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THE CANADIAN INSTITUTE.

Presidential Address. By B. E. Walker, Esq., F.G.S.

(Read 12th November, 1898.)

The scientific student, or even the mere student of science, a quite different thing, by the way, should be one who seeks truth for its own sake, indifferent to the effect it may have on his preconceptions. If we turn to the last century, we find those who were interested in the physical history of the earth readily adopting the speculations of such men as Buffon and Werner, and so captivated by their plausible theories, based on little observation, that men like Guettard and Demarest, industrious observers who gathered facts before they ventured to theorize, were utterly disregarded, although their methods and conclusions were purely scientific in spirit and have helped to build the body of real truth which was so lamentably retarded by their brilliant contemporaries. Practically the spirit of original research and of open-mindedness in accepting the results of the researches of others, is of modern origin, and such liberty of observation and thought is even yet looked upon by some as a dangerous use of our faculties. There are still those who regard the modern spirit of enquiry as an attack upon whatever old foundations may seem to constitute orthodoxy in either religion or science. But this modern spirit of scientific study covers much beside the observation of truths connected merely with the physical and natural world around us. It covers practically all knowledge which may be systematized. It is that state of mind toward all phenomena which, if we were perfectly free from bias, would not permit us to vary any conclusion warranted by the facts, in favour of our preconceived ideas or beliefs. Of course very few, if any, can entirely escape the baneful effect of preconceptions, and it is to be feared that men of science are sometimes as dogmatic and prejudiced as others. Too many follow a quest in science which may not be truth, perhaps a quest of material gain, or of mere intellectual enlargement, by adding to the facts which sustain a theory already held. The scientific student should rise above all other considerations to the moral altitude of mere truth for its own sake. If it is a truth which he is unable to square with other truths, he should be willing that it should remain a disturbing anomaly until time shall have solved it. Let us, however, descend from these high levels into the so-called practical affairs of life.

There are those who question the importance of any new fact in the natural or physical world unless the material good to flow from it to man is apparent. What is the use of studying plants, or insects, or other inedible animals, or fossils? What is the use of Crookes's tube, they would have said a few years ago? And there are those of higher intelligence who although willing to admit the value of studies bearing on the origin of life, on evolution or some recognized philosophy, still question the wisdom of spending long years in the discovery of facts which have no clear connection with other established items of knowledge. Many among the so-called practical men of the world realize the value of the entomologist who can do something to check the ravages of insects injurious to vegetation, the botanist who understands problems of forestry, or who with the added knowledge of the chemist knows the food or the medicinal value of plants, the geologist who happens to discover a coal or a gold mine, the biologist who actually saves human life by his knowledge of bacteria, or who by his knowledge of their habits shows how the fish supply of the world may be increased. But they do not always understand that the scientific discoverers who are thus able to do some direct good to man would not in all probability have attained such knowledge had they attacked the unknown fields of science in any other spirit than that which recognizes that all newly discovered items of fact are infinitely valuable, whether we can at the moment put them to any direct use or not.

No one is wise enough to recognize the full value of a newly-discovered fact. One new fact may seem to have nothing to recommend it, except its anomalous character. Another may seem of enormous importance. But some later discovery may change all this, disclosing the value of the apparently anomalous fact and diminishing the value of that which seemed the most important. Our duty is to treasure every new truth or fact discovered, no matter how unimportant it may appear. We can readily understand that what seems now of trifling value may be intimately connected with the working out of some problem in which man is deeply interested.

This may seem an unnecessarily elaborate manner in which to draw your attention to the claims of palæontology, the subject in which I hope to interest you to-night. In its early history it was peculiarly a study in which patience was necessary in recording facts which seemed to have little more than mere stratigraphical value to the discoverers. And even now that it may claim to be a body of systematized knowledge, its value is certainly underestimated in this centre of colleges and universities.

The simplest manner in which to judge of the value of any particular branch of science, such as palæontology, is doubtless to consider its interdependence with other branches of science. In the ultimate analysis, of course, all science is interdependent, but I refer to that interdependence which at once occurs to the student who desires to be a specialist. The entomologist soon finds that he must know something of botany, the botanist that he must know something of entomology. Both soon learn, also, that without some knowledge of geology, if only of soils and altitudes, they cannot proceed very far.

Let us, then, first consider the value of palæontology to the student who is trying to work out the physical history of the globe. In the record of fossils he finds almost his only sure guide. If he tries to work backward through the crust of the earth, beginning with the most recent conditions on the surface, he finds that there is but one satisfactory guide proving the regular succession of the different strata of rocks, and this is palæontology. If he concludes that the stratigraphical arrangement of the sedimentary rocks is for practical purposes the most satisfactory measure of time, he must also conclude that without the palæontological record there could be no system of stratigraphy, and that where the stratigraphic sequence is broken there is little beside the correlation of the fauna in the two unconformable strata from which to measure the time represented by the break in the sequence. It may be well to recount very briefly how our present knowledge of stratigraphy has been gained and the extent to which this knowledge is due to palæontology. The first attempt to systematize the rocks comprising the crust of the earth was made by the Freiburg professor of mineralogy, Werner.(1)

(1) Many of the references to individual geologists have been taken from Sir Archibald Geikie's "Founders of Geology."

He advanced the theory that the globe was once completely enveloped in water—that is, that the water was high enough to cover the highest mountain. From and in this water the rocks forming the basis of everything were chemically precipitated. These, according to Werner, included granite, gneiss, mica-slate, clay-slate, serpentine, basalt, porphyry and syenite.* He even asserted at first that the chemical deposition was made in the order in which the rocks are here arranged. These were his Primitive rocks, and they were followed by what he termed Transition rocks, some of which were of chemical deposition and some sedimentary. Then came the so-called Floetz rocks, partly chemical, but in the main sedimentary. It became necessary, however, to recognize the existence of volcanoes, and he taught an eager, listening world that volcanoes were the result of the burning up of seams of coal and other inflammable sediments; and that volcanic action was one of the most recent of physical forces at work in the earth. If ever there was an instance of the value of collecting facts, no matter how apparently dissociated from each other, until a system could be built which would defy attack, we have it in the Neptunist geology of Werner. He could not wait for facts, but theorized most brilliantly on the basis alone of what could be gathered in the mining district in which he lived. He contended that basalt was not volcanic, and satisfied most people, after a violent controversy, that it was not, and that obsidian and pumice were chemically deposited in water, while at the same time in France the patient, tireless investigator, Demarest, who refused to theorize, had laid before a world quite deaf to facts, the truth, as now recognized, regarding basalt and the real basis of what we know regarding volcanoes.

It is true that the great founder of accurate geology, Hutton, did not upset the theories of Werner and others by the aid of fossils, but he established forever the value of ascertained facts, of real evidence as opposed to theory. He laid down the great principle in geology, that we must judge of the action of the earth in the past by the action we see around us in the present. The doctrine of Uniformity in its extreme form is, of course, disputed by many,[1] but the main principle as here stated is generally accepted. Hutton thus settled, in many cases for all time, the manner in which the sedimentary rocks were created, setting aside the absurd notion of Werner's ocean depositing, chemically and by sediments, layers on the sloping sides of mountains covered to their tops by the sea. Hutton not only understood correctly the forces creating rocks but the destructive forces of erosion and the creation of watersheds and river systems.

But although both Werner and Hutton knew that the various rocks were created in succession and that in this succession there was an order which it was desirable to understand, other men laid the real foundations of palæontology in its relation to stratigraphy. As early as 1779 the Abbé Giraud-Soulavie, in France, set forth in a paper a stratigraphical description of a district in France in which the different strata were arranged by him in relation to their fossil contents, and in which he demonstrated that in the older rocks the fossils had no similar living species, while in some of the later rocks a percentage of the fossils were identical, or nearly related to living species. Little attention, however, was paid to these important truths, and his systematic arrangement of the rocks in question is not now recognized. The Abbé was followed by two great Frenchmen whom the world was obliged to regard. Cuvier and Brongniart were biologists who realized that they could not disregard the biological relations of fossils to living forms. Indeed, we owe it to Cuvier that palæontology is accorded its place in the study of biology, while Brongniart, in his zoology of the Trilobites, thus early demonstrated to what extent even an extinct tribe of crustaceans may be systematized and accorded their place in the order of natural history. But at the moment we

(1) Lord Kelvin "Popular Lectures and Addresses," vol. ii., page 6. Prestwich's Geology, 1886, vol. i., page 2.

are concerned only regarding their contributions to stratigraphy. Working together, these two great men thoroughly studied the geology and palæontology of the Paris basin, and established the systematic arrangement of the Tertiary or Kainozoic formations so firmly that although many new minor divisions have been added, few alterations have been made, and the main features of the present classification are as they arranged them. They distinctly state that they based their classification and division of the rocks upon the fact that at the same horizon in a series of rocks, even when examined in widely separated places, they found that the groups of fossils were generally alike. Their conclusions, which in the complete form reached the public in 1808, were followed in 1813 by the results of the labours of another Frenchman, D'Omalius d'Halloy, who worked out with true stratigraphical principles the Secondary or Mesozoic rocks of France.

Turning now to the development of stratigraphy in England, as early as 1760 the Rev. John Michell had stated most intelligently the principles of the stratification of rocks, but he contributed nothing towards the nomenclature of a system. English stratigraphy practically began with the well-known William Smith. He was born in the same year with Cuvier, and outlived him seven years, but, instead of the splendidly endowed biologist, we have only a land surveyor, imperfectly educated. He drew up as early as 1799, although he did not publish it beyond distributing copies by hand among a few scientific friends, a card of the English strata, with a tabular list of formations from the Coal up to the Chalk, giving the thickness of the several members, lists of the fossils peculiar to each, and the lithological changes. In 1815 he published a geological map covering all England, of which all subsequent maps are practically but an elaboration, and he established the Jurassic system as permanently in England, besides much of our knowledge of the Secondary rocks, as Cuvier and Brongniart did the Tertiary in France. The geology of the Secondary or Mesozoic rocks in England as known to-day is filled with the names of formations given by Smith, and we owe to him the first sufficient arrangement of the Primary or Palæozoic and the Secondary or Mesozoic rocks from the Old Red Sandstone to the Chalk. So that he and the Frenchmen referred to cleared up on palæontological grounds the entire stratigraphy from the Old Red Sandstone to the present time.

Practically nothing was known in 1831 of the stratigraphy of the rocks below the Old Red Sandstone, and I have only now to refer to the splendid work of Murchison and Sedgwick in establishing as the result of investigation in England, Wales, Scotland, the Alps and elsewhere, the Cambrian, Silurian and Devonian systems; and of the subsequent investigations, still being pursued, to work out the pre-Cambrian rocks, the foundation efforts in which are now by common consent accredited to our own great geologist, Sir William Logan, whose portrait hangs upon our walls as the first President of this Institute. Sir Archibald Geikie, on whom I have drawn most liberally for personal facts regarding the early geologists, says:—(1) "The determination of the value of fossils as chronological documents, has done more than any other discovery to change the character and accelerate the progress of geological inquiry."

The geographical discoverer is unsatisfied as long as there is a shore line not marked upon the map of the world, and naturally the geologist is unsatisfied as long as there is a section in his geological column the nature of which he has not determined. We have shown how the geological column from the top or present time back to the base of the Cambrian has been determined satisfactorily by the aid of palæontology, and we have suggested the value of such a complete record to the student trying to work out the physical history of the globe. But the geological column extends below the Cambrian to the Archæan, representing a period of time regarding the measure of which the geologist, the biologist, and

(1) Sir Archibald Geikie, "The Founders of Geology," page 242.

the physicist are in most thorough disagreement. Are there no more fossils below the base of the Cambrian to illumine this dark period? In the Lower Cambrian of North America, according to Mr. Wolcott, one of the leading authorities on the Cambrian time, there are as many as 160 species, and these cover all classes of marine invertebrates. Clearly, then, in the Lower Cambrian we are not near the beginning of life on this planet, and surely we are not near the earliest preserved remnants of life.

The rocks in North America which are older than the Cambrian are divided by Dr. Dawson(1) in descending order, as follows:—

1. Keweenawan.
2. Animikie.

Here throughout a great part of North America, there occurs a profound unconformity.

3. Huronian.
4. Upper Laurentian or Grenville Series.
5. Lower Laurentian or Fundamental Gi... ..

It is evident that if fossils are found in any of these groups the Palæozoic division must be extended downward to include such groups and the Archæan division be that much diminished. A problem, then, of enormous importance awaits solution by the geologist. How much further down than the recognized Lower Cambrian will he be able to carry the record of fossil forms? In the present state of our knowledge we find vast areas of these older rocks which seem to be sedimentary, but which appear to contain no fossils, vast areas regarding which we are not sure whether they were sedimentary or not, and again vast areas which we believe we have proved never to have been sedimentary. About this confused period floods of argument have been written and many hypotheses advanced, but what we want are fossils. Fortunately we have a few, although they do not help us very materially. Mr. G. F. Matthew, who constitutes our main authority in Canada on the subject, considered palæontologically, has established as pre-Cambrian, but Palæozoic, beds in New Brunswick and Newfoundland which he calls Etcheminian,(2) and which Sir William Dawson thinks to be equivalent to the Keweenawan.(3) They contain "but a meagre fauna, mostly animals of a low type of structure, as Protozoans, Brachiopods, Echinoderms, and Molluscs," with worm-burrows and trails. Mr. Walcott, in a memoir on the Lower Cambrian,(4) writes as follows:—

"The section laid bare in the Grand Cañon of the Colorado, beneath the great unconformity at the base of the known Cambrian, shows 12,000 feet of unaltered sandstones, shales, and limestones, that, I think, were deposited in pre-Cambrian time and should be referred to the Algonkian (Keweenawan). The entire section of pre-Cambrian strata is unbroken, and the sandstones, shales, and limestones are much like those of the Ordovician section of New York. In a bed of dark argillaceous shale, 3,500 feet from the summit of the section, I found a small Patelloid or Discinoid shell, a fragment of what appears to be the pleural lobe of a segment of a trilobite, and an obscure, small Hyolithes, in a layer of bituminous limestone. In layers of limestone, still lower in the section, an obscure Stromatoporoid form occurs in abundance. These fossils indicate a fauna, but do not tell us what it is." In the same memoir, in a note at the foot of page 552, Mr. Walcott mentions the discovery of Salterella and fragments of a trilobite, 500 feet below a series of beds in Vermont which are 700 feet thick, of conformably bedded lime-

(1) G. M. Dawson. Presidential Address, Geological Section, B.A.A.S., 1897.

(2) G. F. Matthew. The Protolenus Fauna, Trans. N.Y. Acad. Science, vol. xiv., page 105, 1895.

(3) Sir W. Dawson. Note on Cryptozoon and other Ancient Fossils, Can. Record Science, vol. vii., page 203, Oct. 1896.

(4) C. D. Walcott. The Fauna of the Lower Cambrian, etc. U.S. Gov't Surv. Annual Report, page 550, 1888-9.

stone, and lie beneath the Olenellus Zone (the so-called base of the Cambrian). In the pre-Cambrian rocks of Wales and elsewhere fossils have been found, but not of a more satisfactory character than those already mentioned. I do not here discuss the so-called fossils of the Huronian and Laurentian, because until the vast beds of the Keweenawan and Animikie are cleared up it is hardly worth while to enter upon a mere controversy as to whether certain forms are fossils or not.

The subject is complicated by the many breaks or unconformities in Cambrian and pre-Cambrian times. In the extended areas of ancient rocks in North America there are sections where the Lower or some younger portion of the Cambrian rests directly upon Archæan or other pre-Cambrian rocks, and there are places where the section is conformable from the Cambrian series downward for many thousands of feet into the Keweenawan. Therefore, considering the many widely separated sections in North America, if at any point downward we were able to say we had reached the stage where in North America the Palæozoic rocks ended, it would seem at first sight as if we might conclude that the fossil remains found at this base, represented the beginning at least or organisms having hard parts. But presuming that the labours of Matthew, Walcott, and others eventually carry the Palæozoic record through the Keweenawan, down to the lowest of the beds of the Animikie, which "except when of volcanic origin," resemble "in their aspect the older Palæozoic sediments," we are then met, at least in the areas which Dr. Dawson has so happily called the "continental Protaxis of the North," with a gap in the record which he describes in the address from which I have already quoted, as "the vast lapse of time, constituting probably one of the most important breaks in geological history, by which the Cambrian and its allied rocks are separated from those of the Huronian and Laurentian systems." Regarding this break, Dr. Dawson says: "It would be difficult to deny that the time thus occupied may not have been equal in duration to that represented by the whole of the Palæozoic."

In the scattered and unsatisfactory fragments referred to above it cannot be said that we have found a fauna essentially different from the Cambrian, but somewhere—it may be in North America, in the Salt Range of India, in the Torridon sandstones of Scotland which are pre-Cambrian and said to be 10,000 feet in thickness, in Bohemia or Wales—we will doubtless be able to carry the history of the highly-developed trilobites and other organisms of the Cambrian at least further back towards their origin. This is the undiscovered shoreline in geology. In quest of it the Nansens of geology will travel as long as the limits of discovery are unsolved. We must not, however, forget that animals without hard parts leave no, or nearly no, record, and that the progenitors of many animals with hard parts had themselves no hard parts. In this connection Professor Marr,(1) after discussing the peculiarities of a well-known Cambrian trilobite, says: "If this be so, the entire outer covering of the trilobites, at a period not very remote from the end of pre-Cambrian times, may have been membranous, and the same thing may have occurred with the structures analogous to the hard parts of organisms of other groups. Indeed, with our present views as to development, we can scarcely suppose that organisms acquired hard parts at a very early period of their existence, and fauna after fauna may have occupied the globe, and disappeared, leaving no trace of its existence."

I have thus far been considering the value of fossils in demonstrating the position and relative age of the different strata of the earth's crust. It is not necessary for such purposes that the fauna of one stratum should bear any likeness to that of an immediately older or younger stratum. Indeed, to some extent,

(1) J. E. Marr. Presidential Address, Geological Section, B.A.A.S., 1896.

the less alike the better for mere purposes of distinguishing strata. It was, therefore, not unnatural that the early geologists, believing, as they did, that each particular animal or plant was a special effort of creation, should fail to recognize the value of biology in connection with the study of fossil remains. Indeed, when Cuvier and Brongniart, and, later, Deshayes and Lyell, undertook to correlate the organisms in the later rocks with living organisms—to point out where they were identical, where they were related but not identical, and where there seemed little relation—there were not wanting those who doubted the value of biology in the study of geology, and who persisted in estimating the value of fossils merely as guides in the stratigraphical arrangement of the rocks. Comparatively few fossils had been gathered, specific differences were often not recognized, the doctrine of evolution had not been advanced, and as I have already said, any particular fossil might be regarded as an organism whose history had no relation to anything but itself. The change which has come about in fifty or sixty years would be incredible were the record not clearly before us. I am not able to state even approximately the number of species now known, but a few detached facts will sufficiently illustrate the scope of modern palæontology. Prestwich estimated the species found in Great Britain in the Palæozoic rocks at 5,697, in the Mesozoic rocks at 7,546, and in the Kainozoic, including the Quaternary, at 4,013. That is, altogether, at 17,256 species, in the British Isles. This, as we know, is but a trifling part of the earth's area, although it is that which has been most thoroughly examined. Barrande estimated the Silurian species alone of Europe and America at 10,674, to which, of course, many have been added since the calculation was made. Every year great numbers of new forms are described and new territory is put under examination. No one would be so foolish as to attempt to guess the number of species which will eventually be recorded in science. If one will turn from the meagre text-books of the first half of this century to Zittel's[1] five large volumes, in which the first effort is made at a complete classification of all branches of palæontology, he will realize that the natural history of fossil animals is scarcely less perfect in its system of classification, or in its range of information, than the natural history of living animals. But it will be urged that after all we have only the hard parts of animals preserved. The soft parts are gone, and, worse still, the animals which had no hard parts have left almost no trace at all. This is quite true, and at first sight it seems an inestimable loss to the student of evolution. How will he ever fill the gaps in his record if only the bones have been preserved for him?

In the case of fossil animals having apparently no living analogues, had there been no theory of evolution there would doubtless have been no great desire to ascertain the nature of the soft parts, and thus to establish them in their proper places in the systems of natural history. And certainly in many cases, where the analogy is now clear, without this interest on the part of the biologist it would not have been suspected. But if in some class of fossil animals there are still a few living analogues, it is wonderful to what a degree the generic relations can be worked out and a system, satisfactory even to the biologist, be created, which shall include all the known extinct and living forms, even when the fossil species outnumber the living by a hundred to one. Allow me to illustrate this point by reference to the work done in connection with one of the most, if not the most, ancient order of shells, the brachiopoda. About 1884 Dr. Thomas Davidson, after thirty years of labour on the subject, finished the first great work on brachiopods[2] It fills five quarto volumes and is illustrated by 250 plates. What is perhaps more striking is the fact that the bibliography which completes the work, consists of 160 quarto pages, containing the titles of over 2,500 publications dealing with brachio-

(1) Karl von Zittel. Handbuch der Palæontologie, 5 vols., 1876-1893.

(2) T. Davidson. British Fossil Brachiopoda, vol. i.-vi., Publications of Palæontographical Society, 1850-1885.

pods. The brachiopod is a bivalve, but with valves of unequal size. In the overwhelming majority of cases in the fossil form the valves are found united, and, as the valves are filled either with sediment or with crystallized matter, the interior is rarely visible. This involved a greater difficulty than that of merely ascertaining the marks of the attachments of the organs on the inner sides of the shells. The brachiopods have supports for the soft parts, the so-called arms, in the shape of loops or spirals, or other processes, and while in modern brachiopods these are not calcareous, in fossil forms they were. These spiral and other processes were occasionally but rarely exposed and separated valves showing the muscular markings were also found, but naturally the first attempts at systematizing the brachiopods were largely based on mere external characters. During the progress of Dr. Davidson's labours, however, the Rev. Norman Glass, assisted him materially. By the exercise of great ingenuity and delicate workmanship he removed the shells and exposed the delicate brachial supports referred to, in the case of many species, so that a greatly improved system was the result. It is but right to say that others were working upon the brachiopods in the same direction, notably Mr. Whitfield, of the American Museum of Natural History, New York. The number of known fossil species has, however, kept on increasing at a surprising rate, and we have also added largely to the known living forms. Dr. Davidson's work was, therefore, soon followed by important contributions from D. P. Oehlert, in 1887,[1] and by Professor Zittel in his Hand-book, already referred to. It was still maintained that we possessed no treatise in which "facts in regard to structure, function, habits, and distribution of these animals, the distinguishing characters and systematic relations of their genera," are included in one work. This Professor Hall and his co-workers have sought to do in the "Introduction to the Study of the Brachiopoda" and in the eighth volume of the Palæontology of New York. Here we can readily follow their history from the very minute and rudimentary brachiopods in the Lower Cambrian through their enormous development in the Palæozoic both in numbers of individuals and in variety of form and size, continuing in lessened though still great numbers through the Mesozoic, and gradually lessening until the present age, of which Professor Hall records only 147 species, many of which are mere varietal forms. Whether we consider the shapes of the valves as they have been influenced by the soft parts which are now gone, the microscopic structure of the shells, the systems of defence by spines, imitative surface markings or otherwise, the infinitely varied and very beautiful processes for supporting the arms, the muscular scars, the complicated nature of the hinge, the foramen, the evidence as to fixity of habit or the reverse, or any other feature which may leave its morphological evidence on the fossil; or the softer parts which may be seen in living forms and by the aid of which both the structure and habits of the fossil organisms may at least to some extent be understood, we must admit that the history of the Brachiopoda, as gathered from the study of both fossil and living forms has produced a result infinitely more satisfactory to the biologist and the geologist than could have been possible by the study of the fossil forms alone by the old-fashioned geologist and of the living forms alone by the old-fashioned biologist. And he would be a foolish man who undertook to say whether the fossil or the living forms had most aided in the final result. Both are absolutely necessary.

In almost any other branch of fossil remains quite as valuable evidence of the growth of palæontology on its biological side might be adduced. In the Protozoans, George Jennings Hinde by his microscopic work is carrying the evidence of the existence of Radiolarian remains farther and farther back in the Palæozoic rocks, and Messrs. W. D. and G. F. Matthew have found Globigerinidae in phos

(1) Paul Fischer. Manuel de Conchyliologie, Paris, 1887, with an appendix on the Brachipods by D. P. Oehlert.

phatic nodules in the Cambrian rocks of New Brunswick.(1) In the Sponges Mr. Hinde has done splendid work,(2) while Dr. Hermann Rauff has been some years labouring upon a systematic arrangement of all the known fossil forms;(3) Professor H. A. Nicholson has made the first attempt at systematizing our knowledge of those difficult Hydrozoans, the Stromatoporoids,(4) and Professor Lapworth and several other investigators are doing similar work upon the almost equally difficult Hydrozoans known as Graptolites. In the Actinozoans a vast quantity of work has been done on fossil corals since the epoch-making volumes of Milne-Edwards and Jules Haime, but the great work of revision has not been undertaken as yet. In the Echinoderms, the camerate crinoids have been revised in a most elaborate manner by Messrs. Wachsmuth and Springer,(5) and work of perhaps a higher character is now being done by Mr. F. A. Bather,(6) of the British Museum. In the Crustaceans there have been monumental works such as Barrande's, but such important discoveries as those of Beecher and others in demonstrating the morphology of the underside of the trilobites, so long practically unknown, and the wealth of forms and knowledge of embryology and zonal conditions made known by the researches of Walcott and G. F. Matthew in the Cambrian will make a general revision necessary sooner or later. In the Molluscoids, in addition to the Brachiopods, a great deal has been done by Professor H. A. Nicholson,(7) E. O. Ulrich,(8) G. B. Simpson,(9) and others, in the Palæozoic Polyzoans or Bryozoans, both towards increasing our knowledge of forms and in systematizing our knowledge, although there is not enough agreement as yet for the comfort of the ordinary student. In the Molluscs good work is being done in every direction, notably in this country, in Mesozoic forms, by Mr. Whiteaves, of our Survey, but the time has perhaps not come for a general revision of any of the classes unless it may be the Cephalopoda. These have, throughout the history of palæontology, attracted great attention, but perhaps the work of Hyatt and of Zittel, based on palæo-biological lines, has been the most important from our own point of view. However, so many men of ability have devoted themselves to the Jurassic ammonites alone, that one is afraid to venture upon an opinion as to the probability of general agreement in a scheme of classification. In connection with vertebrate palæontology, it is not necessary to speak, as the names of Cuvier, Agassiz, Owen, and Cope, among those who have passed away, are well known to you all, and many distinguished workers remain who will continue to fill the gaps, making the vertebrate record more and more complete as the years roll by.

If I had time I should like to discuss the value of that kind of palæontological study, as it is now being carried on by certain investigators, in which regard is had to the stratigraphical relations of certain fossils on the one hand, and their biological relations on the other, in order to demonstrate their evolution. In the Quarterly Journal of the Geological Society of London,(10) for August last, Mr. S. S. Buckman has divided the entire Jurassic system into minute zones, each zone

(1) G. F. Mathew. The Protolenus Fauna, Trans. N.Y. Acad. Science, vol. xiv., page 109, 1895.

(2) G. J. Hinde. British Fossil Sponges. Publication of Palæontographical Society, 1886-1893.

(3) H. Rauff. Palæospongiologie, Memoir in Palæontographica, edited by Prof. K. A. von Zittel, Stuggart, 1893.

(4) H. A. Nicholson. British Stromatoporoids. Publications of Palæontographical Society, 1885-1892.

(5) Watchsmuth and Springer. North American Criniodea Camerata, Memoir, Mus. Comp. Zool., Harvard, 1897.

(6) F. A. Bather. As an example of Mr. Bather's Palæontological work, see Petalocrinus, Q.J.G.S., vol. lv., pages 401-441.

(7) H. A. Nicholson. The Genus Monticulipora, Blackwood, Edinburg, 1881.

(8) E. O. Ulrich. Geological Surv. Illinois, vol. 8, 1890. Geological Surv. Minnesota, vol. 3, 1895.

(9) G. B. Simpson. Different Genera of Fenestellidæ, 13th Annual Report N.Y. State Geologists, 1894. Hand-book, N. A. Palæozoic Bryozoa, 48th Annual Report, N.Y.S. Mus. and 14th Annual Report N.Y.S. Geologist, 1895.

(10) On the grouping of some divisions of so-called "Jurassic" Time, S. S. Buckman, Q.J.G.S., vol. liv., pages 442-462, August 1898.

based upon a species of ammonite; and by the use of these zones in determining the precise age of one species relatively to another, he has been able to produce the genealogical tree of the Jurassic ammonites in a manner which should be satisfactory to the evolutionist. Doubtless this attempt to divide up the geological formations into zones named from apparently dominant species and to work out with this aid the phylogeny of families or orders may be carried too far. Clearly, however, by being able to divide the formations on biological grounds, so as to establish with reasonable precision the relative moment when a particular species arrived and flourished, and by being able to study young and mature individuals of the species so as to work out its embryology, great progress is being made in the history of the development of species through the medium of fossils.

I feel that I owe the members of the Institute an apology for the character of my address. My business duties preclude the possibility of engaging in original investigation even if I possessed ability of that kind. I have, therefore, merely sought by an address of a popular character to engage your attention regarding a branch of study which has been a source of deep interest to myself for many years.

THE PREHISTORIC MONUMENTS OF BRITTANY. BY PROFESSOR A. B. MACALLUM.

(Read 3rd December, 1898.)

(Abstract.)

The menhirs, dolmens, and tumuli of Brittany, though much discussed, still offer problems for solution which are of importance in determining features of the Neolithic and Bronze periods. The age of these monuments also is undecided, for Fergusson[1] believes that they are all post-Roman, while others claim for them an anterior origin. The difficulty in this matter is due to the fact that the remains were not, until the close of the last century, thought worthy of reference by writers who must have seen them. Cæsar, who was in the neighbourhood of Carnac when the sea fight between his galleys and those of the Veneti took place in the Gulf of Morbihan, makes, in his description of that battle, no reference to the thousand menhirs, which, if they were there then, he must have seen also at the time. On this ground Fergusson regards them as of later date, but one cannot depend very much on such a line of argument, for Madame de Sevigné visited Auray and the Carnac region in 1689, and although she wrote copiously about everything that apparently came under her observation then, she makes no reference to the existence of these monuments. Are we, therefore, to conclude that they were erected in the eighteenth century? On the other hand, the site of a Roman camp has been discovered in the area covered by the menhirs of Kermario, in the neighbourhood of Carnac, and some of the menhirs were used in the construction of the wall, while others inside the enclosure are blackeneed with soot, probably due to the legionaries using them as hearthstones. This clearly indicates an Ante-Roman date for the foundation of these monuments. In regard to the age of the dolmens of Brittany, the character of the skulls found in them is decisive—while the skull of the tribesman of Brittany in Cæsar's time was brachycephalic, that of the dolmen-builders was sub-dolicocephalic, or mesaticephalic. From this it is concluded that the dolmen builders were a race which preceded the Celts in Western France. How far back in time dolmens were first erected it is impossible to say, but it must be recognized that in North Germany, in Norway and Sweden, and in Ireland dolmens were erected in the Christian era.

In regard to the significance of the menhirs, nothing as yet has been definitely determined. Remains of human skeletons, accompanied in some cases by flint implements, have been found at the foot of some of them, and hence it is inferred that they are the equivalents of our burial headstones. This explanation must appear doubtful to anyone who has examined the "alignements" of Carnac. Here very few human remains have been found in connection with them, although there are thousands in the district. The view that the "alignements" were connected with sun-worship or with herpetolatry, postulates first of all an explanation of the function of the isolated menhirs in other parts of France and in Great Britain. Sun-worship undoubtedly obtained amongst ancient British and Gallic tribes, but the founders of the menhirs have yet to be shown to be of Celtic or Belgic affinities. There is very little evidence to show that serpent-worship obtained amongst these

(1) Rude Stone Monuments, 1872, chapter 8.

or amongst the earlier inhabitants of France. In the tumulus on the island called Gavr'innis, in the Gulf of Morbihan, the local guide points out to visitors a sinuous line which is believed to represent the serpent, but anyone who examines closely the rich sculpturing about it will see at once that the artist had no preconceived plan, and that the sinuous line, being made last, is the unforeseen, haphazard result.

It is difficult to believe that the "alignements" were not connected with some religious observances or creed. The extraordinary size of some of the menhirs forming them, and particularly of the fallen and broken one near the Dol des Marchands, is such as to force one to question whether any influence, save religious, could have compelled the founders to undertake the gigantic toil of their erection. Undoubtedly they must have been regarded as sacred objects, and this leads one to understand why they were used in some cases for human burial. Their use, therefere, as burial monuments may have been secondary. We have an instance of such secondary use in the case of cathedrals and churches of to-day. The existence of stone circles or cromlechs, like the one which terminates the alignements at Menec, would further seem to strengthen the view that all these monuments were in some way connected with religious observances.

The dolmens present less difficulty as to their significance. They are more or less caverns formed in many cases of gigantic stones which are usually only partially sunken in the earth, and covered by very much larger flat stones, often weighing many tons. In these chambers have been found human bones, flint and sometimes bronze implements, with some specimens of rude pottery. Wedge-shaped specimens (*celtæ*) of jade, or green stone, have also been found in some dolmens. This bears on the "axe" cult which undoubtedly obtained amongst the dolmen-builders. In the dolmen near Locmariaquer, called the Dol des Marchands, a large figure of an axe is engraved on the under surface of the covering stone. On the large flagstone on the floor of another dolmen of that neighbourhood, the *Mané-Lud*, there is a very large figure of an axe in relief. This is pointed out by the local guide as the figure of a sword. On one of the flat stones taken from the tumulus to the south of Locmariaquer, called *Mané-er-H'roec*, there are many axes sculptured. In order to understand the significance of these figures, one must compare them with what has been observed in several of the Marne caves. In these are three instances of a female figure rudely sculptured, associated with the outlines of hafted axes. In the dolmen of Collorgues, in the Department of Gard, the slab forming the central part of the roof has a female figure rudely outlined, and under it is cut the figure of an axe. All these sculptures have been found associated with burial. The axe, therefore, was the symbol of some cult, believed to be that of a deity who is now termed the "Axe Goddess." This cult was accepted by the Celtic and other contemporaries and successors of the dolmen-builders in Gaul, and was continued even during the Roman occupation, for amongst the Romanized Gauls the practice obtained of putting a figure of an axe on a headstone, or in place of the figure the words, "*sub ascia*," or "*sub ascia dedicavit*." What the cult of the Axe Goddess signified it is impossible to do more than conjecture. Its association with death and burial possibly points to the belief in a goddess of death. The cult has for students of the origin of religions this important interest: it is the only one we know as belonging to the Neolithic age, and, further, it was handed down from Palæolithic times, or at least from the transition period between the Palæolithic and Neolithic ages, when the caves were not inhabited, but used as burial places. Borlase(1) attempts to show that the cult obtained over the whole of Western Europe, and he claims that indications of it are shown in the pottery of Hissarlik found there by Schliemann. That it had a wide range may be granted, for in Palæolithic times there was probably one race

(1) The Dolmens of Ireland, vol. ii., page 578.

occupying the whole of Europe, and this fact would account for a wide diffusion of ethnic and religious ideas, but it may be doubted if some of the figures, e.g., those of the pottery at Hissarlik, supposed to be those of the Axe Goddess, are more than accidental resemblances to the symbols of her cult.

The tumuli were undoubtedly used for the sepulture of important persons, such as kings, chiefs or leaders, and their relatives. It is not improbable that they may have been used in the case of certain religious rites, for in the tumulus called Mané-er-H'roec, at Locmariaquer, and in Mont St. Michel, at Carnac, a large number of celtæ (stone axes) were found, and these have been regarded as votive offerings either to the Axe Goddess, the manes of the dead, or to the Divinities of death. In many of the tumuli the bones found were more or less incinerated, proving that cremation was practised. On the exposed surface of the greater number of the slabs forming the walls of the tumulus of Gavr'inis the line-tracing or sculpture is very rich, and gives a marked distinction to this tumulus. It would seem to have been the tomb of a king.

It is in the dolmens, however, that one finds the largest number of inscriptions. These have not been deciphered. They would appear to consist of two kinds—one ornamental, good examples of which are to be observed in the upright supporting stone of the Dol des Marchands, the second totemic of which examples are to be found in the dolmen at Kerioned, in the Alée Couverte des Pierres Plates, near Locmariaquer, and in the Alée Couverte of Luffang. A curious fact is that in the two last named there are the outlines of the same figure, which seems to the writer to be that of an opened lentil pod. On one of the slabs in the Mane Lud dolmen there is an inscription which is difficult to classify. It is clearly not ornamental, and it is not totemic, for an almost similar one has been described as found in the New Grange tumulus, near Drogheda, Ireland. Something similar is to be observed on one of the vertical slabs at the end of the cavern in the Gavr'inis tumulus, but here the outlines are less readily traced, owing to the surrounding lines of sculpture following the curves of the inscription. It may be hierogrammatic in function.

Of what race were the dolmen builders? The definite answer to this question would determine also who were the founders of the menhirs and of the tumuli, for it is generally conceded that the three classes of monuments may have, in Brittany at least, been built by the same tribe or race. Though first looked upon as of Celtic origin, it is now recognized that they are the remains of a race which inhabited the western and north-western part of Europe before the advent of the Celts. This race, known as Iberian, also occupied Ireland, Wales, and the western portions of England and Scotland, and thus the distribution of dolmens and other megalithic remains would be accounted for. There are, however, difficulties in accepting this view. The dolmen-builders were mesaticephalic, the Iberians dolichocephalic. The Iberians who inhabited the Dordogne district and the portion of the Landes district, including Dax and its neighbourhood, from Palæolithic times, did not build dolmens, and in all the country lying between the Garonne and the Pyrenees, inhabited in Cæsar's day by the Aquitani, a tribe of the Iberians, there are very few megalithic remains.

The explanation of these difficulties can only be conjectural. According to Collignon(1) the Iberians were not a race, but an assemblage or collection of tribes, derived from three races which inhabited from the earliest times the Spanish peninsula. These were the Neanderthaloids of Gibraltar, a people like the Cro-Magnon race, and the type called by de Quatrefages the race of Mugem, whose remains are to be found in kitchen middings, on the banks of the Tagus. Accepting this view, it would be possible to regard the Aquitani as a less mixed race descended

(1) Les Basques. Memoires de la Société d'Anthropologie, 3d Serie, Tome 1, Fascicule 4, page 55.

from the Cro-Magnon type of Palæolithic times, and, therefore, not possessed of the same customs as the more mixed Iberian race or tribes. Sergi,(1) on the other hand, claims for the Iberian race a single African origin, and that as a uniform race it spread over Western France and the British Isles.

It would appear that in order to ascertain definitely who the dolmen builders were it is necessary first of all to determine clearly the origin and history of the Iberians, and this can only be done when the anthropology of the Spanish peninsula is as fully worked out as that of France.

(1) Ursprung und Verbreitung des Mittellandischen Stammes. Autorisierte Uebersetzung von A. Byhano Leipzig. Verlag von Wilhelm Friederich.

Corundum in Ontario. By Archibald Blue, Esq.

(Read 10th December, 1898.)

Just one hundred years ago, in a paper read before the Royal Society of London and published in its Transactions, Rt. Hon. Charles Greville established and named the mineral species Corundum, the crystalline oxide of aluminium; and we have it on the authority of Professor Judd that in an appendix to Greville's paper the Count de Bournon correctly defined the crystallographic characters of the species. The names of its gem-varieties, sapphire and ruby, had been in use from a much earlier time;(1) and the name corivindum, or corrivendum, had been given to it by Woodward, in a vaguer way, as early as 1714.

In the western part of Asia Minor, and in some islands of the Grecian Archipelago, the crystalline limestone which is interbedded with the schists and gneisses carries a blue corundum mixed with magnetite, which is the emery of commerce. The corundum occurs in smaller quantities as a constituent of granite and gneiss in Silesia, Auvergne and elsewhere in Europe; in a compact felspar rock in Piedmont; in dolomite with tourmaline at St. Gothard; in crystalline limestone, along with numerous other minerals, in Orange and Westchester counties, New York, and Sussex county, New Jersey, and at various localities in Connecticut, Massachusetts and Pennsylvania. It is said by Dana to be common at many points along a belt extending from Virginia across western North Carolina and Georgia to Dudleyville, Alabama.

In Burma, which became a British Province in 1886, ruby mines have been worked for a very long period. There the country-rock is chiefly gneiss, with bands of crystalline limestone of varying thickness and many miles in length. Most of the mining has been carried on in the hill-wash and alluvium carried down from the decomposed summits of hills and mountain ranges: and it has been observed that where the sands and gravels are mixed with a dark brownish earthy clay, which is a product of the decomposed crystalline limestone, they are richer in such gems as ruby and spinel. The explorations of Barrington Brown appear, indeed, to have satisfactorily established that in Burma the only rock in which rubies are found in place is crystalline limestone. "It is of the usual composition and character of ordinary crystalline limestones," says Mr. Brown, "being made up of finely crystalline or granular limestone in layers, together with irregularly shaped bands of very coarsely crystalline limestone of white and bluish colors, which are interfoliated with the gneissic rocks." Where a quarry has been worked, near Mogok, the matrix of the ruby is a coarsely crystalline, semi-opaque limestone of about twenty feet in width. The rubies are found over a space of six feet in width, extending almost vertically from the bottom of the quarry to the surface of the ground, and along the centre-line, where the rubies are most numerous, are small developments of a grayish diaspore enclosing small crystals of iron pyrites. As to the limestone itself, whether occurring as disseminated crystals through the gneiss, or as great interfoliated masses, it is the opinion of Professor Judd that it has been neither organic nor due to direct chemical precipitation in its origin, but

(1) In the Burma Corundum every shade of colour, from white to the highly prized deep crimson or pigeon's blood, is found, and they are named according to colours instead of composition or system of crystallization,—the red variety as oriental ruby, the blue as oriental sapphire, the yellow as oriental topaz, the purple as oriental amethyst, and the green as oriental emerald.

has resulted from a metamorphism of the lime-bearing felspars; while during the process of change from basic felspar to scapolite, and from scapolite to hydrated aluminium silicates, and from these to aluminium oxide, "the slowly liberated oxide may assume the crystalline form, and thus give rise to corundum." Among other minerals found in the corundiferous limestone are pyrrhotite, hematite, apatite, graphite and spinel.

In Ceylon, in the peninsula of India, and in China, there are numerous occurrences of corundum in crystalline schists; and in almost every case the mineral is of the gem variety. As far as known to the writer, there are no deposits in Asia now exploited for use in the arts, saving the emery of Asia Minor.

In the United States corundum is confined almost wholly to the region of the Appalachian Mountains, along a belt that extends from New Jersey to Alabama. In the form of emery it is found at Chester, Massachusetts, in a chlorite belt about twenty feet wide, that lies between formations of hornblende-schist and talc, and traverses the mountains for about four miles. There is also a productive emery mine in Westchester county, New York, which ships from 500 to 700 tons of abrasive emery per annum.

Along the Appalachian mountain chain corundum is found in felspar veins and associated with chlorite in peridotite and serpentine rocks, in amphibolite, dunite and gneiss, as well as in gravel-beds. The principal deposits are found in association with magnesian rocks, chiefly peridotites, which occur as small lenticular masses in gneiss. As a rule, however, the corundum is neither in the peridotite nor in the gneiss, but in a narrow zone of chloritic minerals between the two. The largest known areas are in the south-western counties of North Carolina, where corundum was first discovered in 1870. This state has furnished nearly all the corundum of commerce for the United States, but the statistics of the mines and works have never been published. There has been much waste of effort in mining for the gem varieties, encouraged by occasional discoveries, but chiefly by the attractive colors in which the corundum is found. The whole process of mining and milling has had to be learned by experience; and the task has been made difficult not only by the character of the formations, which is not favorable to sinking or drifting, but also by the closeness with which the corundum crystals adhere to the matrix.(1) For abrasive use it is very important that the corundum should be free from particles of rock or mineral softer than itself; and for use as an ore of aluminium it should be free from all impurities, to make extraction practicable by present methods.

The first discovery of corundum in Ontario was made by the late Sterry Hunt fifty-one years ago, in the second year of his connection with the Geological Survey of Canada. Dr. Hunt explored part of the county of Lanark in 1847. He was joined in some of his excursions by Dr. Wilson, of Perth, who at that time enjoyed some local reputation as a geologist (the mineral wilsonite is named after him), and who is still remembered as a man who paid considerable attention to the natural history of his district. The first place visited by them was the fourth lot on the eighth range of the Township of Burgess, upon which Dr. Wilson a short time before had discovered a body of apatite. Near by, on the second lot on the ninth range, was a deposit of copper pyrites in crystalline limestone, and this was also visited. The only exploration work consisted of two or three blasts, and among the masses of rock thrown out were some consisting of silvery mica, with quartz, felspar or albite, and calcspar, holding a delicate emerald-green and almost transparent pyroxene of rare beauty, as well as crystals of a dark honey-yellow

(1) Mr. Alexander Rickard of New York, who is owner of a corundum property at Energy, in York County, South Carolina, says, in a letter to me of recent date: "All our corundums are very difficult to clean. While the gangue is soft, it is tough, and adheres to the grains of corundum when it is broken up. This reduces the cutting value, and also creates trouble by fluxing when making into wheels."

sphene. The mica was often aggregated in masses of small crystals, having a columnar arrangement,(1) imbedded in which, and disseminated throughout the rock, were a great number of crystalline grains of a transparent mineral, varying in color from a light rose-red to a deep sapphire blue. Dr. Hunt, in his report to Sir William Logan, said:—

"Their hardness, which is so great as to enable them to scratch readily the face of a crystal of topaz, showed them to be nothing else than the very rare mineral corundum, which from its colors is referable to the varieties known as oriental ruby and sapphire. The grains obtained were small, none indeed larger than a pepper-corn; but at the time I was on the spot they were not noticed, and the specimens were collected for the pyroxene, in only two or three of which I have since detected the corundum. It is probable that further examinations may develop larger and more available specimens of these rare and costly gems. It is in this crystalline limestone that they generally occur, and the corundum found in the State of New Jersey is in the same rock and with similar mica."

Yet it does not appear that this discovery in Burgess received further attention from Hunt or other members of the Geological Survey, and the mineral was practically re-discovered there a year ago by Professor Miller, of the Kingston School of Mining. It will be noticed from Hunt's account that the specimens were collected only for their pyroxene, and that the crystals of corundum were not noticed or identified until a later time.

The largest known deposit of corundum in the Province was discovered twenty-two years ago on the farm of Henry Robillard, in the township of Raglan, Renfrew county; but in this case twenty years elapsed before the mineral was correctly identified. According to Robillard's story, he was returning with his little daughter from a cranberry marsh on the wide flats of York river, and, in climbing a hill which rises about 500 feet above the river, he sat down upon a large boulder to rest. In telling me the story Robillard said:—

"Annie was kneeling behind me, and picked up a queer-shaped stone, and, showing it to me, said it looked like the stopper of a cruet-bottle. It was just like that; and I wondered what fool of a man had gone to work and whittled it out. Then I looked at the stone where I was sitting; and, bless you, sir, it was paved with cruet-stoppers. And here is the very boulder now," he added, as we reached the spot, about half-way down the hill.

Specimens gathered by Mr. Robillard were shown to several persons in Combermere, and one who professed to be a miner of phosphate of lime in Lanark county pronounced them to be crystals of that mineral. In 1884 one John Fitzgerald joined with Robillard in an application to the Crown for the mineral rights on the property, including several lots on the 18th and 19th concessions of Raglan; and for a number of years they sought in vain for a customer to buy an apatite-mine. The sturdy pioneers would brook no contradiction of their claim that the mineral was veritable apatite; and when a doubt was raised by two young mineralogists who visited the region about ten years ago in the interest of a capitalist, and a suggestion was meekly made that it might be emery, one of the pioneers cut negotiations short by threatening to "punch their heads." Last year, how-

(1) It is not improbable that these were decomposed or altered crystals of corundum. On the metamorphoses of the mineral Professor Judd says: "At the earth's surface, as is well-known, corundum or the crystalized oxide of aluminium is one of the most unalterable substances. Fragments found in river gravels and sands, though perfectly water-worn, show no trace of chemical alteration in their surfaces. On the other hand, there can be no doubt that conditions must exist in the earth's crust under which chemical change of this mineral does take place; this is abundantly proved by the frequency with which undoubted pseudomorphs of corundum occur. Among the minerals found replacing corundum as pseudomorphs are muscovite (damourite), various forms of spinel, andalusite, fibrolite, cyanite, margarite, chloritoid, zoisite, ripidolite and other chlorites, various vermiculites, kaolin, and other substances."

ever, these pioneers were overjoyed to learn on the authority of an expert that the mineral was not apatite, but corundum.

Eleven years ago Professor Coleman, now of the School of Practical Science at Toronto, picked up some boulders of nepheline-syenite in the vicinity of Cobourg, on the shore of Lake Ontario, which held crystals of corundum. A fortnight ago I showed Dr. Coleman several specimens of nepheline, rich in corundum, which I had taken from a large deposit recently discovered in the township of Dungannon, and he at once pronounced them to be identical with his own. "I feel sure now," he said, "that I know where my float-boulders came from."

Twelve years ago, in 1886, Nesbitt T. Armstrong, a farmer and mill-owner in Carlow, discovered corundum on lot 14, in the 14th concession of that township, but he did not know its name, and did not suspect that it possessed any value. A sample was shown to a student of Toronto University, who thought it might be emery; and inquiry stopped there. But in 1893 Mr. W F. Ferrier, lithologist of the Geological Survey, acquired by purchase a number of specimens collected by Mr. John Stewart, formerly of Ottawa, among which was a package labelled "Pyroxene crystals, south part of Carlow." On examining these specimens some time afterwards, presumably in 1896, Mr. Ferrier recognized them as corundum, and immediately took steps to ascertain the precise locality from which they came. In October, 1896, he was sent upon this mission by Dr. Dawson, the head of the Geological Survey, and, guided by Mr. Armstrong, he found the corundum in place upon the lot on which Armstrong's discovery had been made ten years before. Then for the first time the fact was established, on the best authority, that this mineral had been found to exist in Canada in commercial quantity, and that it was valuable as an abrasive material on account of its great hardness. But as it was too late in the season for field-work, Mr. Ferrier did not extend his explorations beyond that one locality.

The first geological reconnaissance of the district in which corundum has been found was made by the late Alexander Murray, of the Geological Survey, in 1853; but his notes of it are very meagre. Mr. Murray made two traverses of the country lying between Georgian Bay and Ottawa river—the first from west to east, by way of the Muskoka and Petewawa rivers, and the second by way of the Bonnechere and Madawaska, to the headwaters of the Trent. The source of the Bonnechere, is within a mile of Kaminiskeg lake, on the Madawaska, near to where Barry's Bay station, on the Ottawa and Parry Sound Railway, now stands. Mr. Murray descended the Madawaska to the mouth of its principal tributary, the York branch, or York river; known, also, at that time, by its significant Indian name of Shawashkong, or Mishawashkong, the river of the marshes. The course of this stream, which Mr. Murray ascended, lies for more than forty miles within the corundum belt; and along its banks are numerous exposures of syenite, with occurrences of nepheline-syenite. But no reference is made in the report to the rock formations; and the record of levels for the first ten miles is of very doubtful accuracy.(1)

Forty years elapsed before another attempt was made to work out the geology of this interesting area, and the task was then entrusted to the very capable hands of Dr. Frank D. Adams. The area under examination is comprised in sheet 118 of the Ontario series of geological maps, and the four corners of it lie in the townships of Digby, Finlayson, Hagarty and Grimsthorpe respectively, embracing an area of about 3,500 square miles In his first report, made for the season of 1893, Dr. Adams sketched briefly the geological features of the district, the northern portion of which he found to be occupied exclusively with the ancient crystalline rocks of the Laurentian system, and the southern and eastern portions with the

(1) The rock formations along the York River, however, are carefully noted on the maps which accompanied the report, as are also the waterfalls and rapids of the river from its mouth to its source.

limestones and gneisses of the Grenville series. "The discovery of so large an area of the Grenville series in this district," Dr. Adams says in his report, "is most encouraging, as indicating the probable occurrence in it of large and valuable mineral deposits." An extensive and remarkable mass of nepheline-syenite was discovered in the townships of Faraday and Dungannon, which was traced for a distance of over seven miles in an east and west direction. Dr. Adams says: —

"This is a rare rock, found in but few places in the world, and never before discovered in our Laurentian system. The nepheline is very abundant, forming in many places an almost pure nepheline rock. The mass is flanked on the south, along a considerable part of its course, by crystalline limestone, and it is also intimately associated with a fine-grained reddish rock, resembling aplite. It is of a prevailing gray color, and often has a distinct foliation, coinciding with that of the associated rocks."

The beautiful blue mineral sodalite was also found in a number of places, associated with the nepheline-syenite, in the form of veins and irregular masses; but no occurrence of corundum was observed.

During the past three seasons Mr. Barlow has been associated with Dr. Adams on the work of this field, and a very interesting and valuable report may be confidently looked for upon some of the most intricate questions of Archæan geology. Dr. R. W. Ells has also been engaged at intervals in surveying portions of the Ottawa valley east of the area on which Messrs. Adams and Barlow have been working, into which the corundum belt is known to extend as far at least as the Ottawa and Opeongo road. The two map-sheets, however, as well as the accompanying reports, will deal with the general geology of the districts, and notwithstanding the importance of the corundum discovery it is not likely that prominence will be given to that subject, if the usual practice of the survey is followed.

During the last two seasons Professor W. G. Miller, of the Kingston School of Mining, has been employed by the Ontario Government to make a special report on the field. Beginning last year with the study of the occurrence of the mineral at the place of first discovery in Carlow, he has been able to trace the corundum-bearing rocks eastward across that township, through Raglan and Lyndoch, to the shores of Clear lake, near the eastern line of Sebastopol, a length of about 30 miles. The breadth of the band varies from half a mile to three or four miles, and its total area embraces about 60,000 acres. The prevailing country-rock of the district is gneiss, composed chiefly of hornblende, biotite and felspar, and it is probably an altered gabbro. Numerous dykes or masses, consisting largely of felspar, cut through the older rocks, which sometimes have the character of coarse syenite, passing in places into nepheline-syenite. In both of these rocks corundum was found, as well as magnetite, pyrite, garnets, zircon and sodalite. In continuing his work this year Professor Miller has succeeded in tracing the syenite band continuously for about 75 miles, from the township of Glamorgan, in Haliburton, to the township of South Algona, in Renfrew, besides tracing it to a considerably greater width over the region explored last year. Corundum was found at a number of places in the western part of the belt, and a large and apparently rich deposit in a ridge of nepheline-syenite near the middle of it in the township of Dungannon. But as the rocks, over nearly the whole of their extent, are covered with sand, it is probable that many valuable deposits remain to be discovered. The total area of this band is about 300 square miles; and, as it lies in a Free Grant district, the mineral rights are reserved by the Crown in almost all the lots that have been taken up for settlement. In a few cases, where lands were sold more than thirty years ago, the mineral rights went with the surface rights; and since that time some lands have no doubt been sold or leased as mining lands. But it is safe to say that the Crown holds for disposal the minerals in at least 90 per cent. of the whole tract.

Two years ago corundum was found in a property that was being worked as a mica mine in the township of Methuen, in Peterborough county, about 45 miles southwest from the original discovery in Carlow. This locality has also been explored by Professor Miller this year, and the corundiferous band of syenite has been traced in a northeast and southwest direction about six miles, with a width of two miles. The range of hills over which it extends is known locally as the Blue mountains, and at its southwest end it reaches the shore of Stony lake.

I spent the last week of September with Professor Miller in going over the more northerly band, from the easterly end of it, on Clear lake, in Sebastopol, to the village of Bancroft, on the Hastings road, on the line between Dungannon and Faraday. Only a few of the principal properties were visited, including the Block location in Brudenell, the Robillard location in Raglan, the Armstrong location in Carlow, and a recent discovery in Dungannon, not far from the York river. All these are large deposits, easy of access, and favorably situated for mining operations.

Where the exposure occurs on the Block farm the crystals are in syenite, and are thickly studded in the face of the rock. Outcroppings of nepheline-syenite occur near by; and, owing to its resemblance to limestone, an attempt was made by the owner to burn it for lime. The crystals of corundum have a bronze lustre, and vary in size from half an inch to an inch in diameter. Numerous boulders are strewn over the face of the ground which carry a high percentage of the mineral; and in some cases, the crystals are nearly pure white in color.

On the Robillard hill corundum may be traced for a mile or more along its southern face, wherever the syenite is exposed. The corundum crystals are frequently observed to run in strings several inches wide along the surface of the rock, and are of all sizes from half an inch to two or three inches in diameter, usually barrel-shaped, and ranging from an inch to four or five inches in length. On the western shoulder of the hill there is an outcrop of nepheline-syenite; and in this rock the crystals are finely shaped, but of small size—about a third of an inch in diameter and an inch or an inch and a half in length. An expert who has examined this hill estimates the corundum in sight at several millions of tons. There is certainly a large quantity, and in some places it amounts to from 30 to 40 per cent. of the rock mass. Along the foot of the hill are numerous large boulders of syenite, speckled over with crystals like plums in a pudding.

The Robillard hill is cut off by a stream upon its west side from a range of high hills that extends westward five miles into Carlow. Professor Miller has carefully examined this range, and has discovered corundum in it at a number of points. The largest showing, however, is on the Armstrong lot, where another stream cuts through, on its way to join York river. The rock has scaled off so as to show a perpendicular face about 300 feet in length and 30 feet in height, exposing a mass of syenite which has been thrust up through the gneiss, and which, in its turn, has been cut by a dyke of pegmatite. The gneiss has been thrown up to form an anticlinal arch over the syenite, but is cut through along the north side, where the syenite dyke is well exposed with a thickness of ten or twelve feet. According to Mr. Ferrier, it has been traced along the strike about 700 feet. Crystals of corundum are numerous on the exposed face of the syenite, and are also found in the pegmatite nearest the syenite, which is composed chiefly of felspar. But where quartz comes in with the felspar, the corundum disappears. A lot of several tons, taken without selection from this location last year and treated at the Kingston School of Mining, yielded from 12.75 to 15.5 per cent. of corundum.

The last location I examined is in the township of Dungannon. It is in a ridge of nepheline syenite, having a width of 90 to 100 feet, and rising upon one side to a height of about 60 feet. My time only permitted me to follow it for a length of about 150 yards, but Professor Miller informed me that he had traced it for half a mile. The whole surface, as far as I examined it, was thickly strewn with small crystals of corundum, ranging in color from pearl to blue; but here and there parts of it were altered into white mica. A sample of it, assayed for me under the direction of Dr. Coleman, carried nearly 10 per cent. of corundum, and was remarkably free from iron. An ore of this character ought to be well suited for the production of aluminium, especially as the nepheline itself, the gangue rock, contains about 30 per cent. of alumina.

Here it may be remarked that, owing to the presence of iron and other impurities, makers of aluminium assert that native corundum is unsuited for the production of that metal. But it is safer to keep an open mind on problems of this nature. When one reflects that by the adoption of new and improved processes the cost of producing aluminium has been reduced, within forty years, from its weight in gold to 30 cents per pound or less, one ought not to assume that it is impossible to find a process for producing pure corundum at low cost, if not a process to make aluminium out of an impure ore. Professor DeKalb, of the Kingston School of Mining, was able last winter, with a small experimental plant, to extract corundum (99.61 per cent. pure) from rock that carried five per cent. of magnetic iron ore. What, then, might be expected from a large and well-equipped plant, capable of treating 50 or 100 tons per day, supplied with every device that the wit of man can invent, and especially with a good quality of rock to work upon? In one particular the Ontario mineral appears to differ from the mineral of the Appalachian belt; the gangue is brittle, and is easily broken up and separated from the corundum.

It will certainly add greatly to the value of the corundum deposits of Ontario if they can be used in producing aluminium as well as the material for abrasives, if the history of that metal during the last ten years is a fair index of its future. In the ten years ending with 1897 its production in the United States has risen from 19,000 pounds, valued at $3.42 per pound, to 4,000,000 pounds, valued at 37½ cents per pound; and so much progress in so short a time seems to be ample justification for the statement of Professor Richards, made three years ago in the preface to his admirable book on aluminium: "The abundance of aluminium in nature, the purity of its ores, its wonderful lightness and adaptability to numerous purposes, indicate that the goal of the aluminium industry will be reached only when this metal ranks next to iron in its usefulness to mankind."

None of the discoveries hitherto made in Ontario seem to encourage the hope that gem varieties of the corundum are to be found, although in some localities an occasional crystal is to be seen with qualities not unlike sapphire, being semi-translucent and of bluish color. Perhaps, if search were made in the crystalline limestones, it might be rewarded with better success; not that corundum of any quality has yet been found in the limestones, but because their relations to the gneiss are not dissimilar to those which obtain in Burma. When the source of the limestones has been worked out, it may be shown that, like those of Burma, they have been derived by metamorphosis from the felspar of the gneiss, or perhaps from the felspar of the syenite; and if so, the analogy would suggest that these rocks are worth prospecting for corundum in some of its more valuable forms. In a note received from Professor Miller on this subject, he says:—

"It is quite possible that corundum may yet be found in considerable quantity in crystalline limestone in Ontario, as in India and Burma. In India the mineral occurs under various conditions in metamorphic (limestones, etc.), and igneous rocks. Of course there need be no connection between the occurrence of the mineral in these two classes of rocks. If corundum occurs in our crystalline limestones, it is of a different origin from that occurring in the igneous rocks (the syenites)."

The crystals discovered by Sterry Hunt in Burgess, it will be remembered, were found in association with pyroxene in crystalline limestone.

In view of the extent and apparent richness of the corundum fields in the Province, the Government has taken steps aimed at developing the deposits and establishing a home industry. Regulations have been drawn up under which the mineral rights in lands lying within the two corundiferous belts have been withdrawn from sale, and hereafter the mineral and mining rights in such lands can be acquired only under the leasehold system—the rental for the first year being 60 cents and for subsequent years 15 cents per acre. Instead of allowing speculators to take up and hold lands with a view to sell out their interests to miners and capitalists at a large profit, it is proposed that the advantage of acquiring lands upon the lowest terms shall go to the miner and manufacturer direct; and in the case of parties who will undertake to conduct mining and treating operations on the largest and completest scale, and who can furnish satisfactory assurance that they possess the requisite capital for the proposed operations (including separation of the ore from its gangue, milling for abrasive uses, manufacture of abrasive goods, and the production of aluminium), the Government may concede a preference in the selection of mineral lands. It is also provided that the Government shall have power to require that all corundum mined from lands leased under the Regulations shall undergo certain processes of treatment and milling at works to be erected in the Province to prepare it for market; and may further require, from time to time, as circumstances appear to warrant, that works be established in the Province for the manufacture of all useful or commercial products for which the mineral or ore is economically adapted.

NOTES ON PROSPECTING FOR CORUNDUM. BY WILLET G. MILLER, M.A., SCHOOL OF MINING, KINGSTON.

(Read 10th December, 1898, in discussion on Mr. Blue's paper.)

When I first received instructions from the Director of the Bureau of Mines to make an examination of the occurrence of corundum in the township of Carlow, reported by Mr. W. F. Ferrier, of the Geological Survey,(1) I was not very enthusiastic over the prospect, especially as I was expected to search for other outcrops of the mineral. The district is situated rather near at hand to the chief cities and older settled parts of the Province, and, moreover, it occurs in a region which has attracted considerable attention from prospectors and miners during the last 35 or 40 years. It thus appeared to me that there could not be very much of the material in place in the district or some one would have noticed its existence years before. However, as my instructions authorized me to make notes on any other economic minerals which might be met with in the field, I thought that if I could not find more corundum I could at least get enough material for a report and spend my time to advantage in directing attention to some of the other numerous ore bodies which are to be found in Eastern Ontario.

For the first week after entering the field the outlook for the discovery of other occurrences of the mineral was not very promising. The district is a rather rough one, and the rocks are covered to a considerable extent by soil and timber, and the part of the field in which we first started to work happens to be cut through by two large river channels. Having once obtained the key to the mode of distribution of the deposits it was chiefly then only a matter of time and work to find other deposits. Drift deposits assisted us much in prospecting. In every case, I think, where we found boulders of rock carrying corundum we found the mineral in place a few miles to the northward in the direction from which the glaciers had come. We also soon became familiar with the different varieties of the rock which belonged to the same magma as the corundum-bearing variety, and knew how these different varieties shaded off into one another and into the corundum-bearing variety. We could generally tell when we were approaching the latter variety from the character of the other rocks. We also, of course, made use of the strike and other characteristics of these rocks.

The work on which we were engaged differed materially from ordinary geological field work. In the latter case one does not need to examine every hundred acres, nor in most cases every square mile or so. A fair outline of the geology of a district can generally be given by following the roads or canoe routes.

In the part of the field in which we worked in 1897 the outcrops of corundum rock occur in isolated areas. This made our work more difficult, as, being engaged in examining lands of which the mineral right in most cases belonged to the Government, we were anxious that no good deposits should escape us. It was as important for the Government to know where these deposits were situated, as it would have been for any private company which might have controlled the lands. A rather foresighted policy had been inaugurated in connection with the corundum

(1) Summary Report Geological Surv., Can., 1896, page 116.

deposits, it having been decided to withdraw from sale the promising areas found by us and thus prevent them getting into the hands of speculators, who might tie up the district for years by asking exorbitant prices. By thus withdrawing these areas from sale it was also made feasible to secure better terms, as to working the deposits, from parties securing them. I feel that under this arrangement our work was of as much direct value to the Province at large as it would have been to any private company had we been engaged by such a concern. Our work has increased the value of these Crown lands by enough to pay many times over the amount expended on the examination. My consciencece is, therefore, easy on the financial side of the subject, as the lands could be sold by the Province to-day for much more than they could have been sold for at the time we began the work on them. This ought to satisfy those people who are always asking for direct returns from geological work, and who are often unable to see that practically all geological work has at least an indirect bearing on economic questions.

In our work in 1897 we outlined a belt of country about 30 miles in length and two or three miles in breadth over which outcrops of corundum occur. In our last season's work, 1898, we have succeeded in increasing considerably the length of our belt of corundum rocks, and we have not yet come to the end of it. The rather contorted belt, as we now have traced it out, is over 75 miles in length, and there are two isolated areas of the rock on which I have done some work, but which time has not permitted me to attempt to connect with the main outcrops. One of these lies a considerable distance to the southeast of the eastern end of the main belt and the other area lies to the south of the western end. It might be possible, if one had time, to connect these different areas.

As it now stands, the belt of these rocks holding its irregular and sometimes narrow course through the other members of the Archæan crystalline series is one of the most interesting structures we have, I think I am safe in saying, in our oldest group of rocks. As yet we do not know exactly what this structure signifies. But I hope that when it is carefully worked out and studied in greater detail this group of rocks will aid in solving some of the problems which are now attracting the attention of petrographers.

In the highly metamorphic state in which many of the members of the Archæan occur it is difficult to make certain that igneous rocks, such as granites, syenites and diorites, which are found in isolated outcrops miles apart, belong to one eruption, but in the case of the corundum-bearing rocks we have a mark in the mineral itself which assists us in connecting and proving relationship between masses which would not otherwise have attracted attention as being related.

The corundum, as Mr. Blue has said, occurs typically in what we have called syenite The rock often contains nepheline, which is the primary reason for speaking of the series as syenite. I have found by microscopical and chemical examination, however, that while the greater part of the rock in which corundum occurs may be called in general syenite, there are large masses of rock, consisting in one case of several square miles, which are more properly called gabbros or anorthosites. On the other hand, the syenite appears in some cases to merge gradually into the quartziferous variety, or into granite, in which, however, no corundum has been found. We have thus as products of one magma a series of plutonic rocks, ranging in acidity from granites to gabbros. And if one likes to make hair-splitting distinctions, he might work out representatives of about all of the plutonic group. I might also add that if there is any man who wishes to gain the questionable distinction of introducing a new rock name, I think he could get material for the purpose among this corundum-bearing series.

The first person to report the occurrence of these rocks, which have since been found to so commonly carry corundum, in the district, was Dr. F. D. Adams. In the summer of 1893 Dr. Adams found nepheline syenite in place in the township of Dungannon, Hastings county.[1] The mineral sodalite which so often occurs in this rock had been found in the district years before by prospectors. Dr. Adams and his associates outlined the occurrence of nepheline syenite in what were called three separate areas in the township of Dungannon and the adjoining township of Faraday, and an outcrop of the rock was also known in Glamorgan, to the west.[2] It was not, however, till October, 1896, that corundum was first found in the district by Mr. Ferrier, and it was not till June or July, 1897, that this mineral was known to be associated in the district with nepheline syenite, which had previously attracted considerable attention on account of its comparatively rare occurrence in most parts of the world and on account of the size of the nepheline individuals and the high percentage of the mineral carried by the rock.

In 1890 Dr. A. P. Coleman published a very interesting paper on the character of some glacial boulders which he had found in the vicinity of Cobourg.[3] Among these boulders were some which Dr. Coleman determined to be nepheline syenite. It was, therefore, known at that time that this rock occurred in place somewhere in the region to the north where it has since been found to be so widely distributed.

Although corundum is a mineral of considerable interest scientifically as well as economically, no discovery of it was reported in Canada after Sterry Hunt's discovery of it in the crystalline limestone of North Burgess in the later forties till Ferrier's find was made in the autumn of 1896.

After once having seen the corundum in the nepheline syenite of the township of Raglan, where this association was first found, it seemed to me likely that the mineral would be found to occur in the already known outcrops of the rock in Dungannon and the other two townships to which reference has been made. During 1897 time did not permit of a careful examination of these outcrops, but on the index map of the district published in my report[4] for that year, I outlined these outcrops and stated that the mineral likely occurred in place in these townships Work during the past season, 1898, has shown that my predictions were correct, as we found corundum in place at several points in Dungannon and in other townships to the west. Moreover we have found that the previously mentioned areas of nepheline syenite in Dungannon and Faraday are parts of what is practically one continuous band of these rocks, but which is in places very narrow, and, therefore, difficult to follow. We have also traced this band fifteen or twenty miles farther west, and have connected these outcrops with the belt worked out in 1897. The relations of these outcrops and the different parts of the belt which have now been connected are shown on the map which Mr. Blue has exhibited.

Since the work with which I was charged was intended to be primarily of an economic nature, and, therefore, more closely connected with prospecting than with geology proper, I have not paid any more attention to the general geology of the district than what was required to enable us to prospect intelligently for the mineral for which we were in search. Moreover, the working out of the general geology of the district is provided for by the Geological Survey of the Dominion, and it seems to me that the work of the Province should be in the nature of applying information supplied from this source and making use of it in the working out of problems which have a direct economic bearing. We already have a fair general knowledge of the geology of the Province in the districts penetrated by and surrounded by our railroads, but the discovery at this late day of an occurrence of a mineral of economic value over such a large area in one of what may be called the older mining and prospected districts shows the possibilities there are of finding other economic products in our well-known mineral districts.

(1) Amr. Jr. Science, 1894, and Annual Report Geological Surv., Can., vol. vi. (N.S.)
(2) Summary Report Geological Sur., Can., 1896, vol. 50 A.
(3) Trans. Roy. Soc., Can., 1890.
(4) Part iii., 7th Report Bureau of Mines, Ontario.

We now know of the occurrence of a sufficient number of deposits of corundum to offer anyone desiring to work them considerable choice as to location. I have always been careful not to try to "boom" these deposits, as the abrasive industry is a very complicated one, and it cannot be well foretold what success would be met with on working the deposits. In any case I do not expect to see any corundum millionaires, but I believe there is a fair chance of an industry being established which would be a great benefit to the district in which the deposits are situated. The question of using corundum economically as an ore of aluminium is as yet an open one, and can probably only be settled by a series of prolonged experiments.

I brought with me a specimen or two of another mineral which we found in the field while searching for corundum. This mineral belongs to the comparatively rare columbate group, and as it is the first time one of these minerals has been found in Ontario I thought some of the members of the Institute might be interested in seeing specimens.

I have to thank Mr. Blue for the encouragement and assistance which he has ever been ready to give me during the progress of the work. That the energetic manner in which the development of the mineral industries of the Province has been carried on during the past seven or eight years, the time during which the Bureau of Mines has been in existence, is appreciated abroad is evident from a letter which I receivd a short time ago from one of the most prominent mining men in Eastern Canada. The writer of that letter made this statement:—"The policy which Ontario has adopted with regard to the acquiring of information respecting her minerals and the publishing promptly of reliable reports is a lesson to us which many of us here have been hoping might be copied in our Province."

And now I have to thank you, Mr. President, and the members of the Institute for the privileg you have afforded me, a non-member, of addressing these remarks to you. Since my student days in this city I have had cause to appreciate the encouragement which the Canadian Institute has offered to workers in science throughout the Province. I read some time ago an account of the plan which Mr. Bain has laid before the members of this Institute for the establishment of a Provincial reference library. I hope to see this plan carried out in its entirety, and it will be found it will receive the enthusiastic support of those of us who are interested in science and who live at a distance from the Provincial capital. When this library is established students of science throughout Ontario will be under a still further debt of gratitude to the Canadian Institute, which has now for so many years served as the centre of scientific thought in the Province.

THE INTERNATIONAL SCIENTIFIC CATALOGUE. BY JAMES BAIN, JR.

(Read 17th December, 1898.)

The discussion of the subject of a Scientific Catalogue is singularly appropriate in the Institute at this time, when the Library is being placed on a new footing and arranged for scientific work. The fifty years which have elapsed since the formation of this Institute have witnessed the establishment of an enormous number of similar societies, specializing their scope more and more, until few departments of scientific work are without their organization and printed transactions. It is estimated that there are now published, more or less regularly, 30,000 scientific journals, partly the production of 565 medical and 6,000 scientific societies, and partly published independently. The total number of papers included in these journals, transactions and memoirs is further estimated at 600,000 annually, or an issue of nearly 2,000 per day.

The reasons for the immense increase in this class of publication are not hard to find, and give no indications of a decrease in the immediate future. They are, first, the increasing number of abstruse, valuable papers, which journals dependent on subscriptions cannot see their way to print. These can only be of value to the few, and as scientific men are, as a rule, not wealthy, they are glad to get either the assistance of some society or direct aid from Government. This, freely given, has encouraged the development of memoirs in pure science. Secondly, our universities have so largely adopted the system of post-graduate courses, in which each graduate is encouraged to produce his thesis, and which are published under the name of university studies. And, thirdly, because science has become so specialized that men engaged on minute portions of the work are drawn together to support a special journal where their discoveries and discussions may be certain of a small but appreciative audience.

It is quite evident that no person is able to follow all the scientific publications of the day, even when restricted to one of the great divisions, and that the necessity exists for some means of obtaining a knowledge of at least the titles of those published within a fixed period, and that the catalogue produced by any one society would be both imperfect and expensive. Let us take the Canadian Institute Library as an illustration of what can be done with limited means. We have, in addition to the unbound Transactions, about 8,000 bound volumes, containing on an average twenty papers each. These would require, with a single entry under the author's name, 160,000 entries. An average cataloguer cannot do more than thirty per hour, if allowance be made for all necessary stoppages. This, at seven hours per day, is 210, which, divided into 160,000, gives as the time required for the completion 762 days, or, allowing for holidays, nearly three years. But every student knows that an author's catalogue is only of partial value, and that it must be supplemented by a subject catalogue. This, then, doubles the period, and shows the impossibility of doing such a work single-handed. Many of the older societies, such as the Royal, Antiquarian, Civil Engineers, or Archæological, have, at intervals of 25 or 50 years, printed an index volume to their publications; but the number of these and the long intervals at which they appear, render them useless for the ordinary student. Practical men have seen that the only escape from the difficulty was by co-operation in a joint catalogue. Professor Henry, Secretary of the Smithsonian Institution, was the first to propose a combined catalogue, in 1847.

and, following out the same suggestion, the Royal Society of London, in 1857, commenced the publication of the catalogue which bears its name and now comprises eleven volumes. After much negotiation, representatives from all of the civilized nations were invited to attend a meeting of the International Catalogue Conference, in London, on July 14, 1896. Sir John Gorst was called to the chair, and, after expressing his pleasure at meeting so many representatives of science, said: "Discussions have always been going on as to the best way of extending the catalogue, and of carrying it out in such a way as to make it supply the needs of scientific workers generally. About three years ago a Committee was appointed specially to take into consideration what appeared to be the only way of carrying out such a work in the future, viz.: to consider the preparation of such catalogues by international co-operation. The Royal Society realized from a very early period that it could not itself undertake such a work—that no single body could undertake it; and therefore invited the opinions of scientific men and scientific institutions all over the world. There was practically but one reply—that such catalogues were essential—and there was practically no doubt that the only way of carrying out the work was by international co-operation. The Royal Society worked at the subject during two years, and eventually this Conference was summoned at its instance, through the aid of Her Majesty's Government. If any proof were required of the importance of the work, I think the fact that this meeting is attended by so highly representative a body of delegates is in itself sufficient. . . The great object before us is to produce a catalogue available for use by scientific investigators throughout the world. It is a mere bibliographic work that we are seeking to perfect. We desire to produce catalogues, arranged not merely according to authors' names. but catalogues arranged also according to subject-matter; and a very large number of those who have considered the subject are of opinion that in these catalogues the subject matter must be classified not merely broadly, so as to deal separately with individual sciences, but much more in detail, so as to deal with sections of individual sciences, in order to meet the wants of specialists. Each index, therefore, must be a classified subject index; and many of us also believe that it must be an analytical classified subject index—that we must go beyond the mere titles of papers and consider the subject matter, so that such information is placed in our hands that we shall know practically what is in a paper wherever it may be published. . . But with regard to details—and there must be many details in working out such a scheme, especially when we come to consider questions of classification—it is quite clear that at this meeting we cannot do more than discuss broad principles. The details must be considered by committees, appointed either by this meeting, or by means of machinery set in action by this meeting. And in order that there should be a full study of all these questions, the Royal Society has proposed that the catalogue shall not commence until the year 1900. We have suggested that at least four years should be given to the preliminary work of organization. If means can be devised of leading authors, societies, and publishing bodies generally to co-operate in this work, it is clear that the central organization will exercise almost mechanical functions: it will, so to speak, sit at the receipt of custom; it will see that the scheme is carried out in a uniform way, but the material it requires will flow naturally towards it. In this way much will be done to economise both time and money. Later in the Conference, when we are clear what is the nature of the work to be done, it will be very important to consider what part each contributing country shall take in the enterprise in supporting it financially."

The Conference sat for four days, and agreed upon a basis of international work. English, French, German, and Italian were declared to be official languages, and resolutions were received in any of these. In printing the catalogue, it was resolved, "That English be the language of the two catalogues, authors' names and titles being given only in the original languages, except when these belonged to a category to be determined by the International Council."

The preparation of the catalogue is to be in charge of an International Council, to be appointed, and the final editing and publication shall be conducted by a Central International Bureau, under the direction of the International Council. Any country that is willing to do so shall be entrusted with the task of collecting, provisionally classifying, and transmitting to the Central Bureau, in accordance with rules laid down by the International Council, all the entries belonging to the scientific literature of that country. "In indexing according to subject-matter regard shall be had, not only to the title (of a paper or book), but also to the nature of the contents."

The catalogue shall comprise all published original contributions—periodical articles, pamphlets, memoirs, etc.—to the mathematical, physical, or natural sciences, "such as, for example, mathematics, astronomy, physics. chemistry, mineralogy. geology, botany, mathematical and physical geography, zoology, anatomy, physiology, general and experimental pathology, experimental psychology and anthropology, to the exclusion of what are sometimes called the applied sciences—the limits of the several sciences to be determined hereafter."

The system of collecting and preparing material for the catalogue in each country shall be subject to the approval of the International Council.

"The Central Bureau shall issue the catalogue in the form of 'slips' or 'cards,' the details of the cards to be hereafter determined and the issue to take place as promptly as possible. Cards corresponding to any one or more branches of science, or to sections of such sciences, shall be supplied separately at the discretion and under the direction of the Central Bureau. The Central Bureau shall also issue the catalogue in book form from time to time, the entries being classified according to the rules to be hereafter determined. The issue in the book form shall be in parts corresponding to the several branches of science, the several parts being supplied separately, at the discretion and under the direction of the Central Bureau."

It was also decided that the Central Bureau shall be located in London, and that the Royal Society appoint a Committee to study all undecided questions relating to the catalogue and to report later. As it was thought that the necessary guarantee fund could be raised by private subscription, it was decided that no appeal to the Governments of the several countries represented was necessary.

At the adjourned meeting, which took place in October, 1898, the above was confirmed, with some slight alterations. The first of January, 1900, was fixed as the date for beginning the new catalogue, and the recommendation of the Royal Society was adopted. that. "In 1905. in 1910. and every tenth year afterwards. an International Convention shall be held in London to reconsider, and, if necessary. revise the regulations for the carrying out of the work of the catalogue."