywhere to do with the same elements, under essentially like conditions. A large number of remarkable analogies between the minerals of the two continents will occur to any one familiar with the subject, as, for example, the character and the occurrence of individual minerals in the rocks of the northeastern United States and Canada as compared with those of Norway and Sweden, and numberless instances of like association of minerals in various parts of Europe find their counterparts here. A marked feature of the American minerals is the grand scale upon which crystallization has taken place, individual crystals of large size being very common. The granite veins of New

England afford striking examples of this kind. We have common mica, in sheets a yard across; feldspar has been observed where a single cleavage plane measured ten feet; gigantic hexagonal prisms of beryl, four feet long and more than two feet in diameter, and weighing over two tons, have been described; spodumene crystals six to seven feet in length and a foot or more across, and masses of rock crystal of immense size have been found. Canada and New York have given crystals of apatite, phlogopite and sphene which for these species are of marvellous grandeur in dimensions. Many other American localities might be mentioned where giant crystals occur. While it is true that these are extraordinary instances it is also true as a general fact common to a very large proportion of the minerals found in this country that the species occur in much larger crystals than those obtained from European localities. Another point worthy of note is the occurrence in comparatively large quantities, and over wide areas, of some of the rarer elements as constituents of the minerals found. In illustration of this we have, among the rare earths, *glucina* combined with silica and alumina in the mineral *beryl*, occurring in large quantity, and perhaps in a hundred or more places; *zirconia*, in the mineral *zircon*, is also very widespread in its range of occurrence as an original constituent of the older rocks, as well as a vein mineral; localities are known which have furnished this rare species by the hundredweight. The *cerium* earths are found largely in the mineral *allanite*, which occurs in so many places that it may be said to be a common mineral in the United States. These earths are also found in the rare phosphate *monazite*, a mineral that in America has a wide range of localities, and recently this species has been found in crystals of two, three, and in one instance, of eight pounds in weight. Again, three new earth metals, *mosandrum*, *phillipium* and *decipium* have been described as occurring with the cerium earths and yttria in the North Carolina *samarskite*. The rare alkali metal *lithium*, sometimes associated with the still rarer metals *rubidium* and *caesium*, is found not only of wide-spread occurence in our lithia micas, but the mineral *spodumene*, containing from five to eight per cent. of lithia, occurs by the ton in at least one locality and must be looked upon as one of the common American minerals, being found in the granite veins in Maine, New Hampshire, Massachusetts and Connecticut, and as far south as North Carolina and Georgia. Lithia is also one of the constituents of the phosphate *triphilite*, and there are several localities known where this mineral occurs abundantly. Again we have the frequent occurrence of some of the rare metals which form metallic acids: *Columbium*, the first metal, new to science, discovered in America, associated with its twin metal *tantalum*, is found in Columbite in our granite veins from Maine to Georgia, a range of more than a thousand miles, in a score or more of places, and sometimes is obtained by the hundredweight in a single locality. The American variety of *samarskite*, another rare columbate has also been found in masses of fifty pounds or more in weight, and these acids occur in still other American species. *Molybdenum*, both as sulphide and in the oxidized form as native molybdic acid and molybdate of lead, is found in many localities, and occasionally in large quantity. Quite recently *vanadium* compounds have been discovered in several places, and *tungstates* have also been observed over a wide range of country. *Titanium* has been found in enormous quantities in extensive deposits of titanic iron as well as in the form of ratele and in shpene. The rare metal *tellurium* occurs native in Colorado and in one locality where single masses of twenty-five pounds in weight have been taken out, and several new tellurium compounds have been found in our western mines. It is, perhaps, unnecessary to enumerate more fully the many occurrences of other rare elements in American minerals. Enough has already been said to show that important developments have been made in the discovery and investigation of the minerals found in our American rocks during the past eighty years. Nevertheless it is but a commencement in the work. Only a very small portion of our territory has been explored with any thoroughness, and none of it exhaustively. The enormous production of the precious metals, and the extensive deposits of ores of the more common metals which have been opened up during the past twenty or thirty years, have placed us in tho front rank as metal producers, but we are still far behind Europe in the variety of minerals obtained from our mines. This may be due, in some instances, to the character of the veins or ore deposits, there being, as in many of our gold or silver mines, remarkably few associated minerals. In other cases, however, it is doubtless due to the fact that very few persons connected with our mines have even an elementary knowledge of the rudiments of mineralogy, while in continental Europe almost every mining officer is familiar with all the ordinary minerals. Thanks to the traning of our schools of science, an improvement in this respect is already noticeable, as is shown in the discoveries made in the mines of our western states and territories during the past few years. While the service done for mineralogy by our geological surveys is gratefully acknowledged, we feel we have a right to demand much more from them in the future. Mineralogy has been too largely looked upon as a guide to the discovery of useful ores and minerals and not as a matter for scientific study; fortunately during the past decade the discoveries in optical mineralogy, and their importance in the determination of the constituent minerals of the crystalline rocks, have led many geologists to again recognize the desirability of a knowledge of our science. Much will be accomplished if those in charge of geological surveys will direct competent persons to make observations, not only on the main mineral constituents of rocks but also on the manner of occurrence of individual minerals. The careful inspection of quarries and mines is greatly to be desired. These are rich sources for minerals, but unless constant watchfulness is exercised valuable material for science is in danger of being buried out of sight. It is too true that many of the most interesting discoveries already recorded seem to have been due more to the result of fortunate accident than of systematic and intelligent exploration. If our trained mineralogists, instead of devoting most of their attention to the examination of specimens in cabinets collected by others would give more time to personal observation in the field in the study of the order and manner of occurrence of mineral species in place, our knowledge would doubtless be greatly promoted. Again, if our wealthy amateurs could be induced to spend their money as freely in the exploration of promising American localities as in the importation of costly European specimens, we might hope for more important discoveries, and they could have the satisfaction not only of gaining novelties for their collections, but incidentally they would do much to foster science. In order to keep pace with the progress of the science, we need many more workers who will will devote themselves especially to mineralogical research, and we need more of the spirit of the early workers. It is my belief that the number of persons at present interested in the study here, either as amateurs or investigators is relatively less than in 1825. The mineralogy of to-day is a very different subject from the mine ralogy of the commencement of the period over which we have so hastily glanced. Then the study of minerals was confined almost exclusively to their external characters. Led by Werner, and reinforced by his most gifted pupil, Mohs, the majority of mineralogists claimed mineralogy to be a purely natural history science. They gave their attention, as has been well said, entirely to "how the mineral looked," and not at all to "what it was." On the other hand the development of analytical chemistry by the labors of Klaproth and Berzelius led many to take up mineralogy from a purely chemical stand-point. These two schools working independently brought great confusion into the science. The discoveries of Haüy in crystallography, and especially his labors in establishing a mathematical foundation for the geometrical form of crystals, and the recognition that the constancy of form depended on the constancy of the "integrant molecule," were steps which paved the way for modern mineralogy. In this a union of all the physical, geometrical, and chemical properties is required in order to determine the true character of a mineral. Further, we are called upon to investigate the history of its origin, its relation to associated species, the changes which it undergoes, and the causes and results of these changes. Here we have to do largely with both geology and chemistry. From this it becomes evident that a much broader foundation is now required for the mineralogist than in the early days of the century. The bearing of physics, geology and chemistry in the study of the mineral kingdom must be thoroughly recognized and appreciated by every investigator who desires to contribute to further progress. No mineralogist can expect to have a profound knowledge in all these directions, but he must be at least capable of intelligently applying to his subject the results obtained by experts in these sciences. Mineralogy is deeply indebted to special investigators in all these departments. Without their co-operation it would have been impossible to discover the relations of form and other physical characters with that fundamental arrangement of molecules whose nature it is now admitted controls all the properties of a substance. The study of natural crystals has afforded rich material for the physicist. In the department of optics it has given results from which many fundamental laws have been deduced; and natural crystals, too, have furnished, in many cases, the very apparatus which made investigation possible. Some chemists claim that mineralogy is not at all a science by itself, and constitutes only a small part of inorganic chemistry. It can be unquestionably conceded that a knowledge of chemistry is fundamental, and in consequence this claim has a certain plausibility. On the other hand, we contend that it was largely the labors of the mineralogists on the physical characters of minerals, and especially their demonstration of the relation of form to chemical composition which finally awakened chemists to a more profound study of their own subject. The law of isomorphism was discovered by a chemist, whose training as an expert crystallographer in the examination of natural crystals made it possible for him to recognize the wonderful relation of form to composition. Dimorphism was first established from observations made on minerals, and it is in the study of the mineral kingdom that the laws of isomorphism and dimorphism find abundant demonstration. From the further investigation of the chemical nature of minerals we may hope for new light on the molecular constitution of substances which as yet the chemist has been unable to reproduce. We have already indicated the interdependence of geology and mineralogy. May we not claim the same interdependence of mineralogy, physics and chemistry, letting each go on in its own sphere, contributing to the general progress, sure that every new fact observed and every new law discovered will be for the common advancement of all?

INAUGURAL ADDRESS OF THE PRESIDENT OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE FOR THE YEAR 1882.

Since the days of the first meeting of the Association in York, in 1831, great changes have taken place in the means at our disposal for exchanging views, either personally or through the medium of type. The creation of the railway system has enabled congenial minds to attend frequent meetings of those special Societies which have sprung into existence since the foundation of the British Association, amongst which I need only name here the Physical, Geographical, Meteorological, Anthropological, and Linnean, cultivating abstract science, and the Institution of Mechanical Engineers, the Institution of Naval Architects, the Iron and Steel Institute, the Society of Telegraph Engineers and Electricians, the Gas Institute, the Sanitary Institute, and the Society of Chemical Industry, representing applied science. These meet at frequent intervals in London, whilst others, having similar objects in view, hold their meetings at the University towns, and at other centres of intelligence and industry throughout the country, giving evidence of great mental activity, and producing some of those very results which the founders of the British Association wished to see realised. If we consider, further, the extraordinary development of scientific journalism which has taken place, it cannot surprise us when we meet with expressions to the effect that the British Association has fulfilled its mission, and should now yield its place to those special Societies it has served to call into existence. On the other hand, it may be urged that the brilliant success of last year's Anniversary Meeting, enhanced by the comprehensive address delivered on that occasion by my distinguished predecessor in office, Sir John Lubbock, has proved, at least, that the British Association is not dead in the affection of its members, and it behoves us at this, the first ordinary gathering in the second half-century, to consider what are the strong points to rely upon for the continuance of a career of success and usefulness.

If the facilities brought home to our doors of acquiring scientific information have increased, the necessities for scientific enquiry have increased in a greater ratio. The time was when science was cultivated only by the few, who looked upon its application to the arts and manufactures as almost beneath their consideration; this they were content to leave in the hands of others, who, with only commercial aims in view, did not aspire to further the objects of science for its own sake, but thought only of benefiting by its teachings. Progress could not be rapid under this condition of things, because the man of pure science rarely pursued his enqniry beyond the mere enunciation of a physical or chemical principle, whilst the simple practitioner was at a loss how to harmonise the new knowledge with the stock of information which formed his mental capital in trade.

The advancement of the last fifty years has, I venture to submit, rendered theory and practice so interdependent that an intimate union between them is a matter of absolute necessity for our future progress. Take, for instance, the art of dyeing, and we find that the discovery of new colouring matters derived from waste products, such as coal-tar, cempletely changes its practice, and renders an intimate knowledge of the science of chemistry a matter of absolute necessity to the practitioner. In telegraphy and in the new arts of applying electricity to lighting, to the transmission of power, and to metallurgical operations, problems arise at every turn requiring for their solution not only an intimate acquaintance with, but a positive advance upon, electrical seieuce, as established by purely theoretical research in the laboratory. In general engineering the mere practical art of constructing a machine so designed and proportioned as to produce mechanically the desired effect, would suffice no longer. Our increased knowledge of the nature of the mutual relations between the different forms of energy makes us see clearly what are the theoretical limits of effeot; these, although beyond our absolute reach, may be looked upon as the asymptotes to be approached indefinitely by the hyperbolic course of practical progress, of which we should never lose sight. Cases arise, moreover, where the introduction of new materials of construction, or the call for new effects, renders former rules wholly insufficient. In all these cases practical knowledge has to go hand in hand with the advanced science in order to accomplish the desired end.

Far be it from me to think lightly of the ardent students of nature, who, in their devotion to research, do not allow their minds to travel into the regions of utilitarianism and of self-interest. These, the high priests of science, command our utmost admiration; but it is not to them that we can look for our current progress in practical science, much less can we look for it to "the thumb" practitioner, who is guided by what comes nearer to instinct than to reason. It is to the man of science, who also gives attention to practical questions, and to the practitioner, who devotes part of his time to the prosecution of strictly scientific investigations, that we owe the rapid progress of the present day, both merging more and more into one class, that of pioneers in the domain of nature. It is such men that Archimedes must have desired when he refused to teach his disciples the art of constructing his powerful ballistic engines, exhorting them to give their attention to the principles involved in their construction; and that Telford, the founder of the Institution of Civil Engineers, must have had in his mind's eye, when he defined civil engineering as "the art of directing the great sources of nature."

These considerations may serve to show that although we see the men of both abstract and applied science group themselves in minor bodies for the better prosecution of special objects, the points of contact between the different branches of knowledge are ever multiplying, all tending to form part of a mighty tree—the tree of modern science, under whose ample shadow its cultivators will find it both profitable and pleasant to meet, at least once a year; and considering that this tree is not the growth of one country only. but spreads both its roots and branches far and wide, it appears desirable that at these yearly gatherings other nations should be more fully represented than has hitherto been the case. The subjects discussed at our meetings are without exception of general interest, but many of them bear an international character, such as the systematic collection of magnetic, astronomical, meteorological, and geodetical observations, the formation of a universal code for signaling at sea, and for distinguishing lighthouses, and especially the settlement of scientific nomenclatures and units of measurement, regarding all of which an international accord is a matter of the utmost practical importance.

As regards the measures of length and weight it is to be regretted that this country still stands aloof from the movement initiated in France towards the close of last century: but, considering that in scientific work metrical measure is now almost universally adopted, and that its use has been already legalised in this country, I venture to hope that its universal adoption for commercial purposes will soon follow as a matter of course. The practical advantages of such a measure to the trade of this country would, I am convinced, be very great, for English goods, such as machinery or metal rolled to current sections, are now almost excluded from the Continental market, owing to the unit measure employed in their production. The principal impediment to the adoption of the metre consists in the strange anomaly that although it is legal to use that measure in commerce, and although a copy of the standard metre is kept in the Standards' Department of the Board of Trade, it is impossible to procure legalised rods representing it, and to use a non-legalised copy of a standard in commerce is deemed fraudulent. Would it not be desirable that the British Association should endeavor to bring about the use in this country of the metre and kilogramme, and, as a preliminary step, petition the Government to be represented on the International Metrical Commission, whose admirable establishment at Sèvres possesses, independently of its practical work, considerable scientific interest. as a well found laboratory for developing methods of precise measurement.

Next in importance to accurate measures of length, weight, and time, stand, for the purposes of modern science, those of electricity.

The remarkably clear lines separating conductors from non-conductors of electricity, and magnetic from non-magnetic substances, enable us to measure electrical quantities and effects with almost mathematical precision; and, although the ultimate nature of this, the youngest scientifically investigated form of energy, is yet wrapt in mystery, its laws are the most clearly established, and its measuring instruments (galvanometres, electrometers and magnetometers), are amongst the most accurate in physical science. Nor could any branch of science or industry be named in which electrical phenomena do not occur, to exercise their direct and important influence.

If, then, electricity stands foremost amongst the exact sciences, it follows that its unit measures should be determined with the utmost accuracy. Yet, twenty years ago, very little advance had been made towards the adoption of a rational system. Ohm had. it is true, given us the fixed relations existing between electromotive force, resistance, and quantity of current; Joule had established the dynamical equivalent of heat and electricity, and Gauss and Weber had proposed their elaborate system of absolute magnetic measurement. But these invaluable researches appeared only as isolated efforts, when, in 1862, the Electric Unit Committee was appointed by the British Association, at the instance of Sir William Thomson, and it is to the long-continued activity of this Committee that the world is indebted for a consistent and practical system of measurement, which, after being modified in details, received universal sanction last year by the International Electrical Congress assembled at Paris.

At this Congress, which was attended officially by the leading physicists of all civilised countries, the attempt was successfully made to bring about a union between the statical system of measurement that had been followed in Germany and some other countries, and the magnetic or dynamical system developed by the British Association, also between the geometrical measure of resistance, the (Werner) Siemens unit, that had been generally adopted abroad, and the British Association unit intended as a multiple of Weber's absolute unit, though not entirely fulfilling that condition. The Congress, while adopting the absolute system of the British Association, referred the final determination of the unit measure of resistance to an International Committee, to be appointed by the representatives of the several governments: they decided to retain the mercury standard for reproduction and comparison, by which means the advantages of both systems are happily combined, and much valuable labor is utilised; only, instead of expressing electrical quantities directly in absolute measure, the Congress has embodied a consistent system, based on the Ohm, in which the units are of a value convenient for practical measurements. In this, which we must hereafter know as the "practical system," as distinguished from the "absolute system," the units are named after leading physicists, the Ohm, Ampère, Volt, Coulomb, and Farad.

I would venture to suggest that two other units might, with advantage, be added to the system decided on by the International Congress at Paris. The first of these is the unit of magnetic quantity or pole. It is of some importance, and few will regard otherwise than with satisfaction the suggestion of Clausius that the unit should be called a "Weber," thus retaining a name most closely connected with electrical measurements, and only omitted by the Congress in order to avoid the risk of confusion in the magnitude of the unit current with which his name had been formerly associated.

The other unit I should suggest adding to the list is that of power. The power conveyed by an Ampère through the difference of potential of a Volt is the unit consistent with the practical system. It might be appropriately called a Watt, in honor of that master mind in mechanical science, James Watt. He it was who first had a clear physical conception of power, and gave a rational method of measuring it. A Watt, then, expresses the rate of an Ampère multiplied by a Volt, whilst a horse-power is 746 Watts, and a Cheval de Vapeur 735.

The system of electro-magnetic units would then be :—

(1)	Weber, the unit of magnetic	quantity	$=10^8$
(2)	Ohm, " "	resistance	$=10^9$
(3)	Volt. " "	electro-motive force	$=10^8$
(4)	Ampère, " "	current	$=10^{-1}$
(5)	Coulomb, " "	quantity	$=10^{-1}$
(6)	Watt " "	power	$=10^7$
(7)	Farad " "	capacity	$=10^{-9}$

Electricity is the form of energy best suited for transmitting an effect from one place to another: the electric current passes through certain substances—the metals—with a velocity limited only by the retarding influence caused by electric charge of the surrounding dielectric, but approaching probably under favorable conditions that of radiant heat and light, or 300,000 kilometres per second; it refuses, however, to pass through oxidised substances, glass, gums, or through gases except when in a highly rarified condition. It is easy therefore to confine the electric current within bounds, and to direct it through narrow channels of extraordinary length. The conducting wire of an Atlantic cable is such a narrow channel; it consists of a copper wire, or strand of wires, 5 m. m. in diameter, by nearly 5000 kilometres in length, confined electrically by a coating of guttapercha about 4 m. m. in thickness. The electricity from a small galvanic battery passing into this channel prefers the long journey to America in the good conductor, and back through the earth, to the shorter journey across the 4 m. m. in thickness of insulating material. By an improved arrangement the alternating currents employed to work long submarine cables do not actually complete the circuit, but are merged in a condenser at the receiving station, after having produced their extremely slight but certain effect upon the receiving instrument. So perfect is the channel and so precise the action of both the transmitting and receiving instruments employed, that two systems of electric signals may be passed simultaneously through the same cable in opposite directions, producing independent records at either end. By the application of this duplex mode of working to the direct United States cable under the superintence of Dr. Muirhead, its transmitting power was increased from twenty-five to sixty words a minute, being equivalent to about twelve currents or primary impulses per second.

The minute currents here employed are far surpassed as regards delicacy and frequency by those revealed to us by that marvel of the present day, the telephone. The electric currents caused by the vibrations of a diaphragm acted upon by the human voice, naturally vary in frequency and intensity according to the number and degree of those vibrations, and each motor current in exciting the electro-magnet forming part of the receiving instrument, deflects the iron diaphragm occupying the position of an armature to a greater or smaller extent according to its strength. Savart found that the fundamental *la* springs from 440 complete vibrations in a second; but what must be the frequency and modulations of the motor current and of magnetic variations necessary to convey to the ear through the medium of a vibrating armature, such a complex of human voices and of musical instruments as constitutes an opera performance. And yet such performances could be distinctly heard and even enjoyed as an artistic treat by supplying to the ear a pair of the double telephonic receivers, at the Paris Electrical Exhibition, when connected with a pair of transmitting irtruments in front of the foot lights of the Grand Opera. In connection with the telephone, the names of Reiss, Graham Bell, Edison, and Hughes will ever be remembered.

Regarding the transmission of power to a distance the electric current has now entered the lists in competion with compressed air, the hydraulic accumulator, and the quick running rope as used at Schaffhausen to utilise the power of the Rhine fall. The transformation of electrical into mechanical energy can be accomplished with no further loss than is due to such incidental causes as friction and the heating of wires; these in a properly designed dynamo-electric machine do not exceed 10 per cent. as shown by Dr. John Hopkinson, and, judging from recent experiments of my own, a still nearer approach to ultimate success is attainable. Adhering, however, to Dr. Hopkinson's determination, for safety's sake, and assuming the same percentage in re-converting the current into mechanical effect, a total loss of 19 per cent results. To this loss must be added that through electrical resistance in the connecting line wires, which depends upon their length and conductivity, and that due to heating by friction of the working parts of the machine. Taking these as being equal to the internal losses incurred in the double process of conversion, there remains a useful effect of 100–38=62 per cent, attainable at a distance, which agrees with experimental results, although in actual practice it would not be safe at present to expect more than 50 per cent of ultimate useful effect, to allow for all mechanical losses.

In using compressed air or water for the transmission of power the loss cannot be taken at less than 50 per cent, and as it depends upon fluid resistance, it increases with distance more rapidly than in the case of electricity. Taking the loss of effect in all cases at 50 per cent, electric transmission presents the advantage that an insulated wire does the work of a pipe capable of withstanding high internal pressure, which latter must be more costly to put down and to maintain. A second metallic conductor is required, however, to complete the electrical circuit, as the conducting power of the earth alone is found unreliable for passing quantity currents, owing to the effect of polarisation; but as this second conductor need not be insulated, water or gas pipes, railway metal or fencing wire, may be called into requisition for the purpose. The small space occupied by the electromotor, its high working speed, and the absence of waste products, render it specially available for the general distribution of power to cranes and light machinery of every description. A loss of effect of 50 per cent does not stand in the way of such applications, for it must be remembered that a powerful central engine of best construction produces motive power with a consumption of two pounds of coal per horse-power per hour, whereas small engines distributed over a district would consume not less than five; we thus see that there is an advantage in favor of electric transmission as regards fuel, independently of the saving of labor and other collateral benefits.

To agriculture electric transmission of power seems adapted for effecting the various operations of the farm and the fields from one centre. Having worked such a system myself in combination with electric lighting and horticulture for upwards of two years, I can speak with confidence of its economy, and of the facility with which the work is accomplished in charge of untrained persons.

As regards the effect of electric light upon vegetation there is little to add to what was stated in my paper read before Section A last year, and ordered to be printed with the Report, except that in experimenting upon wheat, barley, oats, and other cereals sown in open air, there was a marked difference between the growth of the plants influenced and uninfluenced by the electric light. This was not very apparent until towards the end of February, when with the first appearance of mild weather the plants under the influence of an electric lamp of 4000 candle-power placed about 5 metres above the surface, developed with extreme rapidity, so that by the end of May they stood above 4 feet high, with the ears in full bloom, when those not under its influence were under 2 feet in height, and showed no sign of the ear.

In the electric railway first constructed by Dr. Werner Siemens, at Berlin, in 1879, electric energy was transmitted to the moving carriage or train of carriages through the two rails upon which it moved, these being sufficiently insulated from each other by being placed upon well creosoted cross sleepers. At the Paris Electric Exhibition the current was conveyed through two separate conductors making sliding or rolling contact with the carriage, whereas in the electric railway now in course of construction in the north of Ireland (which, when completed, will have a length of twelve miles), a separated conductor will be provided by the side of the railway, and the return circuit completed through the rails themselves, which in that case need not be insulated; secondary batteries will be used to store the surplus energy created in running downhill, to be restored in ascending steep inclines, and for passing railways where the separate insulated conductor is not practicable. The electric railway possesses great advantages over horse or stream power for towns, in tunnels and in all cases where natural sources of energy, such as waterfalls, are available; but it would not be reasonable to suppose that it will in its present condition compete with steam propulsion upon ordinary railways.

The deposition of metals from their solutions is perhaps the oldest of all useful applications of the electric current, but it is only in very recent times that the dynamic current has been practically applied to the refining of copper and other metals, as now practised in Birmingham and elsewhere, and upon an exceptionally large scale at Ocker, in Germany. The dynamo machine there employed was exhibited at the Paris Electrical Exhibition, its peculiar feature being that the conductors upon the rotating armature consisted of solid bars of copper 30 m. m. square, in section, which were found only just sufficient to transmit the large quantity of low tension necessary for this operation. One such machine consuming 4-horse power deposits about 300 kilogrammes of copper per 24 hours; the motive power at Ocker is derived from a waterfall.

The electric energy may also be employed for heating purposes, but in this case it would obviously be impossible for it to compete in point of economy with the direct combustion of fuel for the attainment of ordinary degrees of heat. Bunsen and Ste.-Claire De Ville have taught us, however, that combustion becomes extremely sluggish when a temperature of 1800° C. has been reached, and for effects of temperatures exceeding that limit the electric furnace will probably find advantageous applications. Its specific advantage consists in being apparently unlimited in the degree of heat attainable, thus opening out a new field of investigation to the chemist and metallurgist. Tungsten has been melted in such a furnace, and 8 pounds of platinum have been reduced from the cold to the liquid condition in 20 minutes.

The largest and most extensive application of electric energy at the present is to lighting; but, considering how much has of late been said and written for and against this new illuminant, I shall here confine myself to a few general remarks.

The principal argument in favor of the electric light is furnished by its immunity from products of combustion which not only heat the lighted appartments, but substitute carbonic acid and deleterious sulphur compounds for the oxygen upon which respiration depends; the electric light is white instead of yellow, and thus enables us to see pictures, furniture, and flowers as by daylight; it supports growing plants instead of poisoning them, and by its means we can carry on photography and many other industries at night as well as during the day. The objection frequently urged against the electric light, that it depends upon the continuous motion of steam or gas engines, which are liable to accidental stoppage, has been removed by the introduction into practical use of the secondary battery; this, although not embodying a new conception, has lately been greatly improved in power and constancy by Planté, Faure, Volckmar, Sellon, and others, and promises to accomplish for electricy what the gas-holder has done for the supply of gas, and the accumulator for hydraulic transmission of power.

It can no longer be a matter of reasonable doubt, therefore, that electric light will take its place as a public illuminant, and that even should its cost be found greater than that of gas, it will be preferred for lighting drawing-rooms, theatres and concert-rooms, museums, churches, warehouses, show-rooms, printing establishments and factories, and also the cabins and engine-rooms of passenger steamers. In the cheaper and more powerful form of the arc light, it has proved itself superior to any other illuminant for spreading artificial daylight over the large areas of harbors, railway stations, and the sites of public works. When placed within a holophote the electric lamp has already become auxiliary in effecting military operations both by sea and land.

The electric light may be worked by natural sources of power, such as waterfalls, the tidal wave, or the wind, and it is conceivable that these may be utilised at considerable distances by means of metallic conductors. Some five years ago I called attention to the vastness of those sources of energy, and the facility offered by electric conduction in rendering them available for lighting and power-supply, while Sir William Thomson made this important matter the subject of his admirable address to Section A last year at York, and dealt with it in an exhaustive manner.

The advantages of the electric light and of the distribution of power by electricity have lately been recognised by the British Government, who have just passed a Bill through Parliament to facilitate the establishment of electric conductors in towns, subject to certain regulating clauses to protect the interests of the public and of local authorities. Assuming the cost of electric light to be practically the same as gas, the preference for one or other will in each application be decided upon grounds of relative convenience, but I venture to think that gas-lighting will hold its own as the poor man's friend.

Gas is an institution of the utmost value to the artisan; it requires hardly any attention, is supplied upon regulated terms, and gives with what should be a cheerful light a genial warmth, which often saves the lighting of a fire. The time is moreover not far distant, I venture to think when both rich and poor will largely resort to gas as the most convenient, the cleanest, and the cheapest of heating agents, and when raw coal will be seen only at the colliery or the gasworks. In all cases where the town to be supplied is within say 30 miles of the colliery, the gasworks may with advantage be planted at the mouth, or still better at the bottom of the pit, whereby all haulage of fuel would be avoided, and the gas, in its ascent from the bottom of the colliery, would require an onward pressure sufficient probably to impel it to its destination. The possibility of transporting combustible gas through pipes for such a distance has been proved at Pittsburg, where natural gas from the oil districts is used in large quantities.

The quasi monopoly so long enjoyed by gas companies has had the inevitable effect of checking progress. The gas being supplied by meter, it has been seemingly to the advantage of the companies to give merely the prescribed illuminating power, and to discourage the invention of economical burners, in order that the consumption might reach a maximum. The application of gas for heating purposes has not been encouraged, and is still made difficult in consequence of the objectionable practice of reducing the pressure in the mains during daytime to the lowest possible point consistent with prevention of atmospheric indraught. The introduction of electric light has convinced gas managers and directors that such a policy is no longer tenable, but must give way to one of technical progress; new processes for cheapening the production and increasing the purity and illuminating power of gas are being fully discussed before the Gas Institute; and improved burners, rivalling the electric light in brilliancy, greet our eyes as we pass along our principal thoroughfares.

Regarding the importance of gas supply as it exists at present, we find from a Government return that the capital invested in gasworks in England, other than those of local authorities, amounts to £30,000,000; in these 4,281,048 tons of coal are converted annually, producing 43,000 million cubic feet of gas, and about 2,800,000 tons of coke: whereas the total amount of coal annually converted in the United Kingdom may be estimated at 9,000,000 tons, and the by-products therefrom at 500,000 tons of tar, 1,000,000 tons of ammonia liquor, and 4,000,000 tons of coke, according to the returns kindly furnished me by the managers of many of the gasworks and corporations. To these may be added say 120,000 tons of sulphur, which up to the present time is a waste product.

Previous to the year 1856—that is to say before Mr. W. H. Perkin had invented his practical process, based chiefly upon the theoretical investigations of Hofmann, regarding the coal-tar bases and the chemical constitution of indigo—the value of coal-tar in London was scarcely a halfpenny a gallon, and in country places gas makers were glad to give it away. Up to that time the coal-tar industry had consisted chiefly in separating the tar by distillation into naphtha, creosote, oils, and pitch. A few distillers, however, made small quantities of benzene, which had been first shown—by Mansfield, in 1849—to exist in coal-tar naptha mixed with toluene, cumene, &c. The discovery, in 1856, of the mauve or aniline purple gave a great impetus to the coal-tar trade, inasmuch as it necessitated the separation of large quantities of benzene, or a mixture of benzene and toluene, from the naphtha. The trade was further increased by the discovery of the magenta of rosaniline dye, which required the same products for its preparation. In the meantime, carbolic acid was gradually introduced into commerce, chiefly as a disinfectant, but also for the production of coloring matter.

The color industry utilises even now practically all the benzene, a large proportion of the solvent naphtha, all the anthracene, and a portion of the naphthaline resulting from the distillation of coal-tar; and the value of coloring matter thus produced is estimated by Mr. Perkin at £3,350,000.

The demand for ammonia may be taken as unlimited, on account of its high agricultural value as a manure; and, considering the failing supply of guano and the growing necessity of stimulating the fertility of our soil, an increased production of ammonia may be regarded as a matter of national importance, for the supply of which we have to look almost exclusively to our gas-works. The present production of 1,000,000 tons of liquor yields 95,000 tons of sulphate of ammonia; which, taken at £20 10s. a ton, represents an annual value £1,947,000.

The total annual value of the gas-works by-products may be estimated as follows:—

Coloring matter	£3,350,000
Sulphate of ammonia	1,947,000
Pitch (355.000 tons)	365,000
Creosote (25,000 gallons)	208,000
Crude carbolic acid (1,000,000 gallons)	100,000
Gas coke, 4,000,000 tons (after allowing 2,000,000 consumption in working the retorts) at 12s	2,400,000
	£8,370,000

Taking the coal used, 9,000,000 tons, at 12s., equal £5,400,-000, it follows that the by-products exceed in value the coal used by very nearly £3,000,000.

In using raw coal for heating purposes these valuable products are not only absolutely lost to us, but in their stead we are favoured with those semi-gaseous by-products in the atmosphere too well known to the denizens of London and other large towns as smoke. Prof. Roberts has calculated that the soot in the pall hanging over London on a winter's day amounts to fifty tons, and that the carbonic oxide, a poisonous compound, resulting from the imperfect combustion of coal, may be taken as at least five times that amount. Mr. Aitken has shown, moreover, in an interesting paper communicated to the Royal Society of Edinburgh last year, that the fine dust resulting from the impecfect combustion of coal is mainly instrumental in the formation of fog; each particle of solid matter attracting to itself aqueous vapour; these globules of fog are rendered particularly tenacious and disagreeable by the presence of tar vapour, another result of imperfect combustion of raw fuel, which might be turned to much better account at the dye-works. The hurtful influence of smoke upon public health, the great personal discomfort to which it gives rise, and the vast expense it indirectly causes through the destruction of our monuments, pictures, furniture, and apparel, are now being recognized, as is evidenced by the success of recent Smoke Abatement Exhibitions. The most effectual remedy would result from a general recognition of the fact that wherever smoke is produced fuel is being consumed wastefully, and that all our caloric effects, from the largest down to the domestic fire, can be realised as completely, and more economicaly, without allowing any of the fuel employed to reach the atmosphere unburnt. This most desirable result may be effected by the use of gas for all heating purposes with or without the addition of coke or anthracite.

The cheapest form of gas is that obtained through the entire distillation of fuel in such gas producers as are now largely used in working the furnaces of glass, iron, and steel works; but gas of this description would not be available for the supply of towns owing to its bulk, about two-thirds of its volume being nitrogen. The use of water-gas, resulting from the decomposition of steam in passing through a hot chamber filled with coke, has been suggested, but this gas also is objectionable, because it contains, besides hydrogen, the poisonous and inodorous gas carbonic oxide, the introduction of which into dwelling-houses could not be effected without considerable danger. A more satisfactory mode of supplying heating separately from illuminating gas would consist in connecting the retort at different periods of the distillation with two separate systems of mains for the delivery of the respective gases. By resorting to improved means of heating the retorts with gaseous fuel, such as have been in use at the Paris gas-works for a considerable number of years. the length of time for effecting each distillation may be shortened from six hours, the usual period in former years, to four, or even three hours, as now practised at Glasgow and elsewhere. By this means a given number of retorts can be made to produce, in addition to the former quantity of illuminating gas of superior quality, a similar quantity of heating gas, resulting in a diminished cost of production, and an increased supply of the valuable by-products previously referred to.

The greater efficiency of gas as a fuel results chiefly from the circumstance that a pound of gas yields in combustion 22,000 heat units, or exactly double the heat produced in the combustion of a pound of ordinary coal. This extra heating power is due partly to the freedom of the gas from earthy constituents, but chiefly to the heat imparted to it in effecting its distillation. Recent experiments with gas burners have shown that in this direction also there is much room for improvement.

The amount of light given out by a gas flame depends upon the temperature to which the particles of solid carbon in the flame are raised, and Dr. Tyndall has shown that of the radiant energy set up in such a flame, only the 1-25th part is luminous; the hot products of combustion carry off at least four times as much energy as is radiated, so that no more than one-hundredth part of the heat evolved in combustion is converted into light. This proportion could be improved, however, by increasing the temperature of combustion, which may be effected either by intensified air-current or by regenerative action. Supposing that the heat of the products of combustion could be communicated to metallic surfaces, and be transferred by conduction or otherwise to the atmospheric air supporting combustion in the flame, we should be able to increase the temperature accumulatively to any point within the limit of dissociation; this limit may be fixed at about 2300° C., and cannot be very much below that of the electric arc. At such a temperature the proportion of luminous rays to the total heat produced in combustion would be more than doubled, and the brilliancy of the light would at the same time be greatly increased. Thus improved, gas-lighting may continue its rivalry with electric lighting both as regards economy and brilliancy, and such rivalry must necessarily result in great public advantage.

In the production of mechanical effect from heat, gaseous fuel also presents most striking advantages, as will appear from the following consideration. When we have to deal with the question of converting mechanical into electrical effect, or *vice versa*, by means of the dynamo-electrical machine, we have only to consider what are the equivalent values of the two forms of energy, and what precautions are necessary to avoid losses by the electrical resistance of conductors and by friction. The transformation of mechanical effect into heat involves no losses except those resulting from imperfect installation, and these may be co completely avoided that Dr. Joule was able by this method to determine the equivalent values of the two forms of energy. But in attempting the inverse operation of effecting the conversion of heat into mechanical energy, we find ourselves confronted by the second law of thermo-dynamics, which says that whenever a given amount of heat is converted into mechanical effect, another but variable amount descends from a higher to a lower potential, and is thus rendered unavailable.

In the condensing steam-engine this waste heat comprises that communicated to the condensing water, whilst the useful heat, or that converted into mechanical effect, depends upon the difference of temperature between the boiler and condenser. The boiler pressure is limited, however, by considerations of safety and convenience of construction, and the range of working temperature rarely exceeds 120° C. except in the engines constructed by Mr. Perkins, in which a range of 160° C., or an expansive action commencing at 14 atmospheres, has been adopted with considerable promise of success, as appears from an able report on this engine by sir Frederick Bramwell. To obtain more advantageous primary conditions we have to turn to the caloric or gas-engine, because in them the co-efficient of efficiency expressed by $\frac{T-T'}{T}$, may be greatly increased. The value would reach a minimum if the initial absolute temperature T could be raised to that of combustion, and T' reduced to atmospheric temperature, and these maximum limits can be much more nearly approached in the gas-engine worked by a combustible mixture of air and hydrocarbons than in the steam-engine.

Before many years have elapsed we shall find in our factories and on board ships engines with a fuel consumption not exceeding 1 pound of coal per effective horsepower per hour, in which the gas producer takes the place of the somewhat complex and dangerous steam-boiler. The advent of such an engine and of the dynamo-machine must mark a new era of material progress at least equal to that produced by the introduction of steam power in the early part of our century.

When the British Association met at Southampton on a former occasion, Schönbein announced to the world his discovery of gun-cotton. This discovery has led the way to many valuable researches on explosives generally, in which Mr. Abel has taken a leading part.

. . . .

The extraordinary difference of condition, before and after its ignition, of such matter as constitutes an explosive agent, leads up to the consideration of the aggregate state of matter under other circumstances. As early as 1776 Alexander Volta observed that the volume of glass was changed under the influence of electrification, by what he termed electrical pressure. Dr. Kerr, Govi, and others have followed up the same inquiry, which is at present continued chiefly by Dr. George Quincke, of Heidelberg. who finds that temperature, as well as chemical constitution of the dielectric under examination, exercises a determining influence upon the amount and charecter of the change of volume effected by electrification; that the change of volume may under certain circumstances be effected instantaneously as in flint glass, or only slowly as in crown glass, and that the elastic limit of both is dimished by electrification, whereas in the case of mica and of gutta-percha an increase of elasticity takes place.

Still greater strides are being made at the present time towards a clearer perception of the condition of matter when particles are left some liberty to obey individually the forces brought to bear upon them. By the discharge of high tension electricity through tubes containing highly rarified gases (Geissler's tubes), phenomena of discharge were produced which were at once most striking and suggestive. The Spreagel pump afforded a means of pushing the exhaustion to limits which had formerly been scarcely reached by the imagination. At each step the condition of attenuated matter revealed varying properties when acted upon by artificial discharge and magnetic force. The radiometer of Crookes imported a new feature into these inquiries, which at the present time occupy the attention of leading physicists in all countries.

The means usually employed to produce electrical discharge in vacuum tubes was Ruhmkorff's coil; but Mr. Gassiot first succeeded in obtaining the phenomena by means of a galvanic battery of 3000 Leclanché cells. Dr. de la Rue, in conjunction with his friend, Dr. Hugo Müller,, has gone far beyond his predecessors in the production of batteries of high potential. At his lecture "On the Phenomena of Electric Discharge," delivered at the Royal Institution in January, 1881, he employed a battery of his invention consisting of 14,400 cells (14,832 Volts), which gave a current 0·054 Ampère, and produced a discharge at a distance of 0.71 inch between the terminals. During last year he increased the number of cells to 15,000 (15,450 Volts), and increased the current to 0·4 Ampère, or eight times that of the battery he used at the Royal Institution.

On the occasion of his lecture, Dr. de la Rue produced, in a very large vacuum tube, an imitation of the Aurora Borealis; and he has deduced from his experiments that the greatest brilliancy of Aurora displays must be at an altitude of from 37 to 38 miles—a conclusion of the highest interest, and in opposition to the extravagant estimate of 281 miles at which it had been previously put.

The President of the Royal Society has made the phenomena of electrical discharge his study for several years, and resorted in his important experiments to a special source of electric power. In a note addressed to me, Dr. Spottiswoode describes the nature of his investigations much more clearly than I could venture to give them. He says: "It had long been my opinion that the dissymmetry shown in electrical discharges through rarified gases must be an essential element of every disruptive discharge, and that the phenomena of stratification might be regarded as magnified images of features always present, but concealed under ordinary circumstances." It was with a view to the study of this question that the researches by Moulton and myself were undertaken. The method chiefly used consisted in introducing into the circuit intermittence of a particular kind, whereby one luminous discharge was rendered sensitive to the approach of a conductor outside the tube. The application of this method enabled us to produce artificially a variety of phenomena, including that of stratification. We were thus led to a series of conclusions relating to the mechanism of the discharge, among which the following may be mentioned:

"1. That a stria, with its attendant dark space, forms a physical unit of a striated discharge.

2. That the origin of the luminous column is to be sought for at its negative end; that the luminosity is an expression of a demand for negative electricity.

3. That the time occupied by electricity of either name in traversing a tube is greater than that occupied in traversing an equal length of wire, but less than that occupied by molecular streams (Crooke's radiations) in traversing the tubes.

4. That the brilliancy of the light with so little heat may be due in part to brevity in the duration of the discharge.

5. That striæ are not merely loci in which electrical is converted into luminous energy, but are actual aggregations of matter.

This last conclusion was based mainly on experiments made with an induction coil excited in a new way,—viz., directly by an alternating machine, without the intervention of a commutator or condenser. This mode of excitement promises to be one of great importance in spectroscopic work, as well as in the study of the discharge in a magnetic field, partly on account of the simplification which it permits in the construction of induction coils, but mainly on account of the very great increase of strength in the secondary currents to which it gives rise."

These investigations assume additional importance when we view them in connection with solar—I may even say stellar—physics, for evidence is augmenting in favor of the view that interstellar space is not empty, but is filled with highly attenuated matter of such a nature as may be put into our vacuum tubes. Nor can the matter occupying stellar space be said to be any longer beyond our reach for chemical and physical test. The spectroscope has already thrown a flood of light upon the chemical constitution and physical condition of the sun, the stars, the comets, and the far distant nebulæ. which have yielded spectroscopic photographs under the skilful management of Dr. Huggins, and Dr. Draper, of New York. Armed with greatly improved apparatus the physical astronomer has been able to reap a rich harvest of scientific information during the short periods of the last two solar eclipses; that of 1879, visible in America, and that of May last, observed in Egypt by Lockyer, Schuster, and by Continental observers of high standing. The result of this last eclipse expedition has been summed up as follows: "Different temperature levels have been discovered in the solar atmosphere; the constitution of the corona has now the possbility of being determined, and it is proved to shine with its own light. A suspicion has been aroused once more as to the existence of the lunar atmosphere, and the position of an important line has been discovered. Hydrocarbons do not exist close to the sun, but may in space between us and it."

To me personally these reported results possess peculiar interest, for in March last I ventured to bring before the Royal Society a speculation regarding the conservation of solar energy, which was based upon the three following postulates, viz.:—

1. That aqueous vapour and carbon compounds are present in stellar or interplanetary space.

2. That these gaseous compounds are capable of being dissociated by radiant solar energy while in a state of extreme attenuation.

3. That the effect of solar rotation is to draw in dissociated vapors upon the polar surfaces, and to eject them after combustion has taken place back into space equatorially.

It is therefore a matter of peculiar gratification to me that the results of observation here recorded give considerable support to that speculation. The luminous equatorial extensions of the sun which the American observations revealed in such a striking manner (with which I was not acquainted when writing my paper), were absent in Egypt; but the outflowing equatorial streams I suppose to exist could only be rendered visible by reflected sunlight, when mixed with dust produced by exceptional solar disturbances or by electric discharge; and the occasional appearance of such luminous extensions would serve only to disprove the hypothesis entertained by some, that they are divided planetary matter, in which case their appearance should be permanent. Professor Langley, of Pittsburg, has shown by means of his Bolometer, that the solar actinic rays are absorbed chiefly in the solar as in the terrestrial atmosphere, and Captain Abney has found by this new photometric method that absorption due to hydrocarbons takes place somewhere between the solar and the terrestrial atmosphere; in order to test this interesting result still further, he has lately carried his apparatus to the top of the Riffel with the view of diminishing the amount of territorial atmospheric air between it and the sun, and intends to bring a paper on this subject before Section A. Stellar space filled with such matter as hydro-carbon and aqueous vapour would establish a material continuity between the sun and his planets, and between the innumerable solar systems of which the universe is composed. If chemical action and reaction can further be admitted, we may be able to trace certain conditions of thermal dependence and maintenance, in which we may recognise principles of high perfection, applicable also to comparatively humble purposes of humble life.

We shall thus find that in the great workshop of nature there are no lines of demarcation to be drawn between the most exalted speculation and common-place practice, and that all knowledge must lead up to one great result, that of an intelligent recognition of the Creator through His works. So then, we members of the British Association and fellow-workers in every branch of science may exhort one another in the words of the American bard who has so lately departed from amongst us:—

Let us then be up and doing,
With a heart for any fate;
Still achieving, still pursuing,
Learn to labour and to wait.

ON THE PRESENT PHASE OF THE ANTIQUITY OF MAN.

By W. Boyd Dawkins, M.A., F.R.S., F.G.S., F.S.A.

(Address delivered before the Anthropological Section of the British Association for the Advancement of Science at Southampton. August, 1882.)

In taking the chair in this department of the biological section of the British Association, two courses lie open before me. I might give an address which should be a history of the progress of anthropology during the last year, or I might devote myself to some special branch. The swift developement of our young and rapidly growing science, which embraces within its scope all that is known, not merely about man, but about his environment, in present and past times, renders the first and more ambitious course peculiarly difficult to one, like myself, laboring under the pressure of many avocations. I am therefore driven to adopt the second and the easier, by choosing a subject with which I am familiar, and which appears to me to be appropriate in this place of meeting. I propose to place before you the present phase of the inquiry into the antiquity of man, and to point out what we know of the conditions of life—though our knowledge of them is imperfect and fragmentary—under which man has appeared in the Old and in the New Worlds. The rudely chipped implements left by the primeval hunters in the beds of gravel of Hampshire and Wiltshire, and along the shores of Southampton Water and elsewhere, are eloquent witnesses of the presence of man in this district, at a time when there was no Southampton Water, and the elephant and the reindeer wandered over the site of this busy mart of ships; when the Isle of Wight was not an island, and the River-drift hunter could walk across from Portsmouth to Cowes, with no obstacle excepting that offered by the rivers and morasses I propose to enter upon the labors of Prestwich, Evans, Stevens and Blackmore, Codrington, Read, Brown and other investigators in this country, and to combine the results of their inquiries with those in other countries, and with some observations of my own which I was able to make in 1880, during my visit to the United States.

THE LIMITATION OF THE INQUIRY.

The most striking feature in the study of the Tertiary period is the gradual and orderly succession of higher types of Mammalia, so well defined and so orderly, that I have used it as a basis for the classification of the Tertiary period. We find the placental mammals becoming more and more specialised as we approach the frontier of history. The living orders appear in the Eocene, the living genera in the Meiocene, a few living species in the Pleiocene, and the rest in the Pleistocene. The characteristics of this evolution of living forms may be summed up in the following table:—

DEFINITION OF TERTIARY PERIOD BY PLACENTAL LAND MAMMALS.

VI. Historic; in which the events are recorded in history.	Events included in history.	Founded on discoveries, documents, refuse heaps, caves, tombs.
V. Prehistoric; in which domestic animals and cultivated fruits appear.	Man abundant; domestic animals, cultivated fruits, spinning, weaving, pottery - making, mining, commerce; the neolithic, bronze, and iron stages of culture.	Camps, habitations, refuse heaps, surface accumulations, caves alluvia, peat - bogs, submarine forests, raised beaches.
IV. Pleistocene; in which living species of placental mammals are more abundant than the extinct.	Man appears; *Anthropidæ*; the palæolithic hunter; living species abundant.	Refuse heaps, contents of caves, river deposits, submarine forests, boulder clay, moraines, marine sands, and shingle.
III. Pleiocene; in which living species of placental mammals appear.	Living species appear; apes, *Simiadæ*, in Southern Europe.	Fresh-water and marine strata; volcanic débris (Auvergne).
II. Meiocene; in which the alliance between living and placental mammals is more close than before.	Living genera appear; apes, *Simiadæ*, in Europe & North America.	Fresh-water and marine strata; volcanic débris (Auvergne); lignites.
I. Eocene; in which the placental mammals now on earth were represented by allied forms belonging to existing orders and families.	Living orders and families appear; lemurs (*Lemuridæ*) in Europe and North America.	Fresh-water and marine strata; lignites.

The orders, families, genera, and species in the above table, when traced forward in time, fall into shape in a geological tree, with its trunk hidden in the Secondary period, and its branchlets (the living species) passing upwards from the Pleiocene, a tree of life, with living Mammalia for its fruit and foilage. Were the extinct species taken into account, it would be seen that they fill up the intervals separating one living form from another, and that they too grow more and more like the living forms as they approach nearer to the present day. It must be remembered that in the above definitions the fossil marsupials are purposely ignored, because they began their specialisation in the Secondary period, and had arrived in the Eocene at the stage which is marked by the presence of a living genus—the opossum (*Didelphys*).

It will be seen from the examination of the above table, that our inquiry into the antiquity of man is limited to the last four of the divisions. The most specialised of all animals cannot be looked for until the higher Mammalia by which he is now surrounded were alive. We cannot imagine him in the Eocene age, at a time when animal life was not sufficiently differentiated to present us with any living genera of placental mammals. Nor is there any probability of his having appeared on the earth in the Meiocene, because of the absence of the higher placental mammals belonging to living species. It is most unlikely that man should have belonged to a fauna in which no other living species of mammal was present. He belongs to a more advanced stage of evolution than the mid-Meiocene of Thenay, as may be seen by a reference to the preceding table. Up to this time the evolution of the animal kingdom had advanced no further than the Simadæ in the direction of man, and the apes then haunting the forests of Italy, France, and Germany, represent the highest type of those on earth.

We may also look at the question in another point of view. If man were upon the earth in the Meiocene age, it is incredible that he should not have become something else in the long lapse of ages, and during the changes in the conditions of life by which all the Meiocene land Mammalia have been so profoundly affected, that they have been either exterminated, or have assumed new forms. It is impossible to believe that man should have been an exception to the law of change, to which all the higher Mammalia have been subjected since the Meiocene age.

Nor in the succeeding Pleiocene age can we expect to find man upon the earth, because of the very few living species of placental mammals then alive. The evidence brought forward by Professor

Capellinni, in favor of Pleiocene man in Italy, seems both to me and to Dr. Evans unsatisfactory, and that advanced by Professor Whitney in support of the existence of Pleiocene man in North America, cannot in my opinion be maintained. It is not until we arrive at the succeeding stage, or the Pleistocene, when living species of Mammalia begin to abound, that we meet with undisputable traces of the presence of man on the earth.

THE PLEISTOCENE PERIOD.

As a preliminary to our inquiry we must first of all define what is meant by the Pleistocene Period. It is the equivalent of the Quaternary of the French, and the Postpleiocene of the older works of Lyell, and it includes all the phenomena known in latitudes outside the Arctic Circle, where ice no longer is to be found, under the name glacial and inter-glacial. It is characterised in Europe, as I have pointed out in my work on "Early Man in Britain," by the arrival of living species, which may be conveniently divided into five groups, according to their present habitats. The first consists of those now found in the temperate zones of Europe, Asia, and North America. It includes the following animals:—

Mole, musk shrew, common shrew, mouse, beaver, hare, pika, pouched marmot, water-vole, red field-vole, short-tailed field-vole, Continental field-vole, lynx, wild cat, wolf, fox, marten, ermine, stoat, otter, brown bear, grisly bear, badger, horse, bison, urus, saiga antelope, stag, roe, fallow-deer, wild boar.

The second consists of animals of arctic habit:—

Russian vole, Norwegian lemming, arctic lemming, varying hare, musk sheep, reindeer, arctic fox, glutton.

The third is composed of those which enjoy the cold climate of the mountains:—

The Snowy vole, Alpine marmot, chamois, and ibex.

These animals invaded Europe from Asia, and as the cold increased, the temperate group found their way into Southern Europe and Northern Africa, while the arctic division pushed as far south as the Alps and Pyrenees.

The fourth group of invading forms is represented by animals now only found in warm countries:—

Porcupine, lion, panther, African lynx, Caffre cat, spotted hyena, striped hyena, and African elephant.

This group of animals is found as far to the north as Yorkshire, and as far to the west as Ireland. Among the southern animals, too, must be reckoned the hippopotamus, which lived as far north as Britain in the Pleiocene age, and in the Pleistocene occurs in caves and river deposits, in intimate association with some arctic species, such as the reindeer.

The fifth group is composed of extinct species, hitherto unknown in Europe in the Pleistocene age, such as:—

The straight-tusked elephant, mammoth, the pigmy elephants, wooly and small-nose rhinoceroses, the Irish elk, pigmy hippopotamus, and the cave bear.

The question as to which of these groups the River-drift man belongs must be deferred till we can take a survey of the evidence elsewhere.

The early Pleistocene division is characterised by the presence of the temperate and southern species in Britain; the middle stage by the presence of the arctic, but not in full force; and the late Pleistocene by the abundance of arctic animals, not only in Britain, but on the Continent as far as the Alps and Pyrenees, and the lower valley of the Danube.

THE EARLY PLEISTOCENE FOREST AND MAMMALS OF EAST ANGLIA.

The first view which we get of the Pleistocene Mammalia in this country is offered by the accumulations associated with the buried forest of East Anglia. It extends for more than forty miles along the shores of Norfolk and Suffolk, from Cromer to Kessingland, passing into the cliff on the one hand and beneath the sea on the other. The forest was mainly composed of sombre Scotch firs and dark clustering yews, relieved in the summer by the lighter tinted foliage of the spruce and the oak, and in the winter by the silvery gleam of the birches, that clustered thickly with the alders in the marches, and stood out from a dense undergrowth of aloes and hazels. Among the animals living in this forest of the North Sea were species which haunted the valleys of the upper Seine at the time, such as the southern elephant, the Etruscan rhinoceros, the deer of the Carnutes, extinct horses, and the large extinct beaver. There were in addition to the shaggy-mained mammoth, the straight-tusked elephant, and the big-nosed rhinoceros. The stag, the roe, the Irish elk, were in the glades, Sedgwick's deer, with its many pointed antlers, the verticorn deer, and the gigantic urus. The undergrowth formed a covert for the wild boar, and for beasts of prey, many in species and formidable in numbers, the cave bear, the hugest of its kind, the sabre-tooth lion, the wolf, the fox, and the wolverine. Among the smaller animals were to be noted the musk shrew, the common shrew, and a vole. In the trees were squirrels. Under foot the moles raised their hillocks of earth, and from between the lofty fronds of the Osmund royal beavers were to be seen building their lodges, and the hippopotamus as he emerged from the water and disappeared in the forest. Out of thirty species identified, no less than seventeen are living in some part of the world, and we have there obviously the stage in the evolution of mammalian life when the living species were becoming more abundant than the extinct. We may note, too, the absence of arctic animals in this fauna, more particularly of the reindeer.

The presence of these animals in Norfolk and Suffolk implies that at this time Britain was united to the Continent, and the presence of fossil species found in France indicate a southern extension of land in the direction of the Straits of Dover. The forest covered a large portion of the area of the North Sea, and in all probability the Atlantic seaboard was then at the 100-fathom line of the west coast of Ireland.

No traces of man have as yet been discovered in these deposits, although the large percentage of living species of higher Mammalia indicates that the geological clock had struck the hour when he may be looked for.

THE APPEARANCE OF THE RIVER-DRIFT HUNTER AT CRAYFORD AND ERITH.

The living species in the forest bed are to be looked upon as an advanced guard of a great migration of Asiatic and African species, finding their way into North-western Europe, over the plains of Russia, and over barriers of land connecting Northern Africa with Spain by way of Gibraltar, and with Italy by way of Malta and Sicily (see "Cave Hunting and Early Man").

In the course of time the other living species followed, and extinct species become more rare. In the deposits, for instance, of the ancient Thames, at Illford and Grays Thurrock in Essex, and at Erith and Crayford in Kent, out of twenty-six species, six only belong to extinct forms—the new comers comprising the lion, wild cat, spotted hyena, and otter, the bison and the musk sheep. A flint flake discovered by the Rev. Osmund Fisher, at Crayford, and a second discovered by Messrs. Cheadle and Woodward, at Erith, prove that man was present in the valley of the Thames at this time; while the more recent discoveries of Mr. Flaxman Spurrell indicate the very spots where the palæolithic hunter made his implements, and prove that he used implements of the River-drift type, so widely distributed over the surface of the earth. The arctic animals at this time were present, but not in full force, in Southern Britain, and the innumerable reindeer which characterise the later deposits of the Pleistocene age had not, so far as we know, taken possession of the valley of the Thames.

To what stage in the Pleistocene period are we to refer these traces of the River-drift hunter? The only answer which I am able to give is that the associated animals are intermediate between the Forest-bed group and that which characterises the late Pleistocene division in the region extending from the Alps and the Pyrenees as far north as Yorkshire. Nor am I able to form an opinion about their relation to the submergence of Middle or Northern Britain under the waves of the glacial sea. They are quite as likely to be pre- as post- glacial.

THE RELATIONS OF THE RIVER-DRIFT HUNTER OF THE LATE PLEISTOCENE TO THE GLACIAL SUBMERGENCE.

The rudely chipped implements of the River-drift hunter lie scattered through the late Pleistocene river deposits in Southern and Eastern England in enormous abundance, and as a rule in association with the remains of animals of arctic and of warm habit, as well as some or other of the extinct species of reindeer and hippopotamus, along with mammoth and wooly rhinoceros. What is their relation to the submergence of the land and the lowness of the temperature, which combined together have resulted in the local phenomena known as glacial and interglacial?

The geographical change in Northern Europe at the close of the Forest-bed age was very great. The forest of the North Sea sank beneath the waves, and Britain was depressed to a depth of no less than 2,300 feet in the Welsh mountains, and was reduced to an archipelago of islands, composed of what are now the higher lands. The area of the English Channel also was depressed, and the "silver streak" was somewhat wider than it is now, as is proved by the raised beach at Brighton, at Bracklesham, and elsewhere, which marks the sea line of the largest island of the archipelago, the southern island as it may be termed, the northern shores of which extended along a line passing from Bristol to London. The northern shore of the Continent at this time extended eastward from Abbeville north of the Erzgebirge, through Saxony and Poland, into the middle of Russia, Scandinavia being an island from which the glaciers descended into the sea.

This geographical change was accompanied by a corresponding change in climate. Glaciers descended from the higher mountains to the sea level, and icebergs, melting as they passed southwards, deposited their burdens of clay, sand, and erratics, which occupy such a wide area in the portion then submerged of Britain and the Continent.

This depression was followed by a re-elevation, by which the British Isles, again formed a part of the Continent, and all the large tract of country within the 100-fathom line again became the feeding-grounds of the Pleistocene Mammalia.

An appeal to the animals associated with the River-drift implements will not help us to fix the exact relation of man to these changes, because they were in Britain before as well as after the submergence and were living throughout in those parts of Europe which were not submerged. It can only be done in areas where the submergence is clearly defined. At Salisbury, for instance, the River-drift hunter may have lived either before, during or after the southern counties became an island. When, however, he hunted the woolly and leptorhine rhinoceros, the mammoth, and the horse in the neighborhood of Brighton, he looked down upon a broad expanse of sea, in the spring flecked with small icebergs, such as those which dropped their burdens in Bracklesham Bay. At Abbeville, too, he hunted the mammoth, reindeer, and horse down to the mouth of the Somme on the shore of the glacial sea.

The evidence is equally clear that the River-drift hunter followed the chase in Britain after it had emerged from beneath the waters of the glacial sea, from the fact that the river deposits in which his implements occur either rest upon the glacial clays, or are composed of fragments derived from them, as in the oft-quoted cases of Hoxne and Bedford. Further, it is very probable that he may have wandered close up to the edge of the glaciers then covering the higher hills of Wales and the Pennine chain.

The severity of the climate in winter at this time in Britain is proved, not merely by the presence of the arctic animals, but by the numerous ice-born blocks in the river gravels dropped in the spring after the break-up of the frosts.

THE RANGE OF THE RIVER-DRIFT MAN ON THE CONTINENT AND IN THE MEDITERRANEAN AREA.

The River-drift man is proved, by the implements which he left behind, to have wandered over the whole of France, and to have hunted the same animals in the valleys of the Loire and the Garonne as in the valley of the Thames. In the Iberian peninsula he was a contemporary of the African elephant, the mammoth, and the straight-tusked elephant, and he occupied the neighborhood of both Madrid and Lisbon. He also ranged over Italy, leaving traces of his presence in the Abruzzo, and in Greece he was a contemporary of the extinct pigmy hippopotamus (*H. Pentlandi*). South of the Mediterranean his implements have been met with in Oran, and near Kolea in Algeria, and in Egypt in several localities. At Luxor they have been discovered by General Pitt-Rivers in the breccia, out of which are hewn the tombs of the kings. In Palestine they have been obtained by the Abbé Richard between Mount Tabor and the sea of Tiberias, and by Mr. Stopes between Jerusalem and Bethlehem. Throughout this wide area the implements, for the most part of flint or of quartzite, are of the same rude types, and there is no difference to be noted between the *haches* found in the cave of Cresswell in Derbyshire, and those of Thebes, or between those of the valley of the Somme and those of Palestine. Nor is our survey yet ended.

THE RIVER-DRIFT MAN IN INDIA.

The researches of Foote, King, Medlicott, Hacket, and Ball, establish the fact that the River-drift hunter ranged over the Indian peninsula from Madras as far north as the ualley of the Nerbudda. Here we find him forming part of a fauna in which there are species now living in India, such as the Indian rhinoceros and the arnee, and extinct types of oxen and elephants. There were two extinct hippopotami in the rivers, and living gavials, turtles, and tortoises. It is plain, therefore, that at this time the fauna of India stood in the same relation to the present fauna as the European fauna of the late Pleistocene does to that now living in Europe. In both there was a similar association of extinct and living forms, from both the genus *Hippopotamus* has disappeared in the lapse of time, and in both man forms the central figure.

THE RIVER-DRIFT HUNTER IN NORTH AMERICA.

We are led from the banks of tropical India to the banks of the Delaware in New Jersey by the recent discoveries of Dr. C. C. Abbott in the neighborhood of Trenton. After a study of his collection in the Peabody Museum in Cambridge, Mass., I have had the opportunity of examining all the specimens found up to that time, and of visiting the locality in company with Dr. Abbott and Professors Haynes and Lewis. The implements are of the same type as those of the river gravels of Europe, and occur under exactly the same conditions as those of France and Britain. They are found in a plateau of river gravel forming a terrace overlooking the river, and composed of materials washed down from the old terminal moraine which strikes across the State of New Jersey to the westward. The large blocks of stone and the general character of the gravel point out that during the time of its accumulation there were ice-rafts floating down the Delaware in the spring, as in the Thames, the Seine, and the Somme. According to Professor Lewis it was formed during the time when the glacier of the Deleware was retreating ("late glacial"), or at a later period ("post-glacial"). The physical evidence is clear that it belongs to the same age as deposits with similar remains in Britain. The animal remains also point to the same conclusion. A tusk of mastodon is in Dr. Cooke's collection at Brunswick, New Jersey, obtained from the gravel, and Dr. Abbott records the tooth of a reindeer and the bones of a bison from Trenton. Here, too, living and extinct species are found side by side.

Thus in our survey of the group of animals surrounding man when he first appeared in Europe, India, and North America, we see that in all three regions, so widely removed from each other, the animal life was in the same stage of evolution, and "the old order" was yielding "place unto the new." The River-drift man is proved by his surroundings to belong to the Pleistocene age in all three.

The evidence of Palæolithic man in South Africa seems to me unsatisfactory, because as yet the age of the deposits in which the implements are found has not been decided.

GENERAL CONCLUSIONS.

It remains now for us to sum up the results of this inquiry, in which we have been led very far afield. The identity of the implements of the River-drift hunter proves that he was in the same rude state of civilisation, if it can be called civilisation, in the Old and New Worlds, when the hands of the geological clock pointed to the same hour. It is not a little strange that his mode of life should have been the same in the forests to the north as south of the Mediterranean, in Palestine, in the tropical forests of India, and on the western shores of the Atlantic. The hunter of the reindeer in the valley of the Deleware was to all intents and purposes the same sort of savage as the hunter of the reindeer on the banks of the Wiley or of the Solent. It does not, however, follow that this identity of implements implies that the same race of men were spread over this vast tract. It points rather to a primeval condition of savagery from which mankind has emerged in the long ages which separate it from our own time.

It may further be inferred, from his wide-spread range that the River-drift man (assuming that mankind sprang from one centre) must have inhabited the earth for a long time, and that his dispersal took place before the glacial submergence and the lowering of the temperature in Northern Europe, Asia, and America. It is not reasonable to suppose that the Straits of Behring would have offered a free passage, either to the River-drift man from Asia to America, or to American animals from America to Europe, or *vice versâ*, while there was a vast barrier of ice or of sea, or of both, in the high northern latitudes.

I therefore feel inclined to view the River-drift hunter as having invaded Europe in pre-glacial times along with the other living species which then appeared. The evidence, as I have already pointed out, is conclusive that he was also glacial and post-glacial.

In all probability the birth-place of man was in a warm if not a tropical region of Asia, in "a garden of Eden," and from this the River-drift man found his way into these regions where his implements occur. In India he was a member of a tropical fauna, and his distribution in Europe and along the shores of the Mediterranean prove him to have belonged either to the temperate or the southern fauna in those regions.

It will naturally be asked, to what race can the River-drift man be referred? The question, in my opinion, cannot be answered in the present stage of the inquiry, because the few fragments of human bones discovered along with the implements are too imperfect to afford a clue. Nor can we measure the interval in terms of years which separates the River-drift man from the present day, either by assuming that the glacial period was due to astronomical causes, and then proceeding to calculate the time necessary for them to produce their result, or by an appeal to the erosion of valleys or the retrocession of waterfalls. The interval must, however, have been very great to allow of the changes in geography and climate, and the distribution of animals which has taken place—the succession of races, and the development of civilisation before history began. Standing before the rock-hewn tombs of the kings of Luxor, we may realise the impossibility of fixing the time when the River-drift hunter lived on the site of ancient Thebes, or of measuring the lapse of time between his days and the splendor of the civilisation of Egypt.

In this inquiry, which is all too long, I fear, for my audience and all too short, I know, for my subject, I have purposely omitted all reference to the successor of the River-drift man in Europe—the Cave man, who was in a higher stage of the hunter civilisation. In the course of my remarks you will have seen that the story told by the rudely chipped implements found at our very doors in this place, forms a part of the wider story of the first appearance of man, and of his distribution on the earth—a story which is to my mind not unfitting as an introduction to the work of the Anthropological Section of this meeting of the British Association.

THE SUCCESSIVE PALÆOZOIC FLORAS OF CANADA.

By J. W. Dawson, LLD., F.R.S.

Read before the American Association for the Advancement of Science at its Montreal meeting, August 1882.

In eastern Canada, and more especially in the Maritime Provinces, we are so fortunate as to possess very complete and well developed representatives of the Carboniferous and Erian or Devonian systems, and more especially of their shallow-water and estuarine formations. We thus have a nearly continuous series of fossil plants extending all the way from the Silurian to the Permian, and embracing seven sub-floras, as they may be termed, all more or less distinguishable from each other.

In a report recently prepared by request of the Director of the Geological Survey of Canada, and soon to be published, I have endeavored to characterize these several sub-floras so as to render them useful to practical geologists; and in the present paper I propose to illustrate them in such a manner as to direct the attention of members of the Geological section of the Association to the succession observed, and to the use which may be made of it, whether for theoretical or practical purposes.

I shall begin, for convenience, with the newer, and proceed to the older formations.

1. CARBONIFEROUS FLORA.

(1.) *Permo-Carboniferous Sub-flora* :—

This occurs in the upper member of the carboniferous system of Nova Scotia and Prince Edward Island, originally named by the writer the Newer Coal Formation, and more recently the Permo-Carboniferous; and the Upper beds of which may not improbably be contemporaneous with the Lower Permian or Lower Dyas of Europe. In this formation there is a predominance of red sandstones and shales, and it contains no productive beds of coal. Its fossil plants are for the most part of species found in the Middle or Productive Coal-formation, but are less numerous, and there are a few new forms akin to those of the European Permian. The most characteristic species of the upper portion of the formation, which has the most decidedly Permian aspect, are the following:—

Dadoxylon materiarium, Dawson.
* *Walchia (Araucarites) robusta*, *Dn.*
* *W. (A.) gracilis*, Dn.
Calamites Suckovii, Brongt.
C. Cistii, Brongt.
* *C. Gigas*, Brongt.
Neuropteris rarinervis, Bunbury.
Alethopteris nervosa, Brongt.
Pecopteris arborescens, Brongt.
* *P. rigida*, Dn.
P. oreopteroides, Brongt.
* *Cordaites simplex*, Dn.

Of these species those marked with an asterisk have not yet been found in the Middle or Lower members of the Carboniferous system. They will be found described and several of them figured in my Report on the Geology of Prince Edward Island. The others are common and widely diffused Carboniferous species, some of which have extended to the Permian period in Europe as well. From the Upper beds characterized by these and a few other species, there is a gradual passage downward into the productive-Coal measures, and a gradually increasing number of true Coal-formation species.

It is worthy of remark here that the association in the Permo-Carboniferous of numerous trunks of *Dadoxylon* with leafy branches of *Walchia* and with fruits of the character of *Trigonocarpa*, seems to show that these were parts of one and the same plant.

(2.) *Coal-Formation Sub-flora* :—

The Middle or Productive Coal-formation, containing all the beds of coal which are mined in Nova Scotia and Cape Breton, is the head-quarters of the Carboniferous flora. From this formation I have catalogued* 135 species of plants; but as several of these are founded on imperfect specimens, the number of actual species may be estimated at 120. Of these more than one half are species common to Europe and America. No less than nineteen species are *Sigillariæ*, and about the same number are

* Acadian Geology, and Report on Flora of Lower Carboniferous 1873

Lepidodendra. About fifty are Ferns and thirteen are *Calamites*, *Asterophyllites* and *Sphenophylla*. The great abundance and number of species of *Sigillariæ*, *Lepidodendra* and ferns are characteristic of this sub-flora; and among the ferns certain species of *Neuropteris*, *Pecopteris*, *Alethopteris* and *Sphenopteris*, greatly preponderate.

(3.) *The Millstone Grit Sub-flora:—*

In this formation the abundance of plants and the number of species are greatly diminished. Trunks of Coniferous trees of the species *Dadoxylon Acadianum*, having wide wood-cells with three or more series of discs and complex medullary rays, become characteristic. *Calamites undulatum* is abundant and seems to replace *C. Suckovii*, though *C. cannæformis* and *C. Cistii* continue. *Sigillariæ* become very rare, and the species of *Lepidodendron* are few, and mostly those with large leaf-bases. *Lepidofloyos* still continues and *Cordaites* abounds in some beds. The ferns are greatly reduced, though a few characteristic Coal-formation species occur, and the genus *Cardiopteris* appears. Beds of coal are rare in this formation; but where they occur there is in connection with them a remarkable anticipation of the Coal-formation flora, which would thus seem to have existed locally in the Millstone Grit period, but to have found itself limited by generally unfavorable conditions. In America, as in Europe, it is in the North that this earlier development of the Coal Flora occurs, while in the South there is a lingering of the older forms in the newer beds.

(4.) *The Lower Carboniferous Sub-flora:—*

This group of plants is best seen in the Shales of the Horton series, under the Lower Carboniferous marine limestones. It is small and peculiar. The most characteristic species are the following:—

Dadoxylon (*Palæoxylon*), *antiquius*, Dn.—A species with large medullary rays of three or more series of cells.

Lepidodendron corrugatum, Dn.—A species closely allied to *L. Veltheimianum* of Europe, and which is its American representative. This is perhaps the most characteristic plant of the formation, and presents very protean appearances, in its old stems, branches, twigs and *Knorria* forms. It had well characterized stigmaria roots, and constitutes the oldest erect forest known in Nova Scotia.

Lepidodendron tetragonum, Sternberg.
L. obovatum, Sternb.
L. aculeatum, Sternb.
L. dichotomum, Sternb.
These species are comparatively rare, and the specimens are too imperfect to render their identification certain.

Cyclopteris (*Aneimites*) *Acadica*, Dn.—A very characteristic fern, allied in the form of its fronds to *C. tenuifolia* of Goeppert, to *C. nana*, of Eichwald, and to *Adiantites antiquus* of Stur. Its fructification, however, is nearer that of *Aneimia* than to that of *Adiantum*.

Ferns of the genera *Cardiopteris* and *Hymenophyllites* also occur, though rarely.

Ptilophyton plumula, Dn.—This is the latest appearance of this Erian genus, which also occurs in the Lower Carboniferous of Europe and of the United States.

Cordaites borassifolia, Brongt.

On the whole, this small flora is markedly distinct from that of the Millstone Grit and true Coal formation, from which it is separated by the great length of time required for the deposition of the marine limestones and their associated beds, in which no land plants have been found; nor is this gap filled up by the conglomerates and coarse arenaceous beds which, as I have explained in Acadian Geology, in some localities, take the place of the limestones.

In my Report on the Plants of the Millstone Grit and Lower Carboniferous, I have referred at length to their relation to the foreign beds of similar age, and which are known to geologists by a number of local names.

2. ERIAN FLORA.

(1.) *Upper Erian Sub-flora:*—

This corresponds to the Catskill and Chemung of the New York series, and to the Upper Devonian of Europe.

The flora of this formation, which consists mostly of sandstones, is not rich. Its most distinctive species on both sides of the Atlantic seem to be the ferns of the genus *Archaeopteris*, along with species referred to the genus *Cyclopteris*, but which, in so far as their barren fronds are concerned, for the most part resemble *Archaeopteris*.

The representative species *Archaeopteris Jacksoni*, *A. Rogersi* and *A. Gaspiensis*, are described in the Report above referred to, as well as *Cyclopteris obtusa* and *C. Brownii*, both very characteristic species.

Leptophleum rhombicum and fragments of *Psilophyton* are also found in the Upper Erian. There is evidence of the existence of extensive forests probably of Lycopodiaceous trees in this period, in the deposits of spore-cases (*Sporangites Huronensis*) in the shales of Kettle Point, Lake Huron; and Prof. Orton, of Columbus, Ohio, informs me that extensive deposits of similar character exist in that State, though with accompaniments which suggest doubt as to the origin above stated.

The Upper Erian Flora is thus very distinct from that of the Lower Carboniferous, and the unconformable relation of the beds may perhaps indicate a considerable lapse of time. Still, even in countries where there appears to be a transition from the Carboniferous into the Devonian, the characteristic flora of each formation may be distinguished.

(2.) *Middle Erian Sub-flora.*

Both in Canada and the United States that part of the great Erian System which may be regarded as its middle division, the Hamilton and Marcellus Shales of New York, the Cordaites Shales of St. John, New Brunswick, and the Middle Shales and Sandstones of the Gaspé series, presents conditions more favor able to the abundant growth of land plants than either the Upper or Lower member. In the St. John beds in particular, there is a rich fern flora, comparable with that of the Coal formation. It is, however, distinguished by a prevalence of small and delicate species, and by such forms as *Hymenophyllites* and the smaller Sphenopterids, and also by some peculiar ferns, as *Archaeopteris* and *Megalopteris*. In addition to ferns, it has small *Lepidodendra*, of which *L. Gaspianum* is the chief. *Calamites* occur, *C. radiatus* being the dominant species. This plant, which in Europe, appears to reach up into the Lower Carboniferous, is so far strictly Erian in America. *Sigillariæ* scarcely appear, but *Cordaites* is abundant, and the earliest known species of *Dadoxylon* appear, while the *Psilophyton* so characteristic of the Lower Erian, still continues, and the remarkable aquatic plants of the genus *Ptilophyton* are locally abundant. A tabular view of this flora will be found in Part I. of my Report.

(3.) *Lower Erian Sub-flora.*

This belongs to the Lower Devonian Sandstones and Shales, and is best seen in that formation at Gaspé and the Bay des Chaleurs. It is characterised by the absence of true ferns, *Calamites* and *Sigillariæ*, and by the presence of such forms as *Psilophyton*, *Arthrostigma*, *Leptophleum* and *Prototaxites*. *Lepidodendron Gaspianum* and *Leptophleum* already occur, though not nearly so abundant as *Psilophyton*.

The Lower Erian plants have an antique and generalised aspect which would lead us to infer that they are near the begining of the land flora, and practically few indications of land plants have been found earlier within the limits of Canada.

(3.) THE SILURIAN FLORA AND STILL EARLIER INDICATIONS OF PLANTS.

In the Upper beds of the Silurian, those of the Helderberg series, we still find *Psilophyton* and *Prototaxites;* but below these we have no land plants. In the United States, Lesquereux and Claypole have described remains which may indicate the existence of Lycopodiaceous and Annularian types as far back as the beginning of the Upper Silurian, and Hicks has found *Prototaxites* and *Psilophyton* in beds as old in Wales, along with some uncertain stems named *Berwynia*. In the Lower Silurian the *Protannularia* of the Skiddaw series in England, may represent a land plant, but this is uncertain, and no similar species has been found in Canada.

Specimens of the so-called *Eopteris* found in rocks equivalent to the Hudson river series in France, convince me that this is nothing but an aggregation of tabular crystals of pyrite, which would seem, however, to have formed around thread-like stems perhaps belonging to Algae, or perhaps of the nature of scolithoid burrows.

The Cambrian rocks are so far barren of land plants; the so-called *Eophyton* being evidently nothing but markings, probably produced by crustaceans and other aquatic animals. In the still older Laurentian, the abundant beds of graphite probably indicate the existence of plants, but whether aquatic or terrestrial it is impossible to decide at present. I have discussed this subject in a paper on the Laurentian Graphite in the Journal of the Geological Society of London (1870).

It would thus appear that in so far as Canada is concerned, our certain knowledge of Land Vegetation begins with the Upper Silurian, and that its earliest forms were Acrogens allied to Lycopods and prototypal gymnosperms, forerunners of the conifers. In the Lower Devonian little advance is made. In the Middle Devonian this meagre flora had been replaced by one rivalling that of the Carboniferous, and including Pines, Tree-ferns, and arboreal forms of Lycopods and of Equisetaceous plants, as well as numerous herbaceous plants. At the close of the Erian the flora again became meagre, and continued so in the Lower Carboniferous. It again became rich and varied in the Middle Carboniferous, to decay in the succeeding Permian.

In the Mesozoic a new flora appears; and in Western Canada we have, in the Middle Cretaceous, forests of Angiospermous Exogens comparable with those of modern times and including many modern genera. In Eastern Canada we have no known representative of the floras which intervened between the Permian and Pleistocene.

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

The thirty-first meeting of this Association was held at Montreal under the presidency of Principal J. W. Dawson, of McGill College, from August 23rd to 30th inclusive. The meeting was called to order at 10 A.M. on the 23rd, by the retiring president, Prof. Geo. J. Brush, who called upon the president elect to occupy the chair.

Addresses of welcome were delivered by the Mayor of the city on behalf of the citizens, and by Dr. Sterry Hunt, Chairman or the Local Committee. The President replied to these addresses. The work of organising the Sections of the Association was then proceeded with, and at one o'clock the Association sat down to a sumptous lunch, tendered by the Local Committee.

On the evening of the opening day the the address of the retiring president was delivered to a large audience in the Queen's Hall, the subject being the "Progress of American Mineralogy." Following this address came a reception of the members of the Association by the Local Committee in the Assembly Rooms of the same building.

On Thursday the special work of the various Sections was opened by addresses from the several vice-presidents, and continued from day to day until all the papers accepted had been read. On Thursday, 24th inst., Principal Dawson tendered the Association a reception in the new Peter Redpath Museum, which was then formally opened. During a portion of the evening an address on Caves and Cave Scenery was given in the Lecture Theatre of the Museum, by Rev. H. C. Horey. Saturday, the 26th August, was devoted to excursions to Quebec and Ottawa, in one or other of which nearly all the members present took part. On Tuesday evening Dr. W. B. Carpenter, of London, lectured in the Queen's Hall on the "Temperatures of the Deep Sea." The Association adjourned on Wednesday, 30th August, to meet in Minneapolis, Minn., in August, 1883.

During the Session of the Association numerous receptions were tendered the members by prominent citizens of Montreal, and besides the larger excursions noted, smaller ones to the Lachine Rapids and the Victoria Bridge and Grand Trunk Railway Shops were provided for the unoccupied hours. A final excursion to Lake Memphremagog was tendered the Association on Thursday, August 31st, by the South Eastern Railway, and was enjoyed by many of the members who remained to the end.

The Montreal meeting was, with one exception, the largest which has ever been held, the total number of names registered being 937. One of the prominent features of this meeting was the presence of several distinguished European scientists, such as Dr. Samuel Haughton of Dublin, M. Rudolph Koënig of Paris, Dr. J. H. Gilbert, well known in connection with investigations in Agricultural Chemistry; Prof. J. Szabo of Buda-Pesth; Dr. John Rae, celebrated as an Arctic Explorer; Prof. D. W. Kowalevsky of Moscow; Dr. W. B. Carpenter of London. We append a list of the papers read in the Chemical, Geological and Geographical, Biological, Histological and Microscopical, and Anthropological Sections.

CHEMISTRY.

Thomas W. Tobin: On the causes which render flour and organic dust explosive, with suggestions for the prevention of such explosions.

Leonard P. Kennicutt: Action of water at 100° C. on the B-phenyltribrompropionic acid.

Albert R. Leeds: Preliminary notice of a new organic base.

H. Carrington Bolton: Application of organic acids to the examination of minerals: Note on the absorption spectrum of humic acid.

C. F. Mabery and Ralph Wilson: The action of basic hydrate on chlortribrompropionic acids: On certain substituted acrylic and propionic acids.

Chas. W. Dabney, Jr.: Notes on effects of different soils upon soluble phosphates; Some derivatives of isopicraminic acid; A benzoyl anhydro acid from B-metamidosalicylic.

C. F. Mabery: On the products of the distillation of wood at low temperatures.

C. C. Caldwell: Pemberton's Method for the volumetric determination of phosphoric acid.

Harvey W. Wiley and C. A. Crompton: Estimation of dextrine in solid commercial starch sugar by loss of rotatory power on solution.

Arthur H. Elliott and Fred. Sands: Notes on Bone Oil.

R. B. Warder: Observations on the contamination of City Wells.

Ernest H. Cook: Carbon dioxide in the Atmosphere; A simple laboratory appliance.

Arthur H. Elliott: On Nitro-saccharose.

Paper from several Agricultural Chemists on the estimation of reverted phosphoric acid.

Harvey W. Wiley: Direct estimation of dextrose, dextrine and maltose in commercial amylose (sugar starch).

J. B. Lawes and J. H. Gilbert: Determinations of nitrogen in the soils of some of the experimental fields at Rothamsted, and the bearing of the results on the question of the sources of the nitrogen of our crops.

J. Szabo: On a new micro-chemical method of determining the feldspars in rocks.

J. Kitsee: Fire-damp indicator.

C. G. Wheeler and F. Menzel: Transmission of gases through liquids of different densities.

Henry Carmichael: The solution and late crystallization of gold heated with chlorohydric acid in a sealed tube.

William Dudley: Remarks on the application of the Iridium knife-edge to analytical balances.

Wm H. Ellis: Some Tea analyses.

L. W. Andrews: On the constitution of Benzole.

GEOLOGY AND GEOGRAPHY.

James Hall: On the relations of Dictyophyton, Phragmodictyum and similar forms with Uphantænia; Note upon the genus Plumulites.

Edward Orton: A Source of the bituminous matter in the Ohio Black Shale (Huron Shale of Newberry); Suggestions as to the History of the Lower Coal-measures of Ohio.

Richard Owen: Contribution to Seismology.

WILLIAM BROSS: The Topography and Geology of the Great Salt Lake valley.

CHARLES WHITTLESEY: Pre-glacial channel of Eagle River, Lake Superior.

J. F. WHITEAVES: Recent Discoveries of Fossil Fishes in the Devonian Rocks of Canada; Note on the occurrence of Siphonotreta Scotica in the Utica formation near Ottawa, Ont.

T. STERRY HUNT: The Eozoic Rocks of Central and Southern Europe; The Serpentines of Italy.

JOHN RAE: Arctic Explorations in North America.

WM. B. DWIGHT: Recent investigations and palæontological discoveries in the Wappinger limestone of Dutchess and neighboring counties, New York.

SAMUEL LOCKWOOD: A Mastodon Americanus in a Beaver dam near Freehold, N. J.

ROBERT B. WARDER: Silicified stumps of South Park, Col.

J. W. DAWSON: Palæozoic Floras of Eastern North America and more especially of Canada.

J. R. BARTLETT: Deep-sea soundings and temperatures in the Gulf Stream off the Atlantic Coast, taken under the direction of the U. S. Coast Survey.

JOS. W. SPENCER: Terraces and Beaches about Lake Ontario; Occurrence of Graptolites in the Niagara Formation of Canada.

GEO. H. COOK: On the Change of relative level of the ocean and uplands on the Eastern coast of North America.

M. L. BRITTON: On a Post-Tertiary Deposit containing impressions of leaves in Cumberland County, N. J.

W. O. CROSBY: On the classification and origin of Joint Structure.

G. H. PERKINS: On the Winooski Marble of Vermont, with exhibition of specimens.

ALEXIS A. JULIEN: The Comparative stratigraphy of the crystalline rocks of North Carolina and Canada: The Genesis of the crystalline iron ores of North Carolina and Northern Michigan; The Dunyte beds of North Carolina; The Felsyte-tufa of Colorado.

H. F. WALLING: The origin of joint cracks.

H. CARVIL LEWIS: The great terminal moraine across Pennsylvania.

E. W. CLAYPOLE: Note on the exterior markings of bark of Lepidodendron Chemungense; On Amphicœlia Cedarvillensis from the Niagara group of Cedarville, Ohio; Note on the Fauna of the Catskill Red Sandstone.

CHAS. A. GRAHAM: A Rocking Stone in New York city.

W. HAMILTON MERRITT: Occurrence of Magnetic ore deposits in Victoria County, Ontario.

HENRY S. WILLIAMS: The Undulations of the rock-masses across Central New York State.

D. W. KOWALEVSKY: Freshwater lignitic series of the beds in the Cretaceous formation of France.

JOHN C. SMOCK: On the surface limit of the thickness of the Continental glacier in New Jersey and adjacent States, with notes on glacial phenomena in the Catskills.

C. H. HITCHCOCK: The Glacial flood of the Connecticut River Valley

J. S. NEWBERRY: Some mooted points in American Geology; Genesis of North American Flora.

J. BEAUFORT HURLBURT: Currents of air and ocean in connection with climate; Regions of summer rains and summer droughts.

HORACE C. HOVEY: Subterranean Map-making, with new maps of Mammoth and Luray Caves.

RICHARD OWEN: Law of fracture or fissuring, applied to Inorganic and Organic matter.

F. COPE WHITEHOUSE: The Caves of Staffa and their relation to the ancient civilization of Iona.

R. B. HARE: On the association of crystals of Quartz and Calcite in parallel position.

BIOLOGY.

THOMAS MEEHAN: The Fertilization of Yucca.

WILLIAM OSLER: Demonstrations of a series of Brains prepared by Giacomi's method.

ROBT. E. C. STEARNS: Description of a new species of Alcyonoid Polyp.

W. H. EDWARDS: On the Polymorphism of Lycæna pseudargiolus

E. W. CLAYPOLE: Note on the Sterility of the Canada Thistle at Yellow Springs, Ohio; Insects *versus* Flowers in the matter of fertilization; Note on the occurrence of traces of a Northern Flora in Southwestern Ohio.

WM. SAUNDERS: On the Mouth of the larva of Chrysopa.

MRS. A. B. BLACKWELL: Cross heredity from sex to sex.

ASA GRAY: Some remarks on tne Flora of North America.

HENRY F. OSBORN: Achænodon from the Bridger Eocene beds.

HENRY O. MARCY: The Placental development in Mammals.

W. S. BEAL: The motion of roots and radicles of Indian Corn and beans.

C. V. RILEY: Observations on the fertilization of Yucca, and on structural and anatomical peculiarities in Pronuba and Prodoxus; The Hibernation of Aletia xylina in the U. S., a settled fact; Emulsions of petroleum and their value as insecticides.

W. K. BROOKS: A sketch of the History of our knowledge of the budding of Salpa: Fritz Miller and the Nauplius of Decapods.

T. WESLEY MILLS: Examination of some controverted points of the physiology of voice.

G. MACLOSKIE: Achenial hairs and fibres of Compositæ; Observations on the Elm-leaf Beetle (Galeruca xanthomelana).

WM. H. SEAMAN: Blastesis tridens; a pear-tree fungus.

J. F. WHITEAVES: On a recent species of Heteropora from the Strait of Juan de Fuca.

W. A. BUCKHOUT: On the Gall Mites.

J. A. LINTNER: A new Sexual character in the pupæ of some Lepidoptera; On an Egg parasite of the currant saw-fly, Nematus ventricosus.

CLARENCE J. BLAKE: On the position of the Gamopetalæ; Progressive growth of Dermoid coat of the Membrana tympani.

FRANK BAKER: The Morphology of arteries.

ALBERT S. BICKMORE: The Jessup collection to illustrate American Forestry in the Museum of Natural History, Central Park, New York.

LESTER F. WARD: The Organic Compounds in their relations to life; Classification of organisms.

BURT G. WILDER: On the habits of Cryptobranchus.

C. E. BESSEY: Some observations on the action of frost upon leaf-cells.

EDWARD D. COPE: The Fauna of the Puerco Eocene; The primary divisions of the Ungulata.

WYLLIS A. SILLIMAN: Remarks on the Turbellaria.

JOS. F. JAMES: Monograph of the Clematidæ of the United States.

SERENO WATSON: Notes on the Flora of the Rocky Mountains.

HISTOLOGY AND MICROSCOPY.

WM. B. CARPENTER: On angular aperture in relation to biological investigation.

W. OSLER: Demonstration of the Bacillus of Tuberculosis; The third Corpuscular element in the Blood; The development of Blood Corpuscles in the bone-marrow; Note on the Microcytes of the blood, and their probable origin.

LOUIS ELSBERG Plant-"cells" and living matter.

HENRY O. MARCY: Histology of uterine fibroid tumors. Illustrated by micro-photographs.

T. J. BURRILL: Some Vegetable poisons.

W. A. ROGERS: A Study of the problem of fine rulings with reference to the limit of naked eye visibility of microscopic resolution; On a new form of dry mounting.

THOMAS TAYLOR: The House Fly considered in connection with the distribution of infections and contagious poisons; A new economic freezing Microtome for section-cutting, with new mechanical devices.

A. H. TUTTLE: On the epidermis of Marsipobranchs.

D. P. PENHALLOW: Notes on some of the pecularities incident to the diseases of fruit.

ROMEYN HITCHCOCK: Notes on the present status of sanitary inspection, with special reference to the examination of water and air.

C. E. HANMAN: A filtering wash-bottle adapted to the use of the Histologist.

J. H. PILLSBURY: Development of Cilia in the planula of Clara leptostyla.

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OTIS T. MASON: A Scheme of Anthropology.

CHARLES WHITTLESEY: The Cross and the Crucifix.

G. H. PERKINS: Notice of a collection of Sioux weapons and articles of dress: Recent Archæological discoveries in Vermont.

J. McNAB CURRIER: Stone Implements from Bomoseen and Castleton Valleys.

CHARLES RAU: A Stone Grave in Illinois.

ALBERT S. GATSCHET: Chief deities in American religions.

MRS. ERMINNIE A. SMITH: Beliefs and Superstitions of Iroquois Indians; A few deductions from a dictionary of the Tuscarora dialect.

J. OWEN DORSEY: On the comparative phonology of four Siouan languages; The kinship system and marriage laws of the Dhegiha.

P. R. HOY: Who made the native copper implements? Who built the mounds?

F. W. PUTNAM: On copper implements and ornaments from North America; Discovery of a log-building belonging to the stone-grave period in Tennessee; Account of three mounds explored in Ohio and Tennessee; The contents of eighty-four stone graves at Brentwood, Tenn.

HORATIO HALE: Indian migrations, as evidenced by language.

J. W. PHENE: On some hitherto unnoted affinities between ancient customs in America and on the other continents.

R. G. HALIBURTON: Atlas and the Atlantes.

H. N. RUST: A "find" of chipped stone articles on the Pacific coast and exhibition of the specimens; Remarks upon the Davenport tablet.

WILLIS DEHASS: Monumental and art remains in the Lake regions of Ohio, Pennsylvania and New York; Mountain antiquities; Geological testimony to the antiquity of man in America; Archæological exploration, progress of discovery.

A. E. DOUGLAS: A find of ceremonial weapons in Florida.

MISS ALICE C. FLETCHER: Home Life among some of the Indian tribes; Religious ceremonials of some of the Dakotan Family of Indians.

MISS VIRGINIA K. BOWERS: The bleaching of the Aryans.

WM. H. HINGSTON: Influence of Climate of Canada on Europeans.

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