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THE

CANADIAN NATURALIST.

SECOND SERIES.

THE DISTRIBUTION OF PLANTS IN CANADA

IN SOME OF ITS RELATIONS

TO PHYSICAL AND PAST GEOLOGICAL CONDITIONS.

By A. T. Drummond, B.A., LL.B.

More than two years ago, in this journal, the writer endeavoured to indicate and illustrate some of the more obvious features in the distribution of Canadian plants. It was shown that in taking a general view of this distribution several distinct floras could be recognized, viz.:—a general Canadian flora composing species which range over the whole or greater part of the Province; a second flora whose species are confined to the districts around the northern shores of Lakes Superior and Huron; a third to the comparatively narrow district bordering Lakes Erie and St. Clair and the south-western parts of Lake Ontario; a fourth to the Gulf and Lower St. Lawrence shores; and a fifth which had an undoubted boreal aspect. Besides these, were a small inland maritime flora, and two other floras whose limits and characteristics could not then be accurately defined, but which appeared to be limited—the one to Upper Canada and the other chiefly to Lower Canada. A number of plants were also indicated which were apparently confined to the tract of country around the northern shores of Lakes Huron and Superior and to the more eastern parts of Lower Canada, whilst several species were named whose occurrence was quite local. These prefatory references will render subsequent remarks more intelligible.

In investigating the causes which have influenced the diffusion of species in Canada, we find that whilst some have in past time been and are still exerting their influences, others are perhaps correctly referred to far distant periods. And whilst the operation of some is confined to narrow limits, others extend their effects over a wide extent of territory, and many are identical with causes which produce somewhat similar results in other countries.

There are no long ranges of mountains within the Province to retard the free interspersion of its different indigenous forms, nor are the Laurentide hills of such considerable height as to much impede the admission of the cold boreal winds from around Hudson Bay. The great breadth of the lakes, however, must, there is no doubt, preclude a migration from the northern United States as extensive as under altered circumstances it would be.

To the influences effected by our numerous and extensive lakes and rivers through their currents, the formation of prairie land, the evaporation from their surfaces and the necessarily modified temperature of the land surrounding them, references will, in subsequent parts of this paper, be made.

An eminent writer on botanical as well as geological subjects, thinks, that many anomalies in the distribution of Canadian vegetation can be explained by considering the chemical constitution of the soil. "A little more lime or a little less alkali in the soil renders vast regions uninhabitable by certain species of plants. For many of the plants of our Laurentide hills to extend themselves over the calcareous plains south of them under any imaginable conditions of climate is quite as far beyond the range of possibility as to extend across the wide ocean."* This view is, in at least a limited sense, probable. *Rubus Chamæmorus* Linn. and *Empetrum nigrum* Linn. have been cited as illustrations of the preference maintained by some plants for soils of Laurentian origin. It may be more correct to, in part, ascribe the range of these plants to their known predilections for northern situations. They are both in fact sub-arctic plants, and it merely happens to be a coincidence that the Laurentian formations skirt the Lower St. Lawrence and the northern shores of Lake Superior, on the coasts of the former of which both of these plants occur, and on those of the latter *Empetrum nigrum*. Were their distribution entirely dependent upon the nature of the soil, they should occur in the country around the Upper Ottawa and elsewhere, but they are not known to range so far to the southward. *Pinus Banksiana* Lamb.—a less northern form—and probably *Polygonum cilinode* Michx. would seem, in our present knowledge of their distribution, to constitute better illustrations of preference for Laurentian soils and

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* Dr. Dawson; this journal, O. S., vol. vii, p. 342.

strata. It would be interesting, however, to compare the range, in relation to soils, of those plants which are common to Europe and America.

We can conclude from the known distribution in Canada of rocks of the earlier geological formations, and from the direction of the ice-grooves upon them, that soils composed chiefly of Laurentian, or, in some instances, Huronian debris, were spread both over these formations and for at least some distance over the Silurian and Devonian rocks during the epoch of the drift, whilst the strata farther south were carpeted with more calcareous soils. The distribution of these soils was, no doubt, at subsequent periods, somewhat disturbed. Now, the Laurentian strata are composed of such different materials in different localities—some of which lie at but comparatively short distances apart—that knowing the composition of the soil at any given locality, it would be often incorrect to assign a similar composition to soils in the vicinity which we know must have been derived from rocks of the same system. The quartzites have afforded silica in abundance to the soil; the limestones, phosphate and carbonate of lime, and other minerals in variable quantities; the dolomites, carbonates of lime and magnesia; the serpentines, silica and magnesia; and the orthoclase and labradorite, silica, alumina, soda and potash. All of these mineral species, with others, are common in the Laurentian rocks. The Huronian formation also abounds in quartzites and dolomites. Within the limits, then, of a single township there might be met with soils in one case highly calcareous, in another with noticeable quantities of alkalies and but a trace of lime. The very variable proportions in which the same chemical ingredients will frequently occur in soils, at localities not far distant from each other, has been well shown by Dr. T. Sterry Hunt.* It is a noticeable circumstance that lime, potash and soda, appeared in all the soils analyzed by him. These facts are mentioned to show that if the composition of soils has such an influence as to affect the presence of plants upon them, conditions must occur in some parts of but limited areas favourable to the existence of many plants which do not in others. Moreover, when we consider the varied compositions of our early formations, it is easy to conceive that over the immense extent of country in which they are developed, whilst many situations afford the requisite conditions for

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* Geology of Canada, 1863, p. 640.

plants requiring much alkali, many other localities must be well suited for species to whose growth lime is more necessary. And again, the different proportions in which lime exists in soils overlying the Silurian and Devonian rocks, make it probable that in many localities the proportion would be so small as to afford suitable habitats for plants preferring non-calcareous soils. However much, then, there may be in the relation existing between plants and the chemical constituents of the soils in which they grow, it seems exceedingly difficult to arrive at any satisfactory conclusions regarding the effect of this relation upon the general distribution of our native plants.

In the above remarks I do not of course include any reference to sea-shore plants, which, without a doubt, derive sustenance from the chloride of sodium, with which both the air and soil, in the vicinity of the coast, are to some extent impregnated. But the very fact that many of these plants are met with in localities far distant from any possible influence of the ocean, clearly shows that this alkali may not be entirely essential to the existence of all maritime species.

Before leaving the subject, a few instances of apparent preferences for particular soils or locations may be cited. The whitewood, *Platanus occidentalis* Linn., is, at London, only met with on the low alluvial flats on either side of the River Thames, and the two or three trees occurring at Toronto exist in a similar situation on the banks of the River Don. At Chatham, and nearer the mouth of the River Thames, this one of the largest of Canadian trees occupies like locations, and is said to attain there a magnificent size. *Pinus rigida* Miller, again, has only been detected among the Thousand Islands—which form the connecting link between the Laurentide hills of Canada and the Adirondacks of New York State—and in the Township of Torbolton on the Upper Ottawa, in the immediate vicinity of which the Laurentian strata are also largely developed. *Corydalis glauca* Pursh, *Kalmia angustifolia* Linn., *Asplenium ebeneum* Aiton, and *Woodsia Ilvensis* R. Brown—for the most part easily recognized plants—are, judging by our present knowledge of their distribution in Canada, limited in range to the area occupied by the Laurentian rocks. The distribution of these and other species is not, however, so definitely established as to warrant any perfectly safe conclusions regarding the effects upon them of particular soils and locations, and other reasons already mentioned would further induce the withholding of any conclusion. Besides, it seems difficult to escape the conviction that very often local circumstances—to some of which reference will hereafter be made—will, more than the general climate or the presence of any particular ingredients in the soil, account for the occurrence of plants in specific localities.

Other features of interest may be also cited. Those who have visited the Thousand Islands in the River St. Lawrence must have been struck with the vast abundance of *Rhus typhina* Linn. and *Pteris aquilina* Linn. Neither of these plants is, however, limited to Laurentian soils, and it is very probable that the profusion here of at least the former is in part due to the rugged, rocky nature of almost all of the islands. It may be also mentioned that the capacity of land for cultivation is often in Canada judged of by the timber trees growing naturally upon it. Eastern farmers look upon the red pine, *Pinus resinosa* Aiton, as characterizing a poor soil, whilst there are many in the Erie district, where the red pine is unknown, who regard the chestnut, *Castanea vesca* Linn. as evidencing some sterility.

Another circumstance affecting distribution is not to be overlooked. The Laurentian rocks, which are very largely developed in Canada, are remarkable for their rugged, corrugated character—in some places forming ranges of high hills, in others, individual elevations of considerable height, and everywhere, to a greater or less extent, displaying the same characteristic rugged surface. The whole breadth of the strata is, besides, dotted with basins of varying sizes and forms, which have been worn out of the softer material of the rock, and are now filled with sheets of water. The surface of the Laurentian rocks is, to a very considerable extent, bare and only tenanted by numerous saxicolous Parmelias, Lecideas, and other lichens, with mosses and some ferns, and a few often stunted phanerogams maintaining an existence in the little soil collected in the frequent cracks and fissures. The very numerous little hollows and depressions in the surface—probably in most instances grooved out by the action of ice—are covered by a layer of soil generally scanty, but which is often very rich and supports a prolific vegetation. On the other hand, the Silurian and Devonian formations have either a level or somewhat undulating surface, and are everywhere covered by clays, sands, gravels and loams, which attain very often a great thickness, especially in the Upper Canada peninsula, where numerous illustrations are afforded by the oil-well borings. Between the River Ottawa and the Georgian Bay and Lake Superior, the Algoma sands form a prominent feature in the surface deposits, whilst over the Upper Canada peninsula and along Lake Ontario, are chiefly distributed the Erie clays and Saugeen clays and sands. This varied nature of the rock surface, the presence of these very numerous lakes over the Laurentian strata, and the great diversity in the depth as well as general characters of the surface deposits, must have a not inconsiderable influence upon the vegetation of the country, especially in the multiplication or diminution of the numbers of many species.

In many localities throughout Western Canada, there are terraces and ridges of soil extending over, in some cases, considerable surfaces of country—evidences of the much higher levels attained by the Great Lakes and certain rivers in some recent times than exist at the present day. My correspondent, Mr. John Macoun, of Belleville—other of whose careful observations obligingly communicated, are elsewhere in the present paper referred to—has informed me that in his neighbourhood the ridges (the surface soil of which is generally a fine sand slightly mixed with clay, with a subsoil of usually limestone gravel or fine sand) support a vegetation of a southern and western aspect not met with in localities of a different nature in the same section of country. This would appear to be attributable rather to the general nature and state of aggregation than to any particular chemical condition of the materials composing the ridges. When of such loose materials as the sand, clay and gravel referred to, these ridges are always well drained, and where exposed to the action of the sun, absorb the heat with great readiness. This heat in radiating again into space, continues to supply the plants growing upon the ridges with warmth during the intervals of night. Now, much less heat is absorbed, and, consequently, less radiated into the atmosphere by a wet and stiff clay, than by a loose, gravelly, or somewhat sandy soil, and the oxygen of the air has much less access to the organic substances in and the roots of plants growing upon the soil. These consequences are observable among all our surface deposits, in a greater or less degree in proportion to the state of aggregation and general character of their component materials, and would be similar, though in a less marked manner, if the soil were not in ridges. The rather rare *Ranunculus rhomboideus* Goldie, *Helianthemum Canadense* Michx., and

Viola sagittata Aiton, I have found at London, growing along with other interesting plants, nearly side by side, on a gentle slope, well exposed to the rays of the sun, and composed of a very sandy clay. Mr. Macoun has found the same plants upon the ridges of Northumberland County, growing with *Anemone cylindrica* Gray, *Linum Virginianum* Linn., *Trifolium stoloniferum* Muhl., *Liatris cylindracea* Michx., *Aster ericoides* Linn., *Rudbeckia hirta* Linn., *Artemisia biennis* Willd., and a few others. Both southern and western forms require a higher degree of heat than plants of our eastern districts, even under the same parallel of latitude. As in many parts of Western Canada similar ridges of sand and gravel occur, the circumstances detailed are not of mere local interest.

In connection with the subject of soils, Mr. Macoun points out the fact that in his neighbourhood, western plants, where not aquatic, always occur in either a sandy soil, or a soil holding much limestone gravel. My own observations at London, and elsewhere, would tend to confirm this in regard to, at least, some plants.

The flora of the Lake Superior districts, in some of its features, is very different from that of other parts of Canada. Many of the familiar trees and herbaceous plants of the more southern parts of the province are absent, whilst there occur—mingling with the very large number of our more abundant species, and the few northern forms—a little assemblage of plants, more characteristic some of the western woody country and plains, and others of the middle and southern States. Additional species are met with upon the American side of the lake. *Ranunculus abortivus* Linn. var. *micranthus* Gray, *Matricaria inodora* Linn., *Tanacetum Huronense* Nutt., *Senecio canus* Hook., and some others, extend as far eastward as the Lake Huron shores, but the majority have only been found in the vicinity of Lake Superior. It is not difficult to account for their presence in these localities, but why do we not find them about Lakes Erie and Ontario, and farther eastward, as well as around the Upper Lakes ? Questions of a similar nature will occur to United States botanists. What precludes the eastward range of the characteristic vegetation of the western prairies, and of the central wooded plains of the continent ; and to what cause can be ascribed the very peculiar north-westward range of many American plants, by which they occur in Ohio, Michigan, Wisconsin and westward, and about the

Saskatchewan, but are altogether absent from the New England States, and the eastern and central parts of Canada? Two questions are, in fact, involved in considering, in the present place, the distribution of the vegetation of the country surrounding Lake Superior.

The vegetation of the prairies, like that of the pampas of South America and the steppes of Russia, is of a peculiar type—approached, however, in general characters, by that of the marshes and swamps. Lesquereux, Henry Engelman, and others, have pointed out many of the distinctive features of the prairies and their flora.* Conditions are not suitable for the extension of this flora into the more eastern parts of the United States and Canada. In our Erie district, however, there are a few forms which remind us much of the western prairies. To these some allusion will be hereafter made.

With regard to the vegetation of the central wooded districts of British America and the adjoining American States, doubtless the colder climate of Lake Superior and the rugged nature of the surrounding country preclude the eastward distribution of more of its plants. Climatal and physical conditions would, besides, on principles hereafter explained, encourage a different range.

The north wesward diffusion of many American plants has been referred, perhaps correctly in part, to the direction of the valleys in the United States and British America. Other causes must, however, be also taken into account. The principal ranges of North American mountains have a general northern and southern course, with considerable inclinations to either the eastward or westward. The prevalent trends are in fact parallel with the coast lines of the continent. The directions of the large rivers, again, are generally north-east, south-east, or nearly south-west. Here we have furnished to us as the general course of the valleys, along which the southern temperate flora may with facility migrate, two directions—one to the north-east, and the other to the north-west. Still further, the central parts of the continent are comparatively low lying, not exceeding at the headwaters of the Mississippi 1700 feet above the ocean; and the watershed, which separates the rivers which flow into the great lakes and the St. Lawrence from the tributaries and subtributaries of the Mississippi, crosses the northern part of the State of Wisconsin, and

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* Amer. Journal of Science [2] xxxvi. 384; id., xxxix. 317.

almost skirts the southern and western parts of Lake Michigan. Now, it is generally known that the north-eastern parts of North America have a temperature lower than that of the central plains and wooded countries in similar latitudes, and that the lines of mean temperature rise very considerably as they cross the continent from the New England States and Canada westward. The reason for this lies in the much greater mass of land on the western half of the continent extending far into the Arctic Sea, the large areas of polar land on the eastern side separated by extensive bodies of water from the mainland, and the Great Lakes—all of which tend, on principles long since stated by Lyell, Humboldt, Dana, and others, to produce a lower temperature in the north-eastern sections of the continent. Other influences, arising from proximity to the sea, from the Labrador current, and the general configuration of the coast, also lend their aid. Now, a plant from the warmer temperate zone, in migrating northward, would not range far up those valleys having a north-eastward bearing from the gradually lower temperature met with there, and yet, favoured by the course of the valleys and the warmer climate, would be found in much higher latitudes farther inland. Further, the Appalachian chain of mountains must form to some extent a barrier to eastward distribution. It is also a noteworthy circumstance, when taken in connection with the lower temperature in proceeding northward, that at least the larger river valleys of eastern New York and the New England States have a general southern direction. In this way, it seems to me, the apparently anomalous north-westward range of many American plants can be fully accounted for. To some of the causes mentioned, added to the configuration of the coast lines of Lakes Superior, Michigan, Huron, and Erie, must be also ascribed the presence of the few south temperate plants which occur around Lake Superior. The lower temperature and the broken character of the country must alone prevent many other species from also finding homes there.

In the districts which border Lake Erie there is a not unexpected intermingling of northern temperate with more southern forms. The most casual observer will not fail to account for this. Separated on the one side by the River Niagara from the western part of the State of New York, the district extends westwardly along Lake Erie, widening gradually in its course, consequent on the form of the lake, until it almost touches upon a not inconsiderable part of Michigan. We would be quite prepared to meet within the limits of this district many of the characteristic species of the western portions of the States of New York and of Michigan; and from their relatively lower latitude, and their position near the bend at the head of Lake Erie, we would be as well prepared to find in the townships fronting the Detroit River some of the rarer species of Southern Michigan and Northern Ohio.

The prairie lands around Lake St. Clair, and extending towards Chatham, indicate the considerably greater breadth of surface of that lake at a recent period (geologically considered). These prairie soils are, very probably, the most recent surface deposits of any extent existing in Canada. Their deposition took place after the waters of the Great Lakes had assumed their present level, and, consequently, subsequent to the formation of the ancient lake ridges, terraces and beaches, so frequently observed in Canada West. They do not here, however, as in the Western States, occupy extensive tracts of country. At the present day the formation of prairies is in progress along some of our lake shores. On the American side of Lake Erie, the Bay of Sandusky is—as has been well explained by Leo Lesquereux—in process of transformation into prairie land, and on the Canadian side of the same lake, Point Pelée affords an illustration of more recent commencement.

I am not aware that our Canadian prairies have been explored. There are, however, elsewhere, within the Erie district, some outliers, as it were, of the western prairie flora. Illustrations are found in *Vernonia fasciculata* Michx., *Solidago Ohioensis* Riddell, *S. Riddellii* Frank, *Silphium terebinthinaceum* Linn., *Hieracium longipilum* Torrey, and *Phlox pilosa* Linn.

Mr. Macoun, more than a year ago, pointed out to me the very interesting fact, that on the Lake Ontario beach at Wellington and Presquile, occur a few plants which are not to be met with farther inland, and which have been hitherto thought to be limited in range to the more southern districts of Canada, or to New York, Ohio, and other of the middle States. The more interesting species which he has thus far detected are *Jeffersonia diphylla* Pers., *Lithospermum hirtum* Lehm., *Rhynchospora capillacea* Torrey, *Scleria verticillata* Muhl., *Sporobolus cryptandrus* Gray, *Panicum virgatum* Linn., and *Hypnum trifarium* Web. and Mohr. Upon these beaches the same discerning botanist has obtained *Cladium mariscoides* Torrey, and *Scirpus pauciflorus* Smith, neither of which have been hitherto familiar as Canadian plants, nor has the latter been observed in the Northern States; and he has also collected *Conopholis Americana* Wallroth, *Physostegia Virginiana* Benth., *Eleocharis tenuis* Schulter, and *Carex Œderi* Ehrh., species which have been observed elsewhere in the central, or in more northern parts of Canada, but which he had never met with in the Counties of Hastings and Northumberland. The occurrence of these species in the localities named was, I conceive, rightly ascribed by Mr. Macoun, to the drift of Lake Ontario. The currents of the lake take a direction from the Niagara River to the entrance to the St. Lawrence, and the Prince Edward peninsula, extending far into the lake would—aided by the prevailing winds—readily intercept the drift.

It is easy to conjecture that a similar cause to that which occasioned the presence of the above-mentioned plants upon the northern shores of Lake Ontario, would lead to the occurrence of forms still more southern upon the Lake Erie shore, at Point Pelée and Long Point, localities, the very formation of which was due, in the first place, to the action of the winds and current. Some plants not at present familiar to us as Canadian, will yet, I suspect, be detected there. The action of the currents of Lake Huron and of the River St. Clair is, I think, exemplified in the occurrence of *Primula farinosa* Linn. and *P. Mistassinica* Michx. upon the shores of that lake and Lake St. Clair.

It has long been a fact familiar to American botanists that a number of strictly maritime plants are diffused along the shores of the Great Lakes, in the immediate vicinity of some smaller lakes, and extensive swamps, situated at a short distance away, and near salt springs in New York State and Wisconsin. The number of these has been, within the last two years, slightly increased. The Rev. Mr. Paine and Judge Clinton, have detected *Naias major* All., *Ruppia maritima* Linn., and *Leptocloa fascicularis* Gray—a perhaps sub-maritime species—near the margin of the Onondago Lake, in New York State and Canadian botanists, although they have not added to this section of their lake shore flora, have yet thrown some further light upon its distribution. The brief catalogue hereunder, probably includes all the maritime plants, with one or more, perhaps, strictly sub-maritime species, now known to have this peculiar range.

Ranunculus Cymbalaria, Pursh.
Cakile Americana, Nutt.
Polygonum articulatum, Linn.
Rumex maritimus, Linn.

Hudsonia ericoides, Linn.
H. tomentosa, Nutt.
Hibiscus moscheutos, Linn.
Lathyrus maritimus, Bigel.
Atriplex hastata, Linn.
Salicornia herbacea, Linn.
Polygonum aviculare, Linn.
  var. littorale, Link.
Euphorbia polygonifolia, Linn.
Naias major, All.
Ruppia maritima, Linn.
Triglochin maritimum, Linn.
T. palustre, Linn.
Scirpus maritimus, Linn.
Calamagrostis arenaria, Roth.
Leptochloa fascicularis, Gray.
Hordeum jubatum, Linn.

It is to be observed that some of these plants have a very extended inland range, whilst others are apparently distributed over very limited areas. *Hudsonia tomentosa*, *Lathyrus maritimus*, and *Triglochin maritimum* are, perhaps, the most widely diffused.

It is conceived that this peculiar distribution owes its origin to successive changes in the physical aspect of the province during the post-pliocene epoch, and the gradual adaptation of the plants to the new conditions in which they were, by force of circumstances, placed; and further, that these plants indicate the probable existence of a much more extensive maritime flora which flourished on the ocean shores during this epoch. I have already briefly detailed my views on the subject in this journal. I may, however, here explain, that it has not yet been satisfactorily established, what in post-pliocene times were the conditions of land and water in what is now known as Western Canada. The precise age, and the marine or lacustrine origin of the Erie clays, which are largely developed there, are yet involved in some uncertainty from the absence of any fossil evidence; nor is it yet known what relations they bear to the marine sands and clays of Eastern Canada, although they may have been contemporaneously deposited. If, however, I am correct in referring the origin of the distribution of the inland maritime flora to the post-pliocene epoch, it will furnish an argument for the marine character of such deposits as are coeval with those of the eastern sections of the province referable to this epoch. If the Great Lakes were in these distant and yet comparatively recent times, bodies of salt-water, or if they were united into one vast inland sea, as, judging from geological evidence, was probably the case, we can readily account for the migration of the sea-shore species along the coasts. And if these seas or united seas gradually became fresh-water, it does not require much stretching of the imagination to picture the struggle for life which must have taken place among these wanderers from the ocean coast, in consequence of the gradual change in at least one of those conditions, hitherto so apparently essential to their very existence. As year followed year, and the lakes became imperceptibly more fresh, successive individuals of some of the species would, as it were insensibly, become more and more reconciled to the new conditions, whilst, perhaps, most of the species would gradually diminish in both numbers and luxuriance, and finally, unable to perform those functions necessary for their reproduction, would die, and thus completely disappear from the lake coasts. As the lakes receded to their present limits, the survivors, lured by the presence of the waters, would follow, leaving, however, some of their number around the saline springs of New York State and elsewhere. These survivors probably constitute a more hardy race than their fellows on the ocean coast. This would seem to be illustrated by the more northern inland range of some, the extended diffusion along the lake margins of others, and the adaptation of all to new conditions.

These inland maritime plants have only as yet been detected on or near the shores of broad lakes, and extensive bays, on the borders of large swamps, or in the immediate vicinity of salt springs and "salt licks," showing the marked preference which these little ramblers still retain for the neighbourhood of saline waters or for homes near the lake or bog margin, in which the saline element alone is wanting to render complete. It is further to be observed that the greatest number of species exist around, or at smaller sheets of water, not far from the shores of lake Ontario, the lake which, of all our inland fresh-water seas, is much the nearest to, in fact, almost adjoins what formed in post-pliocene times, the ocean coast, and to the shores of which the first migration of sea-shore plants was probably effected.

The animal kingdom affords illustrations of a distribution analogous to that indicated by these little inland maritime plants. Dr. Leconte has recognized upon the north shores of Lake Superior, insects of a sea-shore type; and in fresh-water lakes in Norway have been observed two marine crustaceans whose presence is attributed to a submergence and subsequent rise of the land during the post-tertiary epoch, and a change in the conditions of the waters of the lake from a state of saltness to that of freshness, which these species survived.

There is a probability that many existing species of plants in Canada can date their period of creation as far back as the post-pliocene epoch, and, it may be, to a more distant age. In the Leda clays of Green's Creek, near Ottawa, occur numerous nodules enclosing, among other organic remains, many fragments of plants. Dr. Dawson has, after careful examination, identified *Drosera rotundifolia* Linn., *Acer spicatum* Linn., *Potentilla Canadensis* Linn., *Gaylussacia resinosa* Torrey and Gray, *Populus balsamifera* Linn., *Thuja occidentalis* Linn., *Potamogeton perfoliatus* Linn., *P. pusillus* Linn., and *Equisetum scirpoides* Michx.‡ Now, it will be noticed not only that all of these plants are of still existing species, but also that four, *Drosera rotundifolia*, *Potamogeton perfoliatus*, *P. pusillus*, and *Equisetum scirpoides*, are common to Europe and America. This would appear to establish the fact, irrespective of any evidence which may exist in other countries, that the intermingling of European and American forms, so noticeable a feature in our North American vegetation, took place either during this epoch or at an earlier period. Still further evidence of this is afforded by the inland maritime flora. No less than eleven of these have a European as well as an American range. Thus, a part of the temperate floras of both continents can mark the dawn of its existence at a very early period in this epoch, and probably during the antecedent age.

All of our high northern forms occur either in the districts fronting the Gulf and upon the shores of the Lower St. Lawrence, or upon the coasts of Lake Superior. We have no mountains known to us to be capped with little assemblages of arctic and sub-arctic plants, since Mt. Logan and other considerable elevations in the extreme eastern parts of Lower Canada, on which some may be supposed to occur, remain as yet unexplored. The Island of Anticosti, the Mingan Islands, and, it is to be presumed, the neighbouring districts of the mainland on the northern coast, have a nearly arctic aspect, while the north shores of Lake Superior are as nearly sub-arctic in their floral characters. On the former occur a number of characteristic arctic forms, but associated with many plants of more temperate range; and on the latter, whilst there are sub-arctic species present, they are also accompanied by numerous others which have an extensive diffusion to the southward.

It is a circumstance to be somewhat expected, in consequence of the difference of latitude, that the flora of the south shore of Lake Superior, and of the north shore of Lake Huron, is much less

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‡ Canadian Naturalist, present volume, p. 69.

boreal in its aspect than that of the northern coasts of the former lake.

It is a fact of considerable interest that far up the River St. Lawrence, upon both sides, even towards Quebec, are found, mingling with sub-arctic forms, some species of truly arctic range. *Rubus Chamæmorus* Linn., *Gentiana acuta* Michx., *Pleurogyne rotata* Linn., *Empetrum nigrum* Linn., and *Woodsia hyperborea* R. Br.,* among others, range as far up the river bank as Riviere-du-Loup, where they have been detected by Dr. Thomas; and *Astragalus alpinus* Linn., *A. secundus* Michx., *Vaccinium Vitis Idæa* Linn., *V. uliginosum* Linn., *Euphrasia officinalis* Linn., with one or two other boreal forms, extend to the Island of Orleans and Quebec. In seeking for an explanation of this somewhat peculiar diffusion, it must be borne in mind that arctic plants delight in a low equable temperature, accompanied by a moist atmosphere, and wherever these conditions exist, whether on mountain summits or on northerly ocean coasts, there these little plants can find a home. Now, the coasts of the Lower St. Lawrence amply supply these conditions. They occupy a rather high latitude, and besides frequently rise to considerable elevations, forming extensive cliffs. The broad and deep expanse of water fronting them necessarily has the effect of lowering and equalising the temperature, and the evaporation, which must be very great, continuously taking place, aided by the winds, moistens the surrounding air. Further, a branch of the cold Labrador current flows through the Straits of Bellisle, carrying with it, no doubt, amongst other drift, seeds of arctic and sub-arctic species, and extends its influence far up the St Lawrence. This current would further aid in lowering the temperature of the immediate shores, but its effects, the more marked because the waters are chilled by recent connection with icebergs, would be especially experienced upon the island of Anticosti, which, from its position, would intercept the current, and tend to direct it towards the entrance of the river. To these causes must be ascribed this climate which seems so suited to these little arctic and sub-arctic species of the more eastern sections of the Province.

Upon the northern shores of Lake Superior some of these causes likewise operate. There is the same moist atmosphere and more

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* EDITOR'S NOTE.—*Woodsia hyperborea* R. Br., has been found by Mr. Horace Mann in north-western Vermont; *W. Ilvensis* (Linn.) is abundant on the rocks of the Quebec group south of the St. Lawrence. W.

equalized and lower temperature resulting from the proximity to the widely extended and deep waters of the lake. The higher latitude does not, by any means, alone account for these coasts forming suitable stations for plants of a northern range.

It is a circumstance not without considerable interest that in the alpine and sub-alpine flora of the New England States there is a remarkable paucity of peculiarly American species. With the exception of *Alsine Groenlandica* Fenzl, *Geum radiatum* Michx. var. *Peckii* Gray, *Arnica mollis* Hook., *Solidago thyrsoidea* E. Meyer, *Nabalus nanus* DC., *N. Bootii* DC., *Vaccinium cæspitosum* Michx., *Salix Uva-Ursi* Pursh, *Carex scirpoidea* Michx. and *Calamagrostis Pickeringii* Gray, all of these alpine plants are likewise of European range. This circumstance will, it may be thought, have considerable bearing upon the question with respect to the antiquity of the peculiar flora of Arctic America. The presence of these few species may be thought to be possibly due to the migrations of birds, or to other agencies at work in existing or recent times, and not to causes which, operating in post-pliocene ages, are believed to have given rise to the occurrence of the other members of the flora. In glancing, however, over the arctic plants of Newfoundland, the extreme eastern parts of Canada, and the adjacent coasts of Labrador, it is also somewhat noticeable how comparatively few of these high northern American forms descend, even with the increased facilities afforded now for migration, as far southwards as these districts. In a climate relatively of but little greater severity, we can accordingly conceive the high range which these American arctic plants must have also had in post-pliocene times, and how few could be expected to occur upon the then almost submerged mountain summits of New England.

In the number of this Journal before alluded to, reference was made to an apparent anomaly in the range of *Anemone parviflora* Michx., *Potentilla tridentata* Aiton, *Pinus Banksiana* Lambert, *Allium schœnoprasum* Linn., *Botrychium Lunaria* Swartz, and a number of other species, whose distribution in Canada seems to be confined to the northern coasts of Lakes Superior and Huron, and the Lower St Lawrence, with, at least in some instances, a range between these limits. Without referring to others whose intermediate diffusion is known, I may here mention that the little northern Scrub Pine alluded to has been met with by the Rev. J. K. Macmorine in a few localities in the southern sections of the County of Renfrew. To the species cited might be added *Saxifraga Aizoon* Jacq., *Viburnum pauciflorum* Pylaie, *Aster graminifolius* Pursh, *Vaccinium Vitis-Idæa* Linn., *Primula farinosa* Linn., *P. Mistassinica* Michx., *Comandra livida* Richards., *Tofieldia palustris* Hudson, *Carex Vahlii* Schk., *Aspidium fragrans* Swartz, and many others. I have already suggested the probability that the composition of the soil may, to some extent, affect the range of one of these plants, and it is just possible that the distribution of a few others may be modified by the same cause. It is, however, an observable fact that whilst none of these plants is arctic or perhaps even sub-arctic in its aspect, all have a high northern range. In the United States their distribution is limited to northern New England and Wisconsin, or to mountain sides and summits. The vicinity of the lakes and the broad waters of the St. Lawrence, and their equalizing effects upon the temperature, account in part for the presence of the more boreal forms, and their general northern range for that of others. The little Primulas occur on the American shores of Lakes Huron and St. Clair, but probably the winds, and especially the currents, have brought their seeds from the Manitoulin Islands and the upper shores of the former lake, where both species have been frequently met with by Dr. John Bell. It may be mentioned that in the St. Clair River, especially where the waters of Lake Huron enter it, the current is very considerable.

Montreal, April, 1867.

ON THE GEOLOGICAL FORMATIONS OF LAKE SUPERIOR.

BY THOMAS MACFARLANE.

The crystalline rocks of Lake Superior present many features of interest to the lithologist, and to the student of primary geology; and the sedimentary rocks of that region, being almost destitute of organic remains, have been the subject of much discussion among scientific men, which can, nevertheless, scarcely be said to have settled unequivocally the question of their age. Having, as I believe, observed certain new facts concerning the composition and association of these rocks, which are calculated to throw some light on their origin and age, I have attempted to *describe them in the following paper.*

Four different formations are distinguishable on the north, south and east shores of the Lake, where I have had an opportunity of examining their constituent rocks and mutual relations, but the same formations may be observed elsewhere in this region. These formations have been designated as follows: The Laurentian *system, the Huronian series, the Upper copper bearing rocks* of Lake Superior and the St. Mary sandstones. The two first-named (and older) formations usually occupy those parts of the shores which form high promontories and precipitous cliffs, and they constitute, almost exclusively, the areas which have been explored in the interior. On the other hand, the Upper rocks *and St. Mary sandstones are never found far inland,* but occur close to the shore in comparatively low-lying land and rocks. They seem to have had, as the theatre of their eruption and deposition, the bottom of the Lake, at a time when its surface was at a higher level than it is at present, although not so high as the general surface of the surrounding Laurentian and Huronian hills.

I.—THE LAURENTIAN SYSTEM.

Under this name it has become usual, in Canada, to class those rocks which, in other countries, have been regarded as forming part of the primitive gneiss formation, of the primary or azoic rocks, or of certain granitic formations.

The most prevalent rocks of the Laurentian series on Lake Superior present a massive crystalline character, partaking much more of a granitic than of a gneissic nature. Some of these I shall endeavour to describe first. To the north of the east end of Michipicoten Island, on the mainland, there is a very large area of reddish-coloured granite, which exhibits, in a marked degree, the phenomena of divisional planes, and huge detached blocks. The rock is coarsely granular, has a specific gravity of 2·668 to 2·676, and consists of reddish orthoclase, a small quantity of a triclinic felspar, dark green mica (also in small quantity), and greyish white quartz. The mica is accompanied by a little epidote, and an occasional crystal of sphene may be detected. A few miles to the east of Dog River a grey granite occurs extensively, which does not show any divisional planes. The felspar of this variety is yellowish white, with dull fracture, and is fusible without difficulty. It is associated with black, easily fusible mica, in considerable quantity, and with quartz, which is occasionally bluish tinted. The specific gravity of the rock is 2·750 to 2·763. Large-grained granite is of very frequent occurrence on Montreal River and on the coast betwixt it and Point-aux-Mines. It consists principally of orthoclase, in pieces from one to several inches in diameter, a comparatively small quantity of quartz, and a still smaller proportion of white mica. The promontory of Gros Cap, at the entrance of the Lake from River St. Mary's, is composed of coarse-grained and characteristic syenite. In some places its hornblende is soft, seems decomposed, and is accompanied by epidote. The rock is seldom free from quartz, and some of it contains so much as to be justly termed syenitic granite. A chloritic granite appears to occur at a few points on the north side of Bachewahnung Bay, and a small-grained granite, consisting exclusively of felspar and quartz, occurs in large masses at the north-western extremity of the same Bay. It has not the structure of granulite, and might be properly named aplite or granitelle.

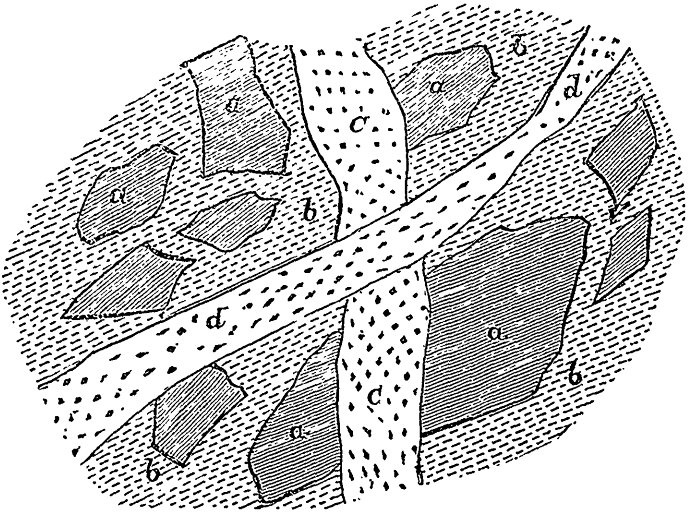
These rocks are all unequivocally granular, without a trace of parallel structure. They far exceed in frequency and extent those which possess a thoroughly gneissic character; indeed, characteristic gneiss was only observed at Goulais Falls and at Point-aux-Mines. The rock of the latter locality varied from the closely foliated, resembling mica schist, to that of a granitic character. Granitic gneiss is found on the north shore of Bachewahnung Bay, between Chippewa River and Bachewahnung Village, on the road between the latter and the Bachewahnung Iron Mine, in the neighbourhood of the Begley Copper mine, and at other points on the north shore of Bachewahnung Bay.

Almost equal in frequency to these thoroughly granitic and gneissic rocks, there are found certain aggregates of rocks which present different lithological aspects almost at every step, and which can only be generally described as brecciated and intrusive gneissic, granitic, or syenitic rocks. There is, however, to be detected a certain uniformity in the manner of their association with each other, which is of the greatest interest, and several instances of which it is now proposed to refer to. On the north shore of the Lake, about twenty-five miles west of Michipicoten Harbour, one of these rock-aggregates may be observed. Here fragments of a dark schistose rock, consisting of felspar and hornblende (the latter largely preponderating), are enclosed in a coarse-grained syenitic granite, and both are cut by veins of another granite containing much less hornblende than the second-mentioned rock. These veins are, in their turn, intersected by a vein of fine-grained granite, consisting of quartz and felspar, with traces only of mica or hornblende. The specific gravities of these different rocks were found to be as follows:—

Hornblendic schist	2·836
Syenitic granite	2·787
Granite	2·608
Fine-grained granite	2·630

That the specific gravity of the last-mentioned rock should be greater than the one preceding, is attributable to its containing more quartz. Figure 1 gives a representation of the phenomena here observed. No chemical analysis of these rocks is required to show that the newer they are the greater are their contents in silica. This is evident as well from their specific gravities as from their mineralogical composition. The following relations, similar to these are observable on the north side of the Montreal River, at its mouth. The prevailing rock here is small-grained granitic gneiss, which contains lighter and darker coloured portions, according as the black mica which it contains is present in smaller or larger quantity. A triclinic felspar is also noticeable in it. Pieces of this rock are seen to be cut off and enveloped in a

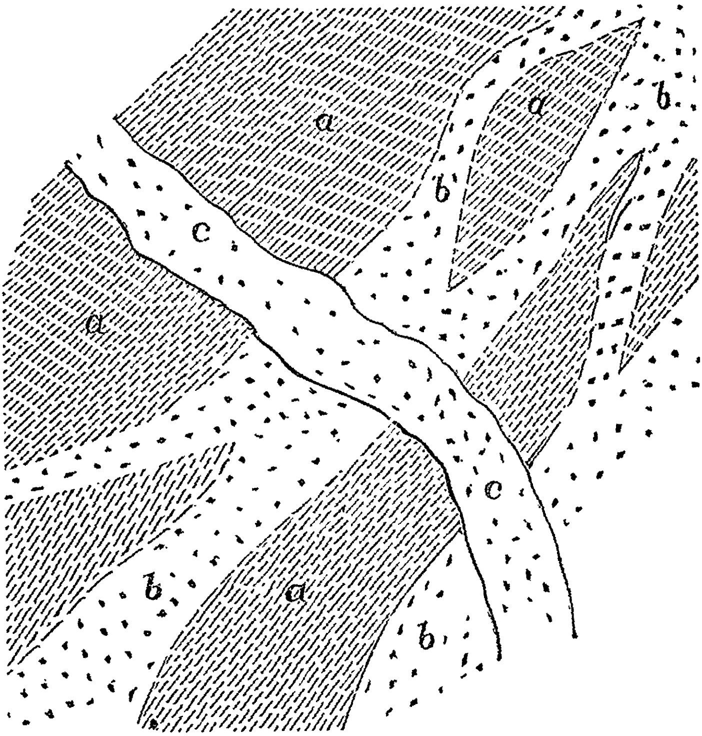
Fig. 1.



a. Fragments of hornblendic schist.
b. Enclosing syentic granite.
c. First intersecting granite.
d. Second intersecting granite.

finer-grained granite, of a much lighter colour than the gneiss, and comparatively poor in the black mica. The specific gravity of the gneiss is 2·667, and that of the granite, 2·648. Veins of large-grained granite, containing very little mica, traverse both of the rocks just mentioned. The appearance of these rocks is shewn in Figure 2. At the falls of the Chippewa or Harmony River, which empties into Bachewahnung Bay, the predominating rock is highly granitic gneiss, consisting of reddish orthoclase, quartz and dark-green mica. It is rather small-grained, and, when observed in mass, shows sometimes a schistose appearance, the direction of which ranges from N. 10° W. to N. 57° E. Occasionally, in the more micaceous portions, broad felspathic bands occur, with selvages rich in mica, forming the nearest approach to gneiss. The direction of these bands is altogether irregular. This is also the case with veins of large-grained granite which intersect the rock just described. This

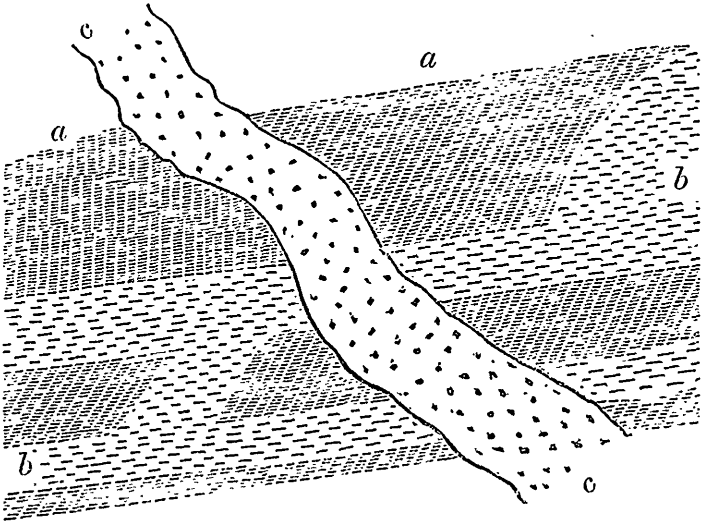
Fig. 2.



a. Granitic gneiss. | *b*. Fine-grained granite. | *c*. Large-grained granite.

granite consists mainly of red orthoclase, with a comparatively small quantity of quartz, with which a still smaller quantity of greenish mica is associated. The specific gravity of the granitic gneiss is 2·676, and that of the coarse-grained rock of the veins 2·594. On the north-east shore of the Bay, close to the landing place of the Begley Mine, rocks are observed consisting principally of granitic gneiss, in hand specimens of which, no parallel structure can be detected. At some places, however, in larger masses, a schistose appearance is observable, with a strike of N. 75° E. This rock, which is syenitic, contains masses and contorted fragments of gneiss very rich in hornblende. Both the fragments and enclosing rock are intersected by veins of large-grained granite, containing little or no hornblende or mica. In the most south-easterly corner of Bachewahnung Bay, rocks occur, which, although they are totally devoid of any approach to gneissic structure, *and possess a very different composition, bear some resemblance in* the manner of their association to those just described. A dark-coloured, small-grained mixture of felspar and greenish-black mica, with occasional crystals of reddish orthoclase, and, more rarely, of greenish-white oligoclase, is enclosed in and intersected by another rock consisting of a coarsely granular mixture of orthoclase and soft dark-green mica, enclosing crystal of orthoclase (but no oligoclase) from one-quarter to three-quarters of an inch in diameter. Both of the rocks might be called micaceous syenites, but as they possess a pdelorphyritic structure, they probably belong to the rock species called minette. The matrix of the first-mentioned and darkest coloured rock is fusible, but the orthoclase which it encloses is less readily so. In both rocks, where exposed to the action of the waters of the Bay, the micaceous constituent has been worn away, and the grains and crystals of orthoclase project from the mass of the rock The specific gravity of the small-grained rock is 2·85, and that of the coarse-grained enclosing rock 2·65. *They are both intersected by* narrow veins of granite, consisting of felspar and quartz only, the specific gravity of which is 2.62. At Goulais Falls, about fifty miles up the Goulais River, gneiss occurs, which is very distinctly schistose, contains a considerable quantity—about one-third—of brownish black mica, interlaminated with quartzo-felspathic layers, in which a transparent triclinic felspar is observable. The gneiss possesses a specific gravity of 2·74 to 2·76. Its strike and dip are variable; the former seems, however, to average N. 55° E., and the latter varies from 14° to 26° north-westward. It is interstratified with a small-grained granitic gneiss, containing much less mica than the last—about one-twentieth only,—no triclinic felspar, and having a specific gravity of 2·71 to 2·72. The same granitic gneiss intersects the characteristic gneiss in veins, and both of these rocks are cut by a coarse-grained granite, almost destitute of mica, and completely so of schistose structure. The strata of the gneiss are much contorted in various places. The intersecting granitic gneiss and granite are almost equal in quantity to the gneiss itself; and although they occur as irregular veins, they are, at the point of junction, as firmly united with the gneiss as any two pieces of one and the same rock could well be. Figure 3 is intended to represent the relations observable at Goulais Falls. Between Goulais Falls and the point where the line of junction between the Laurentian and Huronian rocks crosses Goulais River, there are numerous exposures of gneissoid rocks, but characteristic gneiss is of rare occurrence among them. At several places hornblende schist, in fragments, is observed enclosed in a gneissoid granite. Some of them are longer than others, and have their longer axes running N. 50° to 60° W. Hand specimens of the enclosing granite show little or no mark of foliation, but when seen in

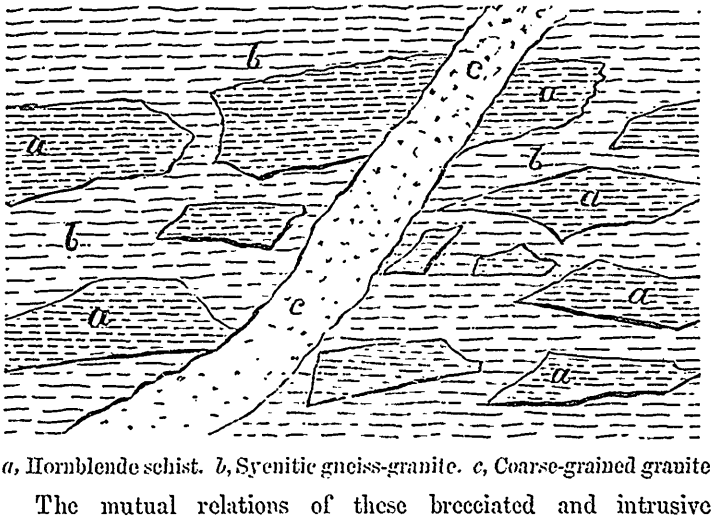
Fig. 3.



a. Gneiss. | *b.* Granitic gneiss. | *c.* Coarse-grained granite.

place, a faint parallel structure is observable, the strike of which is N. 50° to 60° W. Both the hornblendic fragments and the gneissoid granite are cut by veins of newer granite. On the south-east shore of Goulais Bay, a beautiful group of syenitic rocks is exposed, the mutual relations of which are similar to those above described. Fragments of hornblende rock or schist, varying from half-an-inch to three feet in diameter, are enclosed in a coarse-grained syenitic granite, in which, occasionally, a rough parallelism of the hornblende individuals is observable, the direction of which is N. 57° E., and coincides with that of the longer axes of the hornblendic fragments. The specific gravity of the hornblendic rock is 2·94 to 3·06, and of the enclosing granite 2·74. Both are intersected by a coarse-grained granite, having a specific gravity of 2·61 only, and containing little or no hornblende or mica. The appearance here described are represented by Fig. 4.

Fig. 4.



a, Hornblende schist. *b*, Syenitic gneiss-granite. *c*, Coarse-grained granite

The mutual relations of these brecciated and intrusive rocks in eight different localities, some of them upwards of one hundred miles apart, have here been described, and it will be observed that, in every one of the instances mentioned, the oldest rock is the most basic in constitution, and this appears to be the case, without regard to the mineralogical composition or structure of the rocks associated together as above described. It matters not whether the older rocks be brecciated or entire, hornblendic or micaceous, granular, schistose or porphyritic, it is always most deficient in silica. It appears, further, that the newer the rock which encloses or penetrates older ones, the more siliceous it becomes. On reference to the specific gravities above given of the various rocks, it might be supposed that their relations as to age might be equally well expressed by saying, the older the rock the heavier; the more recent, the lighter it is; and, in the majority of instances, this applies. But, as in the case of the rock-aggregate occurring to the west of Michipicoten Harbour, when we come to the very newest granitic veins, consisting only of orthoclase and quartz, those are the heaviest which contain most of the latter mineral, its mean specific gravity being 2·65, while that of orthoclase is only 2·55. It is to be remembered that these newest veins are altogether different in appearance from certain veins of large-grained granite, with distinct side joints, which are occasionally found intersecting these rocks, and the origin of which has been indicated by Dr. Hunt in his recent valuable report on mineral veins. Near Point-aux-Mines a vein of this nature is found, the rock of which is pegmatite, consisting of orthoclase, quartz, and greenish white mica, together with occasional grains of purple copper, copper pyrites, galena, and molybdenite.

It may not be out of place here to advance certain considerations regarding these Laurentian rocks, and especially concerning the peculiar rock aggregates just described. The relations of these rocks to each other we have seen to be as follows:—The older the rock the more basic is its nature, and the richer it becomes in triclinic felspar, hornblende, and mica. The newer the rock the more siliceous it becomes, and the more such minerals as orthoclase and quartz predominate. It can scarcely be supposed that this relation is an accidental one, for it is observable in every one of the instances above given, the localities of many of which are very far distant from each other. It would seem to be the consequence of an unvarying law which was in operation at the time when these rocks were first formed. At first sight, the facts above described would appear to militate against the idea of the igneous origin of these rocks, and, in fact, the relation is a similar one to that which has been observed among the constituent minerals of granite, and which is one of the chief difficulties in explaining the origin of that rock on the igneous hypothesis. In granite the quartz is frequently found filling up the interstices between the other minerals, and sometimes it even retains impressions of the shape of the latter. Nevertheless the felspar and mica are the most fusible, and the quartz the most infusible of the constituents of granite. Similarly, the older basic rocks, among the brecciated and intrusive aggregates above described, are the most fusible, while the newer rocks, being most siliceous, are most infusible. At first sight, it is difficult to conceive how a basic and fusible rock could solidify from a melted mass previous to a more siliceous one. *But the geological relations of these rocks are such* as to afford the fullest proofs of their igneous origin. It may be urged that such an origin for the oldest and more basic fragments does not appear proved, but their similarity in mineralogical composition with the intrusive members of the aggregate is in favour of such a view. Furthermore, these older fragments shew, in every instance, such an analogy as regards their relation to the intrusive rocks that they cannot be regarded as accidental fragments of other rocks brought from a distance. If their origin were of this nature, they would not invariably be more basic in composition than the enclosing rock. The fact of their always bearing a certain relation, as regards composition, to the enclosing rock renders it unlikely that their source is similar to that of *boulders in a conglomerate or fragments in a breccia. On the* contrary, it would appear more reasonable to regard them as the first products of the solidification of the fluid mass from which the granites, and other rocks above described, resulted. In pursuing this subject further, it would appear not unreasonable to base some such theory as the following upon the facts above stated. The area now covered by these rocks must at one time have been occupied by a mass of fused silicates. The temperature of this fluid magma and of the surrounding crust has been intensely high, although perhaps very gradually on the decrease, and the extent of the igneously fluid material must have been such as to render uniformity in its chemical composition an impossibility. Variations in its composition, as well as in the manner of its *solidification, may therefore be supposed to have* obtained in different parts of the fluid area. According to the proportion of silica and bases present where crystallisation commenced and progressed, hornblendic rock, mica syenite, or comparatively basic granite, first assumed the solid form, leaving a part of the fluid or magma beneath or on the outside of it still in a plastic state, but changed in its chemical composition, and rendered more siliceous than the original magma. If the solidification commenced at a point where the fluid mass was comparatively undisturbed, the granular varieties of the rocks above described may have been produced. If, on the other hand, the solidification took place while the fluid mass was in motion, the hornblendic and micaceous schists, and gneisses were most probably the results of this process, and the strike of these would indicate the direction of the current at the time of their formation. The rarity or indistinctness of parallelism in the Laurentian rocks of Lake Superior shews, however, that no very constant and persistent motion in one direction took place in the fluid mass which produced them. This first solidification of part of the fluid magma most likely continued for a long period, and spread over a large surface; but there seems at last to have arrived a time when, from some cause or other, these first rocks became rent or broken up, and the crevices or interstices became filled with the still fluid and more siliceous material which existed beneath them. Gradually, this material solidified in the cracks, or in the spaces surrounding the fragments, and the whole became again a consolidated crust above a fluid mass of still more siliceous material. Further solidification of this latter material doubtless then took place, and continued until a second general movement of the solidified crust opened other and newer crevices, which became filled with the most siliceous material which we see constituting the newer veins among the rocks above described.

Although the theory here given as to the origin of these rock aggregates is in thorough harmony with the facts related concerning them, it is doubtless possible to urge objections against it founded upon the relative fusibility of their constituent rocks. There is no doubt that the point of temperature at which these various rocks become fluid under the influence of heat is higher with the newer than with the older rocks, but it does not follow that in cooling they solidify, that is, become quite hard and solid at the same point of temperature at which they fuse. Bischof describes an experiment which proves that the temperature at which certain substances solidify does not at all correspond with their fusing point. He prepared a flux, consisting of common glass and carbonate of potash, which fused at a temperature of 800° R., and melted it along with some metallic bismuth in a crucible. This metal fuses at 200°, and solidifies with a very uneven surface, on account of its tendency to crystallize. Although the difference between the fusing point of the bismuth and of the flux amounted to 600°, nevertheless, when the crucible cooled, all the irregularities of the surface of the metal were found to have imprinted themselves upon the lower surface of the solidified flux, a very plain proof being thus furnished that at a temperature of 200° R., the flux was still soft enough to receive the impression of the solidifying metal. If we further observe the various fused slags which flow from different furnaces, we shall obtain some idea of the manner in which the rocks above described may have behaved during their solidification. The scoriæ of iron furnaces are usually very acid, containing as much as 60 per cent. of silica. They generally fuse at a temperature of 1450° C. As they flow out of the breast of the furnace, they may be observed to do so very leisurely, to be sluggish and viscid, but nevertheless to continue fluid a long time, and even in some cases to flow out of the building in which they have been produced, before solidifying. On the other hand, slags from certain copper furnaces, or from those used for puddling iron, are more or less basic, containing from 30 to 45 per cent. silica. As they flow out they are seen to be very fluid, and to run quickly, but they solidify much more rapidly than iron slags. Yet these basic slags fuse at about 1300° C., or about 150° less than the more acid slags. Those who have been accustomed to observe metallurgical processes will not find it difficult to conceive how a very siliceous slag might continue fluid at a temperature at which a more basic one might become solid. We conceive, however, that the rocks which we have described must have solidified under circumstances altogether different from those under which furnace slags cool. We suppose that these rocks must have solidified at temperatures not very far below their fusing points; that the temperature of the atmosphere, and of the fluid mass itself, had sunk somewhat beneath the fusing point of the more basic rocks before solidification began, and that at this point it was possible for the basic rocks to crystallize, while a more siliceous magma still remained plastic. This latter supposition does not appear unreasonable when the experiment above referred to, and the behavior of furnace slags above described, is taken into consideration.

It becomes a question of much interest as to whether these rocks are to be regarded as constituting one and the same, or several and distinct geological formations. There cannot be a doubt as to the fact that some of them are of more recent origin than others; but, on the other hand, many of the veins above described do not present such distinct joints as are visible where trap or basalt dykes traverse sedimentary strata. Although the cementing material of the brecciated rocks above described differs in composition from the fragments which it encloses, we nevertheless find that the two are usually so intimately combined with each other as to behave under the hammer like one and the same rock. There is, in the majority of cases, no joint to be found at their junction with each other; and in fracturing them, they very often break just as readily across as along the line which separates them. It would appear, therefore, that, although these rocks solidified at different times, the dates of their formation were not sufficiently far distant from each other to enable the previously existing rock to cool thoroughly before it became penetrated by or enclosed in the newer one; that consequently the older rock, being in an intensely heated condition, readily amalgamated at its edges with the next erupted and fused mass, and formed with it a solid compact whole. Apart from the difficulties which would doubtless attend any attempt to distinguish separate geological groups among these rocks, it would appear just as unreasonable so to separate them, as to regard each distinct stratum of sedimentary rock as distinct geological formations. According to Naumann, a geological formation consists of a series of widely extended or very numerous rocks or rock-members (*Gebirgs-glieder*), which form an independent whole, and are by their lithological and palæontological characters, as well as by their structure and stratigraphical succession (*Lagerungs folge*), recognisable as contemporaneous (geologically speaking) products of similar natural processes. According even to this definition, it would appear just to class all the rocks above described, in spite of the distinctly intrusive character of some of them, as belonging to one and the same geological formation,—in short, to the Laurentian series of Sir W. E. Logan, or the Primitive Gneiss formation of Naumann. The last-named geologist certainly distinguishes a separate granite formation, but the rocks included in it are generally more recent than the primitive gneiss or primitive schists. Where, as in Silesia, in Podolia on the Dnieper, in the central plateau of France, in Finland, in Scandinavia, and in the Western Islands of Scotland, granite occurs in similar intimate association with gneissoid rocks as on Lake Superior, Naumann always regards it as part and portion of the primitive gneiss. As early as 1826, Hisinger, in his work on Swedish mineralogy, shewed that the granite which occurs in intimate combination, by lithological transition and otherwise, with the primitive gneiss of Scandinavia, was of contemporaneous origin with it; and in the Pyrenees, La Vendee, Auvergne, the Black Forest and Hungary, according to Coquand, Riviere, Rozet, Rengger, and Beudant respectively, the gneiss and granite of these countries cannot be separated into distinct formations, but form one and the same mass of primitive rock.

II.—THE HURONIAN SERIES.

The rocks of this system, as developed on Lake Superior, present at first sight rather a monotonous and uninteresting aspect to the student of lithology. Large areas are occupied by schistose and fine-grained rocks, the mineralogical composition of which is, in the most of cases, exceedingly indistinct. These rocks are, to a very large extent, pyroxenic greenstones and slates related to them. On closer examination, they are found to exhibit many interesting features, and it is possible to distinguish among them the following typical rocks:—

Diabase.—The granular varieties among these greenstones belong to this species. It is developed at several points on Goulais River, at some distance to the west of the Laurentian rocks already referred to. It is usually fine-grained, pyroxene is the preponderating constituent, and chlorite is present in considerable quantity in finely disseminated particles. The felspar is in minute grains, and, in many instances, it is only on the weathered surface of the rock that its presence can be recognized. One variety of this rock from the Goulais River has a specific gravity of 3·001. Its colour is dark green, and that of its powder light green. The latter, on ignition, lost 2·29 per cent. of its weight, and changed to a brown colour. On digestion with sulphuric acid, 22·99 per cent. of bases were dissolved from it, which circumstances would seem to indicate that the felspathic constituent is decomposable by acids, and is therefore, in all likelihood, labradorite. This rock is underlaid to the south-west by greenstone schist, striking N. 65° W., and dipping 75° north-eastward, and is overlaid by amygdaloidal diabase and greenstone slates, striking N. 66° W., and dipping 49° north-eastward. Granular diabase is also met with a few miles higher up the river from the rocks just mentioned, associated with porphyritic diabase and diabase schist, the latter striking N. 55° to 65° W., and dipping 60° north-eastward. Similar rocks were observed on the hills between Bachewahnung and Goulais Bay, and at several points on the north shore of the lake between Michipicoten

Harbour and Island. In the neighbourhood of, and on the road to, the Bachewahnung Iron Mine, they are also plentiful. Not unfrequently the pyroxene in them assumes the appearance of diallage.

Augiteporphyry.—The porphyritic diabase above referred to is a small-grained diabase, in which are disseminated crystals of pyroxene, about three-eighths of an inch in diameter. The specific gravity of the rock is 2·906. Its fine powder has a light greenish grey colour, which changes on ignition to dark brown, 2.01 per cent. of loss being at the same time sustained. Hydrochloric acid dissolves from it 23·48 per cent. of bases.

Calcareous Diabase.—The amygdaloidal diabase above mentioned is the same rock as is termed by Naumann *Kalkdiabase.* It is a fine-grained diabase, somewhat schistose, in which oval-shaped concretions of granular calcspar occur. The latter are not, however, always sharply separated from the mass of rock, which is slightly calcareous. The amygdules, if such they can be called, have their longer axis invariably parallel with each other, and with the schistose structure of the rock.

Diabase Schist.—This rock occurs much more frequently than either of those just described. It is, indeed, difficult to find a diabase among these Huronian rocks which does not exhibit a tendency to parallel structure, or which does not graduate into diabase schist. But the latter rock occupies considerable areas by itself, not only on Goulais River, but also on that part of the north shore referred to in this paper. The higher hills to the north-east of Goulais Bay consist, to a large extent, of this rock. Apart from its schistose structure, it possesses the characters of diabase. For example, a specimen of the rock from the north shore has a specific gravity of 2·985. Its powder, which is light grey, changes on ignition to light brown, losing 1·43 per cent. of its weight. On digestion with hydrochloric acid, it loses 14·24 per cent. of bases; and with sulphuric acid, 16·12 per cent. It is fusible before the blow-pipe. Many of these schists are pyritiferous and calcareous, and these graduate frequently into greenstone slate.

Greenstone and Greenstone Slate.—The rocks above mentioned, being small-grained, are recognizable without much difficulty; but, besides these, and occupying much more extensive areas, there occurs finely granular and schistose rocks, many of them doubtless of similar composition to the above mentioned diabase and diabase schist. Where the transition is traceable from the latter rocks to those of a finer grain, the same names are perhaps applicable. But since this is not always the case, it would seem advisable to make use of other terms for them until their composition is more accurately determined. The names aphanite and aphanite slate have been applied to rocks such as these, but since the former term has been applied by Cotta to compact melaphyre, it would seem better for the present to continue the use of the other terms, compact greenstone and greenstone slate, especially since the signification of the first of these has been so limited by Naumann as to denote pyroxenic greenstones only, thus distinguishing them from the hornblendic greenstones or Diorites. These pyroxenic greenstones, or fine-grained diabases, frequently contain more chlorite than the coarser-grained varieties. They are very frequent on the Goulais River, in the district between it and Bachewahnung Bay, and in the neighbourhood of the Bachewahnung Iron Mine. One specimen from a point four miles north-east of Goulais Bay yields 21·44 per cent. of bases to sulphuric acid. Its powder is dark green, changing on ignition to dark brown, and losing 1·72 per cent. of its weight. These greenstones are seldom destitute of iron pyrites. Quartz never occurs in them as a distinct constituent, and even in veins it is rare; but there are a few occurrences of greenstones which are lighter in colour, more siliceous, and harder than others, and which have possibly become so by contact with quartzose rocks. On the other hand, they are frequently found impregnated with calcareous matter. By assuming a schistose structure, these greenstones often graduate into greenstone slate, an apparently homogeneous rock, generally of a dark greenish grey colour and slaty texture. The latter character is sometimes so marked, that it becomes difficult to distinguish it from clay slate. The greenstone slates however, would seem to differ from the latter rock in the small quantity of water which they contain, their generally higher specific gravity, and in their yielding nothing which would form a good roofing slate. On the other hand, they are related to the greenstones and diabase schists not only by gradual transition, but in some of their physical characters. For instance, a greenstone slate from Dog River, on the north shore, of a dark grey colour, has a specific gravity of 2·738, and loses 1·62 per cent. of its weight on ignition, in which operation the colour of its powder changes from a greenish white to a decided brown. It yields to hydrochloric acid 16·44, and to sulphuric acid 10·29 of bases.

Siliceous Slate.—In many places bands of such dark coloured slate as that just described are interbedded with others which are lighter coloured and more siliceous. Such banded slates may, for instance, be observed on the north-east shore of Goulais Bay. Here the darker slate is very evenly foliated, of a dark greenish-grey colour, and has a specific gravity of 2·685. Its powder is light green, changing on ignition to light brown, and losing 2·02 per cent. of its weight. It yields to sulphuric acid 16·75 of bases. The rock of the lighter bands is highly siliceous, and in fusibility equal to orthoclase. The powder has a reddish grey colour, which changes on ignition to brownish grey, 0·54 per cent. of loss being at the same time sustained. Hot sulphuric acid removes only 3·79 per cent. of bases. A similar association of slates is found at a point bearing 41° 30' E. from the east end of Michipicoten Island. Here, a series of lighter and darker coloured bands of very decided slate occur, striking N. 78° to 86° W., and dipping 50° to 52° northward. They are overlaid by a band of dark green slate, which contains granitic pebbles, and this band is again overlaid by light coloured slates. Small bands may be observed to leave the dark green slates and to join with those of a lighter colour. The latter are not only lighter in colour, but harder and less dense, and occasionally show on their cleavage planes a silky lustre. A specimen gave a specific gravity of 2·681, and its powder, which was almost quite white, lost 1·12 per cent. on ignition, becoming slightly brown. It fuses only in fine splinters, and, generally, the fusibility of these slates is the greater the darker their colour.

Chlorite Schist.—Some of the greenstone slates occasionally contain an unusually large quantity of chlorite, and sometimes so much as to form chlorite schist. This schist forms the side rock of the Palmer Mine on Goulais Bay.

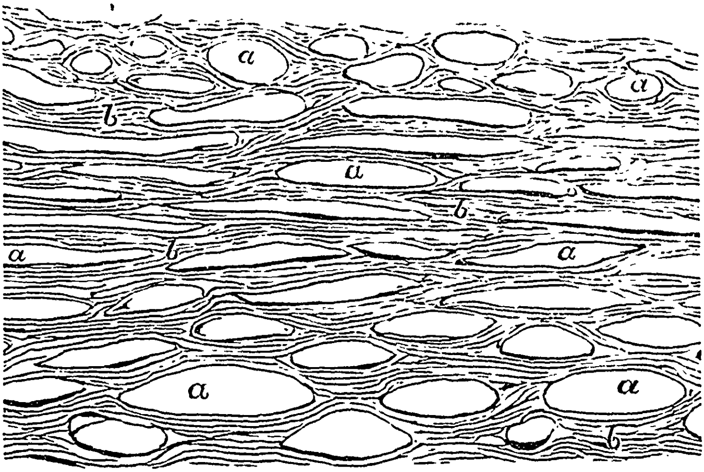
Quartzite.—This rock is of less frequent occurrence than I had anticipated. It is most frequent on the west and south-west side of the hills between Bachewahnung and Goulais Bay, and in the district north-eastwards from Sault Ste. Marie.

Hematite.—This mineral often occurs in such quantity as to constitute rock masses. It will however be referred to under the economic minerals of the series.

Greenstone Breccia.—The occurrence of angular fragments of other rocks in the greenstones above described is by no means rare, and the resulting breccias are common between Bachewahnung and Goulais Bays. In the majority of instances where the matrix is granular, the fragments are angular; on the other hand, where the matrix becomes schistose, the fragments are generelly rounded, and there results the slate conglomerate so characteristic of the Huronian series.

Slate Conglomerate.—This rock is extensively developed at the mouth of the Dore River, some distance to the west of Michipicoten Harbour. Its matrix is the greenstone slate above described. The boulders and pebbles which it encloses seem, for the most part, to be granite, and are rarely quite round in form. The most of them are oval or lenticular shaped, and then their outlines are scarcely so distinct as in the case of those which approach more closely to the round form. Very frequently those of a lenticular form are drawn or flattened out to such an extent that their thickness decreases to a quarter or half-an-inch, and they are sometimes scarcely distinguishable from the slate, except by their lighter colour. Part of the rock exhibits merely a succession of lighter and darker coloured bands, the former of which sometimes resemble in form the flattened pebbles above-mentioned. On account of the presence of these lighter bands, it is often impossible to select a piece which may be regarded as the real matrix of the rock. As in the case of some of the rocks above described, the light bands are more siliceous and less dense than the darker ones. The latter are, not unfrequently, calcareous. A specimen of this character had a density of 2·768 to 2·802. Its powder was light green, which changed on ignition to light brown, with a loss of 2·75 per cent. On treatment with sulphuric acid, it effervesced strongly, and experienced a loss of 36·85 per cent. Iron pyrites impregnates the matrix quite as frequently as calcareous matter. The direction of the lamination in the matrix is parallel with the longer axis of the lenticular pebbles, and where the boulders are large (they seldom exceed twelve inches in diameter) and round, the lamination of the slate winds round them, and resumes its normal direction after passing them. Occasionally a flattened pebble is seen bent half round another, and, among the very thin pebbles, twisted forms are not uncommon. The nature of the pebbles, especially of those which have been flattened, is sometimes very indistinct. The quartz is generally easily recognized in the larger boulders, but the felspar has lost its crystalline character, and the mica is changed into dark green indistinct grains, where it has not altogether disappeared. Besides the granitic pebbles, there are others which seem to consist of quartzite. An idea of the structure of this rock is attempted to be given in figure 5.

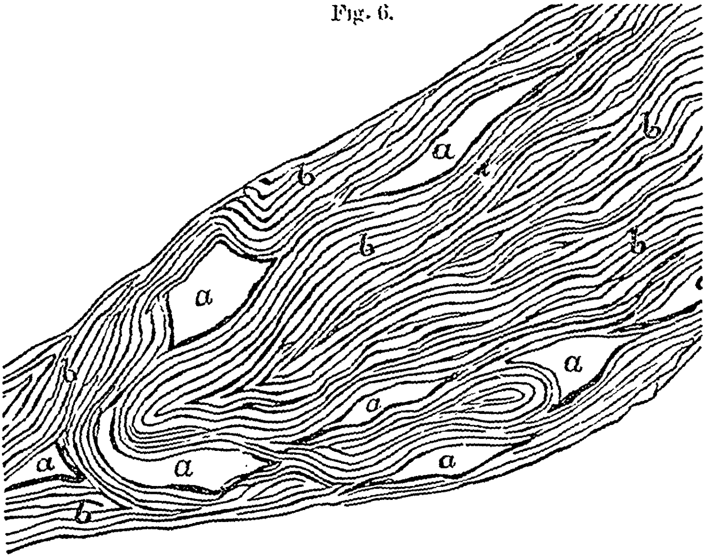
Fig. 5.



a. Granite boulders, and long drawn masses. *b.* Schistose matrix.

The manner in which these rocks are occasionally associated with each other is calculated, as in the case of the Laurentian rocks, to suggest to the observer some definite ideas regarding their origin. Equally instructive is the manner in which they adjoin the Laurentian areas at several points on the north shore, between Michipicoten Harbour and Island. I paid some attention to that point of junction which lies to the west of Eagle River, the precipitous cliffs to the east of which consist principally of diabase schist and greenstone slate. A few miles to the west of these cliffs, and at a point bearing N. 29° E. from the east end of Michipicoten Island, the Laurentian granite is penetrated by enormous dykes of dense basaltic greenstone (having the peculiar doleritic glitter when fractured), which contain fragments of granite. This greenstone is also seen in large masses, which can scarcely be called dykes, overlying the granite and enclosing huge masses of that rock, one of which I observed to be cut by a small vein of the greenstone. From this point to Eagle River those two rocks alternately occupy the space along the shore, seldom in such a manner as to show any regular superposition of the greenstone on the granite, but almost always more or less in conflict with each other. The greenstone, however, becomes more frequent towards the east, and at Eagle River it has almost wholly replaced the granite, and assumed a lighter colour and an irregular schistose structure. The strike of these schists is, at places, quite inconstant; they wind in all directions, and what appear, at first sight, to be quartz veins, accompany their contortions. On closer inspection, however, of the largest of these, they are seen to be of granite, but whether twisted fragments of that rock or really veins of it, is, at first glance, very uncertain. Observed superficially, they have the appearance of veins, but they do not preserve a straight course, and bend with the windings of the enclosing schist. They often thin out to a small point and disappear, and, a few feet or inches further on in the direction of the strike, reappear and continue for a short distance. Sometimes a vein thins out at both ends and forms a piece of granitic material or a lenticular shape, always lying parallel with the lamination of the enclosing slate. Figure 6 is a representation of the phenomena here described.

Fig. 6.



a. Fragments and contorted pieces of granite.
b. Slates enclosing same.

At another point of junction, on the north shore, to the east of that above described, there is a large development of similar basaltic greenstone. Its constituents, with the exception of iron pyrites, are indistinguishable; it has a greenish black colour, and a specific gravity of 3. Its powder has a dark green colour, which changes on ignition to dark brown, with a loss of 1·79 per cent. of its weight. It yields to sulphuric acid 18·41 per cent. of bases.

It exhibits numerous divisional planes and a tendency to slaty structure, the direction of which is not, however, parallel with that of the divisional planes. It contains numerous fragments and long drawn contorted masses of granite, which are best discernible on the worn surface of the rock, and not readily so where it is freshly fractured. To the eastward it changes to a much harder light grey siliceous rock, having a specific gravity of 2·709 only. In fine powder this rock is white, but on ignition becomes brownish, and loses 0·55 per cent. of its weight. It yields only 4·62 per cent. of bases to sulphuric acid. At one place it seems to contain fragments and twisted pieces of the dark greenstone, and further eastward it assumes the character of a breccia, granite fragments being enclosed in the slaty rock, which is at some points darker, at others lighter, coloured. The fragments are sometimes quite angular, and sometimes rounded off, and not sharply separated from the matrix. Their longer dimensions are invariably parallel with the lamination of the matrix. The distance over which the transition extends renders it impossible to give any accurate sketch of the phenomena described.

Similar relations are observable at the junction of the two formations in the north-east corner of Bachewahnung Bay. Here the greenstone is compact, but still possesses the glittering basaltic fracture. The Laurentian rock is a highly granitic gneiss, and pieces of it are enclosed in the dark greenstone, which at one place seems to underlie the granite. A reddish grey felsitic rock, with conchoidal fracture, is observed at the point of junction. Eastward from it banded traps occur, striking N. 55° W., together with greenstone—breccia, and conglomerate. On ascending the hills behind this point another breccia is observed, of which the matrix is greenstone and the fragments granite.

With regard to the succession of these rocks, it will doubtless be found a matter of very great difficulty to establish any such, even if any order of superposition of a tolerably regular character should exist among them. That this is not very likely to be the case, will appear from the considerations yet to be advanced regarding the origin of these rocks. As to their general strike, it is scarcely possible to give any such, but within certain limits a tolerably constant strike may be observed. In the Huronian area, betwixt Goulais River and Bachewahnung Bay, although there are occasional north-easterly directions, the strike generally ranges from N. 40° to N. 80° W. On the north shore it is generally east and west, seldom deviating more than 20° to the north or south of these points. The following observations were made in the neighbourhood of Eagle River, at points where the slates appeared most regular: N. 83° E., dip 45° northward; N. 80° W., dip 46° northward; N. 45° E., dip 34° north-westward.

In the foregoing description an attempt has been made to delineate with fidelity the most important features of the Huronian formation as developed on Lake Superior. It is now proposed to give a fair unstrained interpretation of the characters stamped upon the rocks of that series. The fact of the Laurentian granite being pierced, as above described, by Huronian rocks, and the fact of their enclosing fragments of such granite, proves incontestably that some of them are of eruptive origin, and of later age than the Laurentian series. The enclosure of the huge sharply angular fragments of granite in the very basic greenstone, above described, stands in intimate connection with the enclosure of smaller and contorted granite fragments in a matrix of similar chemical composition, but different (slaty) structure. The appearances visible near Eagle River, of which figure 6 is an illustration, prove that enclosed granitic fragments sometimes undergo modifications of form through contact with certain Huronian rocks. In Foster and Whitney's Lake Superior Report (Part II., pp. 44 and 45), analogous phenomena are described, but the exactly opposite conclusion is arrived at, viz., that the granite is in the form of veins, and is the newest rock. There would seem to be only the two methods of explaining the facts described: either the granite forms veins penetrating the schistose greenstones, in which case the latter are the oldest rocks, or it is in the form of contorted fragments, in which case the enclosing rocks must be of eruptive origin. The fact that the granitic fragments do not cut but run parallel with the slates which enclose them, is the strongest argument against considering them to be veins. The supposition that they are long drawn and contorted fragments seems to be most in harmony with the facts stated, and with what is known as to the relative ages of the Laurentian and Huronian rocks. The true explanation most likely is, that the basic greenstone, after enveloping the granitic fragments, *continued for some time in motion, and, previous to* solidification, softened and rendered plastic the fragments, which then became drawn out in the direction of the flow of the igneous mass, and forced to accompany its sinuosities, and that the motion of the fluid mass previous to and during solidification developed in the greenstone its 'schistose structure. The other facts, described above as observable at a considerable distance east of Eagle River, shew that something more than a mere modification of form is caused by the action of basic greenstone upon granite fragments. Not only are the latter there observed to be enclosed in, softened by, and twisted around with the greenstone, but the phenomena observed fully justify the supposition that they have been dissolved in it, that is to say, actually fused in and incorporated with its material. The fragments are seen to be firmly joined together with the enclosing rock, especially where the latter becomes more siliceous. Furthermore, their sharp angles are often rounded off, indicating plainly that these parts were first melted away by the fluid greenstone. Moreover, the product of the union of the latter with the dissolved parts of the granite is plainly visible. It is the siliceous slate rock described above as forming in places the matrix of the breccia. This siliceous rock, the specific gravity of which is much lower than that of the greenstone, is further seen to be twisted about with the latter in such a manner as, in its turn, to envelope parts of the greenstone, thus shewing that motion assisted the incorporation of the two. The reddish grey felsitic rock, mentioned as occurring at the junction of the two formations in the north-east corner of Bachewahnung Bay, has doubtless had a similar origin to t' at of this siliceous rock, and it is not unlikely that the banded traps and slates, so frequently found among Huronian rocks, are attributable to a similar mode of formation. Closely connected with the breccias just alluded to, so far as regards the cause of its peculiar structure, is the Huronian slate conglomerate. It is impossible to examine closely this rock without being impelled to the conclusion that its origin is not very different from that of the breccias; that its matrix has been a fused mass, flowing slowly but constantly in the one direction; and that its boulders are merely fragments which have been half melted and rounded off by contact with the igneous rock. The oval, twisted, lenticular and long drawn forms of the boulders are such as could never have been produced by ordinary attrition, and they frequently furnish examples of such intimate amalgamation with the matrix as are never found in aqueous conglomerates. Further, the fact of the boulders being frequently drawn out into what are simply bands of light coloured slate, not only disproves the sedimentary origin of the conglomerate, but indicates the manner in which the association of greenstone slate and siliceous slate above described have been formed. They have simply been produced where no tumultuous motion was at hand thoroughly to incorporate the material of the greenstone with that derived from the softened fragments, but where a steady continuous motion, always in the one direction, drew out the materials of the different slates into long bands side by side with each other. It thus seems to us reasonable, and quite compatible with a scientific interpretation of the facts above given, to explain the origin of by far the greater number of the above enumerated Huronian rocks upon a purely igneous theory; and it has occurred to us that many of the instances of local metamorphism, recorded by geologists, in which the contact of an igneous rock caused the silicification or lamination of another, might be capable of thorough explanation in a manner similar to that in which we have tried to account for the origin of the breccias, conglomerates, siliceous greenstones and banded slates, which constitute such a large part of the Huronian series.

The Huronian series, whatever its mode of origin may have been, must undoubtedly be regarded as an independent geological formation. It has been represented as being "a mixture of the St. Alban's group of the upper Taconic with the Triassic rocks of Lake Superior, the trap native-copper bearing rocks of Point Keeweenaw, and the dioritic dyke containing the copper pyrites of Bruce mine on Lake Huron" * but surely such a description is based upon a misconception of Sir W. E. Logan's views on the subject. Until its discovery by Sir William, the Huronian formation was unknown to geologists as a separate and independent system, and even now it is only in comparatively few countries besides Canada that it has been shown to exist. On a former occasion, in the columns of the *Naturalist* † I endeavoured to shew that the Azoic schists of Tellemarken, in Norway, were almost identical in lithological characters with the Huronian rocks, and Dr. J. J. Bigsby ‡ shortly afterwards insisted upon the fact of their being the same formations. Dr. Bigsby is of opinion that the Huronian also occurs on the Upper Loire, in France, and that it is a totally distinct formation from the Cambrian, with which it has hitherto been customary to associate it. The Huronian forms part of what Naumann calls the primitive slate formation.

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* Marcou; The Taconic and Lower Silurian Rocks of Vermont and Canada.

† Vol. vii, p. 113.

‡ Quart. Journ. Geol. Soc. Vol. xix, p. 49.

Besides the black and greenish black dykes which occur in the neighbourhood of, and stand in connection with, Huronian rocks, there are others which occur at a distance from Huronian areas, and whose rocks differ somewhat from those of that formation. This is the case, for instance, with a set of dykes which occur on the south-east shore of Goulais Bay, cutting Laurentian rocks. They are there separated from the gneissoid rocks by very distinct joints. They vary in thickness from nine to seventy feet, and strike N. 72° to 75° W. In the widest veins the rock is fine grained at the side and small grained in the centre, so that even there it is difficult to determine its constituents. They seem, however, to be dark green pyroxene and greyish felspar, with magnetic and minute grains of iron pyrites. The rock has a specific gravity of 2·974. Its powder, from which a magnet extracts magnetite, has a grey colour, which changes on ignition to a dirty brown, with a loss in weight of 1·67 per cent. Hydrochloric acid produces no effervescence, but removes 21·74 per cent. of bases. Sulphuric acid removes 20·83 per cent. The presence of magnetite and absence of chlorite would seem to indicate that the rock inclines more to the nature of dolerite than diabase. A similar vein of fine grained rock penetrates the syenite of Gros Cap, on the summit of that hill, striking N. 40° W. A very large mass of small grained doleritic rock likewise occurs at the mouth of the Montreal River, on its south bank. It probably forms a dyke of very large dimensions in the granitoid gneiss there. It consists, seemingly, of black augite, white or greyish white felspar (on some of the cleavage planes of which parallel striæ are distinctly observable), and magnetite. Its specific gravity is 3·090. Its powder yields magnetite to the magnet, and does not effervesce on treatment with sulphuric acid, which removes 11·15 per cent. of bases. Other dykes of this nature cut the reddish granite of the north shore opposite Michipicoten Island, and, nearer to Michipicoten Harbour, a sixty feet dyke of diorite cuts the grey granite. It is fine grained at the sides, but granular and even porphyritic in the centre. Its direction is N. 63° E. About a mile further east another dyke occurs, which seems to contain fragments of granite. Close to the landing place of the Begley Mine, in Bachewahnung Bay, a dioritic dyke, bearing N. 80° E., cuts gneissoid rocks Further investigation is necessary to determine what relation, if any, these dykes bear to the Huronian series.

(To be continued.)

ON SOME REMAINS OF PALÆOZOIC INSECTS
RECENTLY DISCOVERED IN
NOVA SCOTIA AND NEW BRUNSWICK.

By J. W. Dawson, LL.D., F.R.S., F.G.S.

In connection with the preparation of the second edition of "Acadian Geology," I have obtained, from friends who have been engaged in geological investigations in Nova Scotia and New Brunswick, some interesting illustrations of the entomology of the Carboniferous and Devonian Periods, which I have thought it might be useful to publish in advance of the appearance of my work.

1. Carboniferous Insects.

The existence of insects in the Carboniferous period has long been known. The coal formations of England and of Westphalia afforded the earliest specimens; and, more recently, some interesting species have been found in the Western States.* They belong to the order of the Neuroptera (shad-flies, etc.), the Orthoptera (grasshoppers, crickets, etc.), and Coleoptera (beetles, etc.)

In the coal-field of Nova Scotia, notwithstanding its great richness in fossil remains of plants, insects had not occured up to last year, except in a single instance—the head and some other fragments of a large insect, probably Neuropterous, found by me in the Coprolite or fossil excrement of a reptile enclosed in the trunk of an erect Sigillaria at the Joggins, along with other animal remains. This specimen was interesting, chiefly as proving that the small reptiles of the coal period were insectivorous, and it was noticed in this connection in my "Airbreathers of the coal period." Last year, however, Mr. Jas. Barnes, of Halifax, was so fortunate as to find the beautiful wing represented in Fig. 1, in a bed of shale, at Little Glace Bay, Cape Breton. The engraving is taken from a photograph kindly sent to me by Rev. D. Honeyman, F.G.S. It will be observed that in consequence, probably, of the mutual attraction of loose objects floating about in water, a fragment of a frond of a fern, *Alethopteris lonchitica*, lies partly over the wing, obscuring its outline, but bearing testimony to its carboniferous date. The wing has been examined by Mr. S. H. Scudder, of Boston, who has made such specimens his special study, and who

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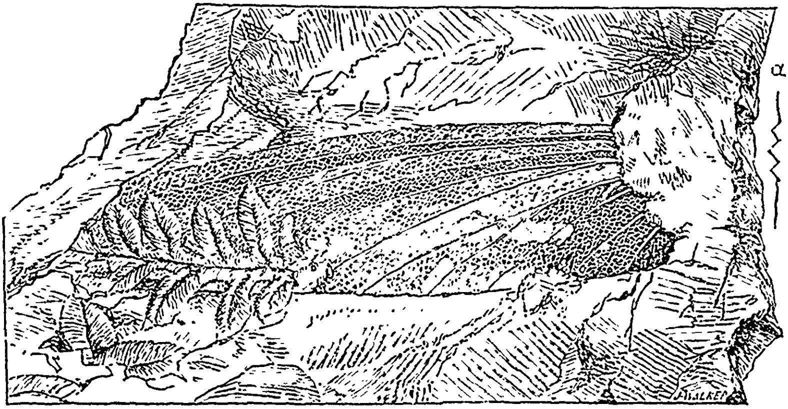
* See Lyell's Elements, and Dana's Manual for references.

refers it to the group of Ephemerina (day-flies, shad-flies) among the Neuroptera, and has named it *Haplophlebium Barnesii.* It must have been a very large insect—seven inches in expanse of wing—and, therefore, much exceeding any living species of its group. When we consider that the larvæ of such creatures inhabit the water, and delight in muddy bottoms rich in vegetable matter, we can easily understand that the swamps and creeks of carboniferous Acadia, with its probably mild and equable climate, must have been especially favorable to such creatures, and we can imagine the larvæ of these gigantic ephemeras swarming in the deep black mud of the ponds in these swamps, and furnishing a great part of the food of the fishes inhabiting them, while the perfect insects emerging from the waters to enjoy their brief space of aerial life, would flit in millions over the quiet waters and through the dense thickets of the coal swamps.

Mr. Scudder describes the species as follows:—

Fig. 1.



(*a*) Profile of base of wing.

"HAPLOPHLEBIUM BARNESII Scudder; (Fig. 1.)—This is probably one of the ephemerina, though it differs very much from any with which I am acquainted. The neuration is exceedingly simple, and the intercostal spaces appear to be completely filled with minute reticulations without any cross-veins. The narrowness of the wing is very peculiar for an Ephemeron. The form of the wing and its reticulation remind me of the Odonata, but the mode of venation is very different; yet there is apparently a cross-vein between the first and second veins in the photograph (not rendered in the cut) which, extending down to the third vein, occurs just where the "nodus" is found in Odonata, and if present would, unquestionably, remove this insect to a new synthetic family between Odonata and Ephemerina. I cannot judge satisfactorily whether it is an upper or an under wing. The insect measured fully seven inches in expanse of wings —much larger than any living species of Ephemerina."

2. DEVONIAN INSECTS.

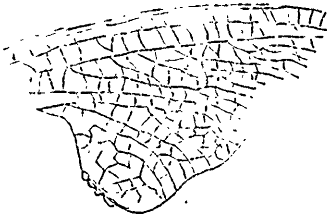
The only known remains of insects of this age are the wings of four species found by Mr. C. F. Hartt, in the plant-bearing Devonian Shales of St. John, New Brunswick. The figures now given of these remains, taken from drawings made by Mr. Scudder, though they represent fragmentary specimens only, are of the highest interest, as the most ancient remains of insects known to us, and contemporary with the oldest known land flora; their age being probably about that of the Hamilton or Chemung formations of New York.

Their geological date is unquestionable, since they are found in beds richly stored with species of Devonian plants, and unconformably underlying the oldest portion of the carboniferous series. The containing beds are fully described in a paper by Mr. Matthew, in the *Journal of the Geological Society of London*, and also in Prof. Bailey's *Report on the Geology of Southern New Brunswick* —Appendix A, on the Devonian Plant locality of Lancaster, by Mr. C. F. Hartt.

These insects, it will be observed, are of older date than the carboniferous species previously noticed, and they bore the same relations to the land and the water of the Devonian which the former did to those of the carboniferous period. They were all Neuropterous insects, and allied to the Ephemeras. It is interesting, however, to observe that, like many other ancient animals, they show a remarkable union of characters now found in distinct orders of insects; or constitute synthetic types, as they have been named. Nothing of this kind is more curious than the apparent existence of a stridulating or musical apparatus like that of the cricket, in an insect otherwise allied to the Neuroptera. This structure also, if rightly interpreted by Mr. Scudder, introduces us to the sounds of the Devonian woods, bringing before our imagination the trill and hum of insect life that enlivened the solitudes of these strange old forests.

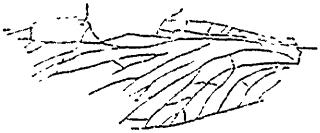
Mr. Scudder has kindly furnished descriptions of these insects as follows:—

Fig. 2.



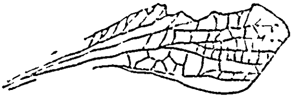
"PLATEPHEMERA ANTIQUA Scudder; (Fig. 2.)—The direction of the principal nervures in this insect convinces me that it belongs to the Ephemerina, though I have never seen in living Ephemerina so much reticulation in the anal area as exists here—so, too, the mode in which the intercalary nervules arise is somewhat peculiar. It is a gigantic species, for it must have measured five inches in expanse of wings—the fragment is a portion of an upper wing.

Fig. 3.



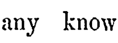
"HOMOTHETUS FOSSILIS Scudder; (Fig. 3.)—At first sight the neuration of the wings seems to agree sufficiently with the Sialina to warrant our placing it in that family; but it is very interesting to find, in addition to minor peculiarities that near the base of the wing, between the two middle veins, there is a heavy cross-vein from which new prominent veins take their rise; this is characteristic of the Odonata, and of that family only. We have, therefore, a new family representing a synthetic type which combines the features of structure now found in the Odonata and Sialina, very distant members of the Neuroptera. The fragment is sufficiently preserved to shew the direction, extent and mode of branching of nearly every principal nervure. It is evidently a portion of an upper wing; the insect measured not far from three one-half inches in expanse of wings.

Fig. 4.



"LITHENTOMUM HARTTII Scudder; (Fig. 4.)—This was the first specimen discovered by Mr. C. F. Hartt. I have therefore named it after him:—apparently, it does not belong to any family of Neuroptera represented among living forms. It agrees more closely with the family Hemeristina, which I founded upon a fossil insect discovered in Illinois, than it does with any other; but is quite distinct from that, both in the mode of division of the nervures and in the peculiar cross-veining. The fragment which Mr. Hartt discovered is very imperfect; but, fortunately, preserves the most important parts of the wing. I am inclined to think that it was a lower wing. The insect probably measured three one-half inches in expanse of wing.

Fig. 5.



"XENONEURA ANTIQUORUM Scudder; (Fig. 5.)—Although in this fragment we see only the basal half or third of a wing, the peculiar mode of venation shows that the insect cannot belong to any known family of Neuroptera living or fossil; yet it is evidently a neuropterous insect. In addition to its other peculiarities, there is one of striking importance, viz.:—the development of veinlets, at the base of the wing, forming portions of concentric rings. I have endeavored in vain to explain these away as something foreign to the wings, accidentally introduced upon the stone; and I know of nothing to which it can be compared but to the stridulating organ of some male Orthoptera! It is difficult to tell whether the fragment belongs to an upper or an under wing. Its expanse of wings was probably from two to two one-half inches."

ON THE RELATION BETWEEN THE GLACIAL DEPOSITS OF SCOTLAND AND THOSE OF CANADA.

By the Rev. HENRY W. CROSSKEY.

Principal Dawson, of Montreal, among his other great services to Geology, has very carefully investigated the Canadian glacial beds, and the following notes are suggested by a study of his writings:—

I. The difference between the glacial fossil fauna of Canada and that now existing in the Gulf of St. Lawrence is far less marked than the difference between the glacial fauna of the Clyde beds and that now existing in the Firth. The fossil fauna of Canada, in its general aspect, and in the proportions and characteristic varieties of its species, is slightly more arctic than that of the Gulf, but does not present that broad contrast with which we are familiar between the fossil contents of our local clays and the living inhabitants of our waters. There are only two species in Canada which can be regarded as locally extinct, viz., *Leda Portlandica* (Gould), and *Astarte Laurentiana* (Lyell); while in Scotland there is a very remarkable list of species fossil in the clay, but extinct through the whole range of the neighbouring seas. Upon the west, we find:

Tellina calcarea *(proxima.)*
Saxicava (*Panopœa*) Norvegica.
Astarte borealis.
Leda pernula.
Pecten Islandicus.
Modiolaria discors.
Littorina limata (*Loven*).
Mangelia pyramidalis.
Natica affinis (*clausa*).
Trophon clathratus (*scalariformis*).
Velutina undata.
Cyclostrema costulatum.
Balanus cariosus (*Darwin*).

The eastern clays comprise extinct species even more artic in character, viz.:—

Leda arctica (*Portlandica, Gould*).
  „ lucida.
  „ thraciæformis.
Pecten Grœnlandicus.
Thracia myopsis.
Cardium Grœnlandicum.
Scalaria Grœnlandica.

It is evident, therefore, from this very marked contrast, that the change of climate in Scotland has been more complete than in Canada. From this fact important physical consequences ensue: the glacial epoch cannot have been caused by any of those cataclysmal agencies to which it has been attributed. Any heaping up of the land at the North Pole; or passage of the earth through colder regions of space; or shiftings of the earth's axis; or alteration in the heat-conducting power of the atmosphere, would leave, I apprehend, a more uniform distribution of climatic results, and obliterate those delicate proportions of species, varying in different beds of the same epoch, in exact analogy to those variations produced by the causes now at work. To account for the fact we are examining, there must have been a deflection of the Gulf Stream from our coasts. The effect of the Gulf Stream is shown by the lingering of a species like *Saxicava* (Panopæa) *Norvegica* upon the Dogger bank, which is protected from its influence, and subject to an arctic current, while it is extinct on the west of Scotland. Moreover, the existence of *Pecten Islandicus* in its natural position over large beds in the glacial clay, combined with the fact of its total absence, not only from our present sea, but from any intermediate bed, renders its comparatively sudden extinction by warmer currents taking the place of the more arctic, the most probable hypothesis. The cause of extinction must have been quiet, or its position would not have been so natural, and at the same time sufficiently marked to permit little lingering. The deflexion of the Gulf Stream must be considered in connection with those movements of the land which we know to have been going on in Scotland during the whole epoch. The subsidence indicated by the shell beds at Airdrie and elsewhere was followed by an elevating movement, which, judging from the peculiarly undisturbed arrangement of different clays in various uplifted beds, must have been very gradual. This elevating movement itself also, is proved by the sections given by Mr. Jamieson[*] to have been broken by a second, although slighter subsidence. The *shifting arrangements of the boundaries of land and water*, occasioned by these undulations of the earth's crust, would materially affect climate, distributing variously the points of insular and more continental temperatures, and in connection with the deflection of the Gulf Stream, would (I am at present disposed to think) sufficiently account for the cold of the glacial epoch. Upon this point, however, Mr. Croll's most able and remarkable papers give him a right to be heard, and I would venture to suggest to him the consideration of the variable eccentricity of the earth's orbit (as claimed by his theory) upon the climate of Canada, so as to account for the fact that its temperature was,

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[*] Journal of Geological Society, Vol. xxi.

during the glacial epoch, so little different from that now prevailing, while in Scotland the contrast has been so extreme.

II. Another most important point connected with the Canadian glacial beds, as compared with those of Scotland, is that they occur in a distinct order, whereas in the Clyde district, their order is only a matter of inference.

Dr. Dawson gives some instructive sections. In the lower beds are the deep water fossils, while littoral species occur in ascending order, manifesting the gradual alteration of the old sea bottom.

In collections of Clyde fossil shells we have a mixture of deep-sea coralline, laminarian, and littoral species ; but while we have superimposed beaches, we have no orderly succession in any exposed section, equivalent *e.g.* to that of Logan's farm, Montreal.

By carefully collecting the fossils from each separate pit in Scotland, and comparing them together, it may be proved, I think, that we have beds equivalent to those of Montreal, although our local sections are physically more obscure. Taking our glacial beds as a whole, it cannot be said that they co-existed at one depth, or were even synchronous. The Canadian beds justify the conviction I have long entertained and endeavoured to work out in the field, that our clay beds can be classified, and that there exists a definite order to reward patient research. They also support the proofs we have accumulated in this district of the theory that the rise of land was gradual, and that the passage from the ice epoch to the present was accomplished by forces extending over that vast period of time, necessarily demanded for those very delicate changes, involved in the distribution and redistribution of a specific fauna. It is not simply that a few mollusca disappear from their accustomed haunts—a great deal more is involved in a change of climate as it affects a fauna. Zoophytes, Foraminifera, Entomostraca, must gradually alter their proportions and their specific representatives, as well as mollusca, so that between any two marked points of contrast, must stretch vast periods of geologic time.

III. All our Clyde shells occur in beds, resting upon the oldest boulder clay. The absolute absence of fossils, and the superposition of the shell-bearing clays, are facts which prove that the old boulder clays of the west of Scotland are the produce of land ice. The boulder clay appears the base of the section quoted from Logan's farm, just as it is of our Clyde series.

Undoubtedly, however, it is possible to have a boulder clay with marine remains. This may happen in two ways—(1) a glacier may lap over the sea, and melting, deposit the striated stones and mud which it has gathered on its course; or (2) striated boulders may be dropped from floating ice upon the mud beneath, and when the sea-bottom is uplifted, there will be a boulder clay of marine origin.

Patches of boulder clay containing shells may thus occur along the seaboard, as, for example, at Caithness, and on the east coast of England; but these patches of marine boulder clay will be *newer* than the clay at the base of the Clyde sections. Upon this point I hope soon to submit a detailed argument to the Society. Meanwhile, I remark, as a curious coincidence, that Dr. Dawson pronounces the shells collected from an "indubitable instance of a marine boulder clay" at Rivière-du-Loup, to be, on the whole, a more modern assemblage than those of the Leda clay of Montreal, which rests UPON the boulder clay.

Dr. Dawson gives one or two localities for fossils in "stony clays of the nature of true till;" but in the greater part of his sections, the fossiliferous beds are superimposed on the boulder clay, exactly as in the Clyde sections.

IV. Very curiously, a bed is noted beneath the boulder clay, for which we have a Scottish equivalent. A peat deposit, with fir roots, is found beneath boulder clay at Cape Breton, while at Chapelhall, Airdrie, we have vegetable remains in the same position—indicating the existence in both countries of land in parts afterwards depressed beneath the sea and again uplifted. The exact climate when this land existed, is believed by Dr. Dawson to have been, at Cape Breton, that of Labrador—in this country I believe it to have been such as to support the *Elephas primigenius*, whose remains have been found beneath boulder clay (certainly) at Kilmaurs, and (probably) at Airdrie.

V. The researches of the last few years have brought the Clyde list of fossils into nearer relation to the Canadian list than has hitherto been supposed. The *Leda arctica* from Errol is undoubtedly the *L. Portlandica* of the Canadian beds. This species occurs in such large quantities at Errol as to be characteristic of that clay. The *Astarte compressa* of the Clyde beds is not identical with *A. Laurentiana*, but often approaches exceedingly near to it. *Menestho albula* has been found at Paisley. It is doubtful whether the *Menestho albula* of the Canadian beds is Möller's species. Mr.

J. Gwyn Jeffreys considers a specimen from Quebec to which that name has been affixed to be *Scalaria borealis*. Taking the contents of one section, as collected by Dr. Dawson (this journal, April, 1865); out of twenty species of Lamelli-branchiata, fifteen occur fossil in Scotland, and seventeen out of twenty-seven species of Gasteropoda.

Speaking generally, about two-thirds of the Scottish fossils at present collected are also fossil in Canada, while the differences are no greater than those which geographical position might easily cause. At the period, therefore, when our glacial fossils lived in the Scottish seas, the climate was nearly the same as that prevailing in Canada during the same epoch—that is, slightly colder than in the present Gulf of St. Lawrence. The fossils, however, can not be considered as marking the extreme point of cold reached during the epoch, but rather as indicating the commencement of slightly milder climatic conditions than had hitherto prevailed. When the deposition of the oldest boulder clay commenced (which it must always be remembered is beneath the shell beds in the Clyde sections), the land must have stood higher than at present, and the temperature would be more intense than during its subsidence.

The question of climate as indicated by the fauna, thus resolves itself into this—what conditions would produce in the Clyde a temperature slightly colder than that of the Gulf of St. Lawrence?

The existence of an arctic current, the wide expanse of land in the American Arctic regions, exercising its chilling influence, and other circumstances connected with the directions of the mountain ranges and heights of the watershed, well known to the physical geographer, sufficiently account for the climate of Canada. A corresponding series of circumstances, therefore, would adequately explain the existence of a more arctic climate in Scotland. There is no necessity to introduce causes for the production of cold which do not now exist. Those alterations of level, for which there is ample evidence, would involve re-arrangements of the relative proportions of land and water, and vital changes in the directions of the arctic currents. For the solution of the problems involved in the great history indicated by the fossil fauna of Canada and Scotland, we must first consult those great principles of physical geography, which may now be studied in hourly action over the surface of the globe. From Transactions of the Geol. Society of Glssgow.

ON A SUBDIVISION
OF THE ACADIAN CARBONIFEROUS LIMESTONES,

WITH A DESCRIPTION OF A SECTION ·CROSS THESE ROCKS AT WINDSOR, N.S.

BY C. FRED. HARTT, A.M.

During several excursions made to Nova Scotia, previous to the year 1864, I visited Windsor, Brookfield, Shubenacadie, and Stewiacke, making extensive collections of the fossils of the carboniferous limestone, so abundant at these localities. Taking care to keep all the species obtained from any one bed or set of beds separate from those from any other, I soon found that certain groups of fossils were limited in their occurrence to certain beds, and that by means of these the whole series might be subdivided somewhat after the manner of the sub-carboniferous limestones of the west. In the summer of 1864, I spent some time in examining the same ground, and in working out a section exposed on the river Avon, at Windsor. The collection made at that time I had an opportunity, through the kindness of Prof. Agassiz, of examining at the Museum of Comparative Zoology; but before my studies had been brought to completion, they were interrupted by my Brazilian journey, and as I have in this city no facilities for resuming them, I have sent, for determination, a considerable number of these fossils to Dr. Dawson and Mr. Billings, so that ample material will be afforded for the establishment of the faunal differences of the subdivisions of the Acadian carboniferous limestones, which I shall attempt to point out in this paper.

On the right bank of the river Avon, at Windsor, a few rods below the bridge, there begins a bluff, which, attaining in some places a height of fifty or sixty feet, skirts the shore for the distance of about half-a-mile above the bridge, when it gradually descends into a tract of marsh, which occupies the shore for nearly three-quarters of a mile further up, where there is a good exposure of a heavy bed of limestone seen in a bluff, called the Otis King rock. The bluff below the toll-house of the bridge is composed of drift, a great part of the mass being derived from the underlying dark red, soft, friable, calcareous, marl-like sandstone. At the toll-house the first rocks *in situ* appear buried deeply under the drift deposit, thence southward, for about half the length of the bluff above the bridge, the beds of carboniferous limestone, clayey sandstone, etc., crop out under the drift. Some of the harder beds extend from top to bottom of the cliff, but owing to the softness and friable nature of the marly beds, and the way in which the beds of limestone are broken up by the action of the weather and hidden by drift and *debris*, the section is not easy to work out. Fortunately, the line of strike of the beds is such as to carry them out on the sloping shore, and though they are much hidden by shingle and mud deposited by the turbid Avon, we are able to gather material for the piecing together of our section, and occasionally to gain a clue as to the arrangement of the beds which is not given on the cliff.

Beginning at the beds of the toll-house, and going thence southerly along the shore, we find the following succession of beds:—

The first rocks seen at the toll-house are beds of limestone, having a strike of E. 15° S., and a dip of 65° to the northward, and of which a thickness of about twelve feet is visible. In the upper part these limestones are, in their weathered state, cream coloured, earthy, soft, and highly laminated, but with some compact bands. They afford fucoids of a slender, flattened cylindrical kind, without carbonaceous coating, a Productus of the Cora type, exactly like that so common in a reef just south of the bridge; and a Bakevellia-like shell. In the middle portion is a band of soft, earthy, light lead-colored limestone, apparently full of fucoids, and with a few fragments of shells. In the lower part there is a not very compact, light brown, weathered limestone of a beautiful oölitic structure. Then follows, in descending order, a bed of very friable, fine-grained, greenish sandstone, cemented by carbonate of lime, which is succeeded by a bed of the same character, but of a deep red color from the presence of iron; but this has several greenish layers. This bed occupies the shore for a distance of about seventy-five feet. In the lower part it is much obscured by rubbish. The cliff is then occupied for a distance of about thirty feet (horizontal) by a limestone of a loose texture and a light blueish color mottled with white, and probably altered by the action of the weather. The bed is much fractured and hidden by *debris*. Then succeeds an irregular mass of breccia, composed of angular fragments of limestone, and this rests on beds of light lead-colored, highly laminated calcareous shales, and limestone bands: thickness, six feet; strike, E. 15° S.; dip, 25° northward; fucoids. Underlying this is a highly vesicular limestone, the cavities being lined with minute crystals of calc-spar: thickness, five feet. Then come fifteen feet of light, lead-colored fissile, often highly laminated limestone, which, from its hardness, forms *the most prominent part of the cliff, and extends in a reef down* to low-water mark. These beds are very rich in fossils.

The most characteristic fossil of this bed is a Productus of the true Cora type, but differing from *P. Lyelli* De Verneuil, in its smaller size, its long perpendicular posterior marginal prolongation, its more prominent and less numerous surface lines, which increase by a more regular and frequent implantation or bifurcation.* This Productus is exceedingly common in certain layers of the shelly limestone. *Among the few other forms associated with it* is a Bakevellia, usually indifferently preserved, and a slender branching fucoid, often preserved as a carbonaceous film; minute stems of crinoids occasionally occur. It is worthy of note that crinoidal remains are exceedingly rare in the limestone of the carboniferous about the Basin of Minas, and I have observed only the stems, which are always minute. The dip of these beds varies from 35° to 50° northward; strike, same as last observed.

Succeeding these are beds of a very dark, blackish limestone, very hard, cracking into small irregular pieces, and wearing nodular: thickness five to six feet. This is full of fossils; the most characteristic is a Spirifer, which appears to differ from *Spirifer glaber* Martin, only in its smaller dimensions; a small Rhynconella, with large plaits (*R. Ida, nob.*); a Spirifer like *S. Octoplicatus*, but larger. I have found here a single specimen of a Phillipsia, which differs from *P. Howi* in wanting the tubercles on the axial rings and pleuræ of the side lobes, in the shape of the pygidium, which is more rounded in outline, and in which the grooves are distinctly marked on the six anterior pleuræ. For this species, which appears to be new, I have proposed the name of *P. Vindobonensis*. Dr. Dawson has, in his description of this section, in his Acadian Geology, inadvertently placed this bed on the southern side of the gully about to be mentioned. There is also a minute plaited Aviculopecten which occasionally occurs in this bed. For this series of beds, characterized by *P. Cora* Var. *Nova-Scotica*, and *Spirifer Glaber*, I propose the name of Avon Limestone.

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* Mr. Billings regards this as a variety of *P. Cora*. It may be designated as Var. *Nova-Scotica*, this name being proposed by Mr. Hartt.

Underlying these beds are seven and one-half feet of calcareous sandstone, of a light lead color, and decomposing into a soft, incoherent mass; then nine feet of compact, flaggy, light brown limestone, with shaly partings, apparently without fossils; and very friable shales of a blueish tint, much decomposed at the surface, and hidden by rubbish. Here we have a fault, a dislocation of about six feet. Then comes a bed of red, very friable, marly, calcareous sandstone, of which a thickness of about thirty feet is exposed. Here the surface water has excavated a considerable gully through the soft sandstone. There can be no doubt, as Dr. Dawson has stated, that there is a fault here, for the beds on the other side of the gully are seen dipping southward, and there is no repetition of the strata.

Continuing the section, the first bed seen on the opposite side of the gully is exactly like that last described, and occupies the shore for some sixty feet. This is overlaid by a bed of limestone, flaggy, with more compact bands. In the cliff these beds have a dip southward of 50°, but at its foot they become more nearly vertical, and run out some twenty feet on the beach, with a strike of E. 10° S., and an almost vertical dip, inclining, however, to the south about 96° to 95°. Crossing a belt of mud on the shore at low tide, we find the same beds appearing, with the same strike, near the bed of the river, but their dip is reversed, and they are inclined to the northward at an angle of 25° to 30°. The thickness of beds just described is twenty to twenty-five feet.

A bed of the red, marly sandstone, about thirty-five to forty feet thick, next follows. It seems to be irregularly stratified, and there are several green layers. This same bed, in ascending order, succeeds at low-water mark to that last mentioned. Beds of limestone, with a strong southerly dip, next come, occupying the cliff for a distance of sixty to seventy feet along its base, whence they extend out on the shore for some twenty feet, with an easterly strike and an almost vertical dip. In their line of strike across a belt of mud and shingle, a few yards down the beach, the same beds appear again, describing a slight curve to the north on the inclined beach. Tracing them towards low-water mark, they gradually change their dip towards the north, until, at the bed of the river, it is about 60° N. Examined at the base of the cliff, the limestone of these beds is of a blueish color, weathering light brown, concretionary in the lower part, and with a band in the middle of a beautiful oölitic structure. This limestone appears to be quite unproductive of fossils, except in one or two thin bands, which are closely packed full of minute gasteropods, and the joints of slender stemmed crinoids. Associated with these are occasionally found a fossil resembling a large Dentalium, but Mr. Meek writes me that it does not belong to that genus.* The fossils which characterize this bed seem to me to be quite distinct from those found in the other beds. I have not observed this limestone elsewhere.

A bed of the red, marly sandstone overlies the limestone, appearing also at the foot of the beach, and this is overlaid in turn by a bed of limestone, 'fifteen feet in thickness, having a southward dip of 45°. This last bed is seen to be overlaid by a bed of the red marly sandstone, having a layer of a green tint about a foot thick at its base. The face of the cliff is here not very clear, but the limestone is seen to be broken abruptly off by a fault, and the marly sandstone to occupy the face of the bluff from top to bottom. This fault I developed by cutting away the face of the bluff.

The limestone last described is very compact, and of a light, clear, leaden blue color, weathering, however, to a brown. It seems to be made up of alternate layers of a very hard and concretionary limestone, and of a softer kind, so that they wear unequally, which gives to their upturned edges, exposed on the sea shore, a rubbly appearance. This bed has usually been supposed to be non-fossiliferous, and it is not mentioned by Dr. Dawson in Acadian Geology. Struck with the resemblance the highly tinted limestone bore to that which at Kennetcook affords the *Phillipsia Howi* of Billings, I was led to examine it with care, and was rewarded by finding a specimen of that trilobite, together with a Zaphrentis, common in the Kennetcook and Cockmegun limestones, and a number of other fossils. Among these was a Spirifer over two inches long, a valve of what Mr. Meek refers doubtfully to *Athyris lamellosa* L'Eveille, a Productus quite undistinguishable from the ordinary form of *P. semi-reticulatus* and another species like *P. costatus*, with very long spines. There are also several species of Myoid Lamellibranchs, and occasionally one finds a minute fish tooth. An Athyris, somewhat like *A. subtilita*, but distinct, occurs in this bed, both at Windsor and Kennetcook, together with a Stenopora and a Fenestella

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* It is apparently a *Serpulites.*—J. W. D.

(or Retepora), both of which are not found in the other beds. In Dr. Dawson's collection there is a large Orthoceras and a Bellerophon from Kennetcook. The Kennetcook limestone is quarried for building purposes, and the library of King's College at Windsor is partially built of it. From this limestone Professor How has collected many of these fossils. A fucoid occurs quite abundantly in some of the layers at Kennetcook, but I have never detected it at Windsor.

These same beds appear low down on the shore, but badly exposed, owing to the loose material encumbering the surface. The same limestones, bearing the same fossils, are exposed at Lower Stewiacke, on the Stewiacke River, near the house of Mr. Jacob Stevens, where it has a strike of N. 50° E., and a dip of 45° S.W. This bed is so well characterized, both faunally and lithologically, and has an extension over so large an area, that it seems to merit a special name, and I would propose for it the name of Kennetcook Limestone.

Continuing our examination of the bluff still farther southward from the fault last described, we find the rocks so disintegrated and stratification so obscured by the falling of rubbish over its sloping face, that little else can be ascertained except the presence of beds of marly sandstone and limestone from the oblique lines seen on the face of the bluff. About one hundred yards beyond the fault occurs a bed of snowy white gypsum, containing stellar crystals of Selenite disseminated through it, which, being of a brownish tinge, are very conspicuous on the weathered surfaces. This gypsum was formerly quarried at this point for exportation. If we cross the hill in the line of strike of the bed, we reach, at a short distance from the river, the principal quarry of this vicinity excavated in this same bed, which is here about thirty feet in thickness, with a strike of E. 35° N., and a dip of 15° to 30° to the southward. The excavation made in quarrying the gypsum is some thirty feet deep, one hundred feet wide, and five hundred feet long. The bed does not seem to be very regular, and it appears to be considerably contorted.

Returning to the river side, we find the section fails from the gypsum bed, and it is not until we reach a fence, where the shore bends eastward, that we meet with any exposure of rock of any interest. Here there is an irregular mass of limestone of a brownish color, exceedingly rich in fossils, being almost wholly made up of shells. These are often empty, so as to give the rocks an open texture. Following the higher land of the shore eastward along a marsh for a few rods, we find it making a bend southward once more along a low bluff of the same limestone, and here, as well as at the first named exposure of this limestone, beautiful specimens of its characteristic fossils may be obtained in great quantity. The bed is so badly exposed that its thickness cannot be determined. It has a slight southward dip.

This bed, which I shall call the Windsor Limestone, has afforded me a large number of very interesting species, among which the following may be named as the most characteristic:—

Of Radiates, a few crinoid joints, very minute, have been detected, but they are by no means common. A Stenopora (*Ceriopora spongites* of Acadian Geology) is exceedingly common, and very characteristic of this bed. The fauna of this bed is not rich in Articulates, but it has afforded a Leperditia, a Serpula (?), and part of the cephalo-thorax of another crustacean (a Decapod?), which is in the hands of Dr. Dawson and Mr. Billings for study.*

It is in Mollusks that this bed is especially rich, and of these the following may be named:—

BRYOZOANS.—A species of Fenestella, different from the species occuring elsewhere; very rare.

BRACHIOPODS.—*Rhynchonella Evangelina, nob*†, very common. This has the characteristic oral supports of Rhynconella, which are easily examined, a large proportion of the specimens being hollow. A small Productus of the Cora type is very abundant. It is very different from the other Producti of Nova Scotia, and it differs from *P. Lyelli* De Verneuil, in being constantly smaller, more globose, and wanting in the large marginal prolongations. A Terebratula (*T. sacculus* Mart.) is a common fossil in this bed. I have examined large numbers of specimens of this form, and have compared them, not only with the *T. sacculus* of Davidson's paper, from the overlying bed, but also with specimens of that species from de Koninck's collections in the Museum of

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* The specimen is too imperfect for determination.—J. W. D.

† This is probably the shell which Davidson has referred to in his paper on Acadian Carboniferous Brachiopods as *Rh. pugnus*, but it bears a striking resemblance to the form which he has figured as *Camarophoria globulina ?* This is certainly a Rhynconella, for it has the characteristic oral supports of the genus. It is quite distinct from *Rh. Pugnus*.

Comparative Zoology, but I cannot satisfy myself that they are specifically identical. There is a not uncommon Terebratula-like shell, which shows, finely preserved, the characteristic loop of Centronella (*C. Anna* Hartt). This is the first evidence we have of the existence of this genus above the Devonian.

LAMILLIBRANCHS.—Several species of Aviculopecten are especially abundant. Of one of these, *A. simplex* Daws., Mr. Meek writes me as follows: "There are among the Windsor collection several good specimens of a little shell, exceedingly like the so-called *Pecten pusillus* (not a true Pecten), from the European permian rocks. They are very similar, and, indeed, almost the only differences observable on direct comparison with good European specimens now before me, are the slightly more ventricose form of the valves, and the rather more prominent anterior ear of the left valve of the Windsor shell. Perhaps this ear, in its left valve, is also a little more defined from the swell of the umbo in some of the large specimens from Windsor, but on comparing examples of the same size as the German specimens here (which are not near so large as some figured in foreign works), it is difficult to see characters by which they can be distinguished. They are, in fact, more nearly alike than the figures given of *P. pusillus* by different European authorities, or, in some cases, by the same author, as varieties of that species. In short, if found associated in the same rock at the same locality with *P. pasillus*, few would suspect them to be distinct species." *Aviculopecten fallax* McCoy? Windsor and de Bert River, Dr. Dawson; *A. Nova-Scotica* Daws., Schubenacadie, Dr. Dawson; *Pteronites Gayensis* Daws., Gay's River, Dr. Dawson; *Macrodon elegans* De Koninck? Windsor, Dr. Dawson and Mr. Hartt; *Modiola Pooli* Daws., Windsor, Poole and Hartt. Besides the above, there are several other Lamillibranchs not yet determined.

GASTEROPODS.—*Naticopsis Howi, nob.*, one of the commonest fossils of the Avon beds. I have detected only a single fragment of Conularia in these beds, and this appears to be different from the species of the overlying beds.

CEPHALOPODS.—A single Orthoceras has been collected at Windsor.

The Windsor limestone is well developed at Brookfield and Stewiacke, and Gay's River, where it holds the same fossils as at Windsor. I have not had an opportunity of examining extensive collections from the other Acadian localities, so that I am unable to report its existence elsewhere.

At the eastern end of the little bluff last described, there is an accumulation of broken masses of a limestone, similar to that of the Windsor limestone, but it is lighter in color, more compact, of a light brownish tint, and composed almost entirely of fossil remains, the species are, with rare exceptions, distinct from those which are found in the Windsor limestone. Among the masses of rock here found there is not a single piece from the Avon beds, so that it is evident that here there is a bed of limestone which overlies the Avon beds. Three quarters of a mile farther up the river, across a wide marsh, is the Otis King rock, which is composed of the same limestone and furnishes the same fossils. Here, however, the beds are seen with a slight *northward* dip. The beds in their lower part are less compact than in the upper, where they pass into a very hard fine-grained limestone, capable of taking a high polish. Fossils occur all through the bed, but they are especially abundant in the upper part. This bed which I would call the Stewiacke limestone, appears to be overlaid by a bed of gypsum, seen between the two localities, at the head of the marsh, which appears to occupy a synclinal valley. The Stewiacke limestone is very rich in beautifully preserved fossils.

RADIATES.—Of Radiates there is a great paucity of species, as elsewhere in Nova Scotia; minute crinoid stems are occasionally found, and there is a pretty Stenopora (*S. exilis* Daws.) which is very common, and is one of the most characteristic fossils of this limestone.

ARTICULATES.—Of Articulates there are very few species, a Serpula (?) tube occurs rarely, together with a Leperditia and a Spirorbis.

MOLLUSKS are the reigning type. Bryozoans are represented by a Fenestella, *F. Lyelli* Daws. This is exceedingly abundant and eminently characteristic of this limestone, wherever it occurs. Of Brachiopods there are many representatives. *Prodactus Lyelli* De Verneuil, (*P. Cora,*) is one of the commonest fossils both at Windsor and elsewhere, and this is associated with an abundance of *P. semi-reticulatus*, and the Terebratula referred by the last mentioned author to *T. Sacculus* Martin, and the forms referred by him to *Athyris subtilita, Spirifer acuticostata* De Koninck, and *Spiriferina cristata.* Besides there are a number of Rhynconellæ and other Brachiopods, which appear to be confined to this bed. Lamellibranchs are abundant, and among the most characteristic may be named the following:—

Aviculopecten reticulata, Daws., Windsor and Gay's River; *A. Nova-Scotica* Daws., (*A. plicata* of Acadian Geology); *Macrodon Hardingii* Daws., very characteristic; *Conocardium Acadicum, nob.*, rare. The Gasteropods are all minute and as yet undetermined. A Conularia is occasionally met with at Windsor and Stewiacke.

Of the Cephalopods, we have a large Nautiloid shell, *Nautilus* (*Cryptoceras*) *Avonensis* Daws., not uncommon at Windsor and Stewiacke; a Trematodiscus (?), and also two or more species of Orthoceras. I cannot report a single fragment of a vertebrate for the Stewiacke limestone. *

The question naturally arises as to the relative position of these beds, but this is one which it seems impossible to settle from the Windsor section, and I have seen no localities elsewhere, where their relations to one another were distinctly exhibited. I think that there can be no doubt that the Stewiacke limestone is the highest, the Windsor limestone coming next below, the Kennetcook limestone appears to come next in order, and the oölitic fossiliferous band, to which I give no name, underlies this again, but the Avon limestone at Windsor, is separated from the rest by a fault, and although I believe it to be the lowest of the four limestones, it may be that subsequent observations made elsewhere, may not confirm that belief. These carboniferous limestones whenever they occur, are much disturbed and broken up, while the disintegration of the intercalated soft marly strata and gypsum beds, adds to the obscurity of the exposures.

The resemblance borne by the faunæ of the Acadian carboniferous limestone to the permian of Europe, has been ably discussed by Lyell, Dawson and Davidson; but these gentlemen have united in expressing the opinion that they are really members of the carboniferous system. In studying the Windsor fossils at the Museum of Comparative Zoology, I failed to find any marked resemblance between them and those of the sub-carboniferous of the West, while I was exceedingly struck with the greater similarity borne by these in their *facies* to the fauna of the Kansas permo-carboniferous; and in a list of New Brunswick fossils, which I contributed to Professor Bailey's Report on the Geology of the

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* The whole of the fossils referred to in this paper, will be described in the forthcoming edition of Dr. Dawson's Acadian Geology.—EDS.

Southern Counties of New Brunswick, I ventured to express a doubt as to the precise age of the Acadian carboniferous limestones, for a few species collected in the vicinity of the Albert mines had the same permo-carboniferous look as those at Windsor. Dr. J. S. Newberry, in looking over my collection, was also impressed with their permo-carboniferous *facies*. At his suggestion, I sent a small collection of these fossils to Mr. Meek, who writes me as follows :—"A small collection of these same fossils from Windsor was presented to the Smithsonian Institution, by Dr. E. Foreman, some three or four years since, and they have remained a puzzle to me ever since. If they had been brought in from some unexplored region of the Rocky Mountains, for instance, I confess I should have referred them to the horizon of the upper coal measures, or to that of a series of rocks known in Kansas as the permo-carboniferous, from the remarkable mingling in them of coal measure and permian types there; but in reading over the able publications of Dr. Dawson, Sir Charles Lyell, and Mr. Davidson, on the age of these Nova Scotian beds, I was led to the conclusion that this must be one of those very rare cases where physical structure shows palæontology to be at fault. Although I am not positively sure that any of the species are absolutely identical with those of the higher horizon, these fossils certainly present a remarkable permo-carboniferous look, and, when viewed collectively, they are unlike the western sub-carboniferous fauna. For instance, there are here from Windsor several good specimens, showing both valves, with the surface markings of an Aviculopecten undistinguishable by any characters yet observed from *A. Occidentalis* of Shumard (*Pecten Cleavelandicus* Swallow), one of our most common and characteristic coal measure, permo-carboniferous and permian species in the west, which, so far as yet known, has never been found below the upper coal measures, at any rate in the western localities. Another shell represented in the collections from Windsor, by casts, is very similar to varieties of the so-called *Mytilus squamosus* from the English permian. It has almost precisely the form, and agrees in size, as well as in showing between the beaks the cast of a little depression on a shelf or septum within the beaks, such as we often see in species of Myalina, to which these shells doubtless belong. Another little shell, from Windsor, is quite or nearly like a little permo-carboniferous species in the west, known as *Sedgwickia ? concava*, M. and H.; while you have from the same casts of an

Edmundia very like a western coal measure form. . . . Taking the whole group of Windsor Mollusca, including the Lamillibranchs, any one familiar with the fossils of the western coal measure and permo-carboniferous beds, would, upon palæontological grounds alone, be very strongly inclined to refer the Windsor rocks at least to the upper coal measures." This conclusion Mr. Meek hardly feels that we ought to accept, seeing that so many able geologists have united in placing the beds in the sub-carboniferous, but expresses his opinion that "it *may* be an example of what Barrande would call an upper coal measure, or even permo-carboniferous fauna, 'colonized' far back in the sub-carboniferous period."

The carboniferous limestones and marls of Windsor certainly overlie the plant bearing shales and sandstones of the lower coal measures, which are seen exposed at Windsor Brook, Horton Bluff, Gaspereaux, and Wolfville, skirting the edge of the carboniferous basin; and Dr. Dawson has described these marine limestones, marls and gypsums as occupying a synclinal trough in these lower coal measure strata, extending from Windsor to Stewiache, a distance of some fifty miles.* Over this region the middle coal measures do not occur, so that of these limestones there is no stratigraphical evidence to contradict the evidence afforded by palæontology as to their permo-carboniferous age, and in this region Dr. Dawson has suggested that the upper limestones may represent the coal measures. I have not had any opportunity of studying these limestones except about the Basin of Minas, neither have I been able to examine sufficient suites of fossils to enable me to determine whether the above divisions I have marked-out obtain elsewhere. From a careful study of the evidence brought forward by Dr. Dawson, it certainly seems proven that the limestones, with their fossils, underlie the true coal measures in other parts of Nova Scotia.

This whole subject is one of great interest, and needs the most careful investigation. It will now be of much importance to have the limestones of north-eastern Nova Scotia and of Cape Breton compared with those of the Basin of Minas, in order to ascertain whether the same divisions obtain there as at Windsor. Another interesting point to be studied is the extension of the marly sandstones and gypsums, the conditions of their deposition, and the influence which they may have had in the extinction of

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* Proceedings of Geological Society, Vol. xv., Part I., pp. 64-65.

life over the regions they occupy. Might not some material be gathered from this new and rich field bearing on that vexed question of descent with modification ?

NEW YORK, May 28th, 1867.

NOTE BY DR. DAWSON.—Much credit is due to Mr. Hartt for the careful manner in which he has worked up the succession of fossils in the limestones of the Avon estuary. I have endeavoured, in the new edition of Acadian Geology, to apply his results to other parts of Nova Scotia. In regard to the resemblance of the Windsor fauna to the permo-carboniferous of the west, it is to be observed—(1) That no such distinction as sub-carboniferous and carboniferous can hold in Nova Scotia. The Windsor fauna is simply the marine fauna of the carboniferous, and some of the beds may be coeval with the coal measures, as I suggested many years ago (Acad. Geol. 1st. ED.). (2) The lithological character of these beds is like that of the permian, and similar sea bottoms of different periods often present resemblances of fauna. (3) That the fauna in question actually lived in the lower carboniferous period, is proved by the sections in Cumberland, Pictou and Cape Breton, which show the limestones with these shells lying below the productive coal measures. (4) It is to be observed that the supposed permo-carboniferous *facies* applies to the upper members of the Windsor limestones more especially. I have fully illustrated these points in the new edition of Acadian Geology.

ON THE CHEMISTRY OF THE PRIMEVAL EARTH.

By T. Sterry Hunt, LL.D.. F.R.S.*

The natural history of our planet, to which we give the name of geology, is, necessarily, a very complex science. including, as it does, the concrete sciences of mineralogy, of botany and zoology, and the abstract sciences chemistry and physics. These latter sustain a necessary and very important relation to the whole process of development of our earth, from its earliest ages, and we find that the same chemical laws which have presided over its changes, apply also to those of extra-terrestrial matter. Recent investigations show the presence in the sun, and even in the fixed stars—suns of other systems—the same chemical elements as in our own planet. The spectroscope, that marvellous instrument, has, in the hands of modern investigators, thrown new light upon the composition of the farthest bodies of the universe, and has made clear many points which the telescope was impotent to resolve. The results of extra-terrestrial spectroscopic research have lately been set forth in an admirable manner by one of its most successful students, Mr. Huggins. We see, by its aid, matter in all its stages, and trace the process of condensation and the formation of worlds. It is long since Herschel, the first of his illustrious name, conceived the nebulæ, which his telescope could not resolve, to be the uncondensed matter from which worlds are made. Subsequent astronomers, with more powerful glasses, were able to show that many of these nebulæ are really groups of stars, and thus a doubt was thrown over the existence in space of nebulous luminous matter; but the spectroscope has now placed the matter beyond doubt. By its aid, we find in the heavens, planets, bodies like our earth, shining only by reflected light; suns, self luminous, radiating light from solid matter; and, moreover, true nebulæ, or masses of luminous gaseous matter. These three forms represent three distinct phases in the condensation of the primeval matter, from which our own and other planetary systems have been formed.

This nebulous matter is conceived to be so intensely heated as to be in the state of true gas or vapour, and, for this reason, feebly

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* Report of a lecture delivered before the Royal Institution of Great Britain, London, May 31st, 1867, and reprinted from the Proceeding of the Royal Institution.

luminous when compared with the sun. It would be out of place, on the present occasion, to discuss the detailed results of spectroscopic investigation, or the beautiful and ingenious methods by which modern science has shown the existence in the sun, and in many other luminous bodies in space, of the same chemical elements that are met with in our earth, and even in our own bodies.

Calculations based on the amount of light and heat radiated from the sun show that the temperature which reigns at its surface is so great that we can hardly form an adequate idea of it. Of the chemical relations of such intensely heated matter, modern chemistry has made known to us some curious facts, which help to throw light on the constitution and luminosity of the sun. Heat, under ordinary conditions, is favourable to chemical combination, but a higher temperature reverses all affinities. Thus, the so-called noble metals, gold, silver, mercury, etc., unite with oxygen and other elements; but these compounds are decomposed by heat, and the pure metals are regenerated. A similar reaction was many years since shown by Mr. Grove with regard to water, whose elements—oxygen and hydrogen—when mingled and kindled by flame, or by the electric spark, unite to form water, which, however, at a much higher temperature, is again resolved into its component gases. Hence, if we had these two gases existing in admixture at a very high temperature, cold would actually effect their combination precisely as heat would do if the mixed gases were at the ordinary temperature, and literally it would be found that "frost performs the effect of fire." The recent researches of Henry Ste.-Claire Deville and others go far to show that this breaking up of compounds, or dissociation of elements by intense heat, is a principle of universal application; so that we may suppose that all the elements which make up the sun or our planet, would, when so intensely heated as to be in that gaseous condition which all matter is capable of assuming, remain uncombined—that is to say, would exist together in the condition of what we call chemical elements, whose further dissociation in stellar or nebulous masses may even give us evidence of matter still more elemental than that revealed by the experiments of the laboratory, where we can only conjecture the compound nature of many of the so-called elementary substances.

The sun, then, is to be conceived as an immense mass of intensely heated, gaseous and dissociated matter, so condensed, however, that notwithstanding its excessive temperature, it has a specific gravity not much below that of water; probably offering a condition analogous to that which Cagniard de la Tour observed for volatile bodies when submitted to great pressure at temperatures much above their boiling point. The radiation of heat, going on from the surface of such an intensely heated mass of uncombined gases, will produce a superficial cooling, which will permit the combination of certain elements and the production of solid or liquid particles, which, suspended in the still dissociated vapours, become intensely luminous and form the solar photosphere. The condensed particles, carried down into the intensely heated mass, again meet with a heat of dissociation; so that the process of combination at the surface is incessantly renewed, while the heat of the sun may be supposed to be maintained by the slow condensation of its mass; a diminution by $\frac{1}{1000}$th of its present diameter being sufficient, according to Helmholtz, to maintain the present supply of heat for 21,000 years.

This hypothesis of the nature of the sun and of the luminous process going on at its surface is the one lately put forward by Faye, and although it has met with opposition, appears to be that which accords best with our present knowledge of the chemical and physical conditions of matter, such as we must suppose it to exist in the condensing gaseous mass, which according to the nebular hypothesis, should form the centre of our solar system. Taking this, as we have already done, for granted, it matters little whether we imagine the different planets to have been successively detached as rings during the rotation of the primal mass, as is generally conceived, or whether we admit with Chacornac a process of aggregation or concretion, operating within the primal nebular mass, resulting in the production of sun and planets. In either case we come to the conclusion that our earth must at one time have been in an intensely heated gaseous condition, such as the sun now presents, self-luminous, and with a process of condensation going on at first at the surface only, until by cooling it must have reached the point were the gaseous centre was exchanged for one of combined and liquefied matter.

Here commences the chemistry of the earth, to the discussion of which the foregoing considerations have been only preliminary. So long as the gaseous condition of the earth lasted, we may suppose the whole mass to have been homogeneous; but when the temperature became so reduced that the existence of chemical compounds at the centre became possible, those which were most stable at the elevated temperature then prevailing, would be first formed. Thus, for example, while compounds of oxygen with mercury or even with hydrogen could not exist, oxides of silicon, aluminium, calcium, magnesium, and iron might be formed and condense in a liquid form at the centre of the globe. By progressive cooling, still other elements would be removed from the gaseous mass, which would form the atmosphere of the non-gaseous nucleus. We may suppose an arrangement of the condensed matters at the centre according to their respective specific gravities, and thus the fact that the density of the earth as a whole is about twice the mean density of the matters which form its solid surface may be explained. Metallic or metalloidal compounds of elements, grouped differently from any compounds known to us, and far more dense, may exist in the centre of the earth.

The process of combination and cooling having gone on until those elements which are not volatile in the heat of our ordinary furnaces were condensed into a liquid form, we may here inquire what would be the result, upon the mass, of a further reduction of temperature. It is generally assumed that in the cooling of a liquid globe of mineral matter, congelation would commence at the surface, as in the case of water; but water offers an exception to most other liquids, inasmuch as it is denser in the liquid than in the solid form. Hence, ice floats on water, and freezing water becomes covered with a layer of ice, which protects the liquid below. With most other matters, however, and notably with the various mineral and earthy compounds analogous to those which may be supposed to have formed the fiery-fluid earth, numerous and careful experiments show that the products of solidification are much denser than the liquid mass; so that solidification would have commenced at the centre, whose temperature would thus be the congealing point of these liquid compounds. The important researches of Hopkins and Fairbairn on the influence of pressure in augmenting the melting point of such compounds as contract in solidifying, are to be considered in this connection.

It is with the superficial portions of the fused mineral mass of the globe that we have now to do; since there is no good reason for supposing that the deeply seated portions have intervened in any direct manner in the production of the rocks which form the superficial crust. This, at the time of its first solidification, presented probably an irregular, diversified surface from the result of contraction of the congealing mass, which at last formed a liquid bath of no great depth, surrounding the solid nucleus. It is to the composition of this crust that we must direct our attention, since therein would be found all the elements (with the exception of such as were still in the gaseous form) now met with in the known rocks of the earth. This crust is now everywhere buried beneath its own ruins, and we can only from chemical considerations attempt to reconstruct it. If we consider the conditions through which it has passed, and the chemical affinities which must have come into play, we shall see that there are just what would now result if the solid land, sea, and air were made to react upon each other under the influence of intense heat. To the chemist it is at once evident that from this would result the conversion of all carbonates, chlorides and sulphates into silicates, and the separation of the carbon, chlorine, and sulphur in the form of acid gases, which, with nitrogen, watery vapour, and a probable excess of oxygen, would form the dense primeval atmosphere. The resulting fused mass would contain all the bases as silicates, and must have much resembled in composition certain furnace-slags or volcanic glasses. The atmosphere, charged with acid gases which surrounded this primitive rock must have been of immense density. Under the pressure of such a high barometric column, condensation would take place at a temperature much above the present boiling point of water, and the depressed portions of the half-cooled crust would be flooded with a highly heated solution of hydrochloric acid, whose action in decomposing the silicates is easily intelligible to the chemist. The formation of chlorides of the various basis, and the separation of silica, would go on until the affinities of the acid were satisfied, and there would be a separation of silica, taking the form of quartz, and the production of a sea-water holding in solution, besides the chlorides of sodium, calcium, and magnesium, salts of aluminium and other metallic basis. The atmosphere, being thus deprived of its volatile chlorine and sulphur compounds, would approximate to that of our own time, but differ in its greater amount of carbonic acid.

We next enter into the second phase in the action of the atmosphere upon the earth's crust. This, unlike the first, which was subaqueous, or operative only on the portion covered with the precipitated water, is sub-aerial, and consists in the decomposition of the exposed parts of the primitive crust under the influence of the carbonic acid and moisture of the air, which convert the complex silicates of the crust into a silicate of alumina, or clay, while the separated lime, magnesia, and alkalies, being converted into carbonates, are carried down into the sea in a state of solution.

The first effect of these dissolved carbonates would be to precipitate the dissolved allumina and the heavy metals, after which would result a decomposition of the chloride of calcium of the sea-water, resulting in the production of carbonate of lime or limestone, and chloride of sodium or common salt. This process is one still going on at the earth's surface, slowly breaking down and destroying the hardest rocks, and, aided by mechanical processes, transforming them into clays; although the action, from the comparative rarity of carbonic acid in the atmosphere, is less energetic than in earlier times, when the abundance of this gas, and a higher temperature, favoured the chemical decomposition of the rocks. But now, as then, every clod of clay formed from the decay of a crystalline rock corresponded to an equivalent of carbonic acid abstracted from the atmosphere, and equivalents of carbonate of lime and common salt formed from the chloride of calcium of the sea-water.

It is very instructive, in this connection, to compare the composition of the waters of the modern ocean with that of the sea in ancient times, whose composition we learn from the fossil sea-waters which are still to be found in certain regions, imprisoned in the pores of the older stratified rocks. These are vastly richer in salts of lime and magnesia than those of the present sea, from which have been separated, by chemical processes, all the carbonate of lime of our limestones, with the exception of that derived from the sub-aerial decay of calcareous and magnesian silicates belonging to the primitive crust.

The gradual removal, in the form of carbonate of lime, of the carbonic acid from the primeval atmosphere, has been connected with great changes in the organic life of the globe. The air was doubtless at first unfit for the respiration of warm-blooded animals, and we find the higher forms of life coming gradually into existence as we approach the present period of a purer air. Calculations lead us to conclude that the amount of carbon thus removed in the form of carbonic acid has been so enormous, that we must suppose the earlier forms of air-breathing animals to have been peculiarly adapted to live in an atmosphere which would probably be too impure to support modern reptilian life. The agency of plants in purifying the primitive atmosphere was long since pointed out by Brongniart, and our great stores of fossil fuel have been derived from the decomposition, by the ancient vegetation, of the excess of carbonic acid of the early atmosphere, which through this agency was exchanged for oxygen gas. In this connection the vegetation of former periods presents the curious phenomenon of plants allied to those now growing beneath the tropics, flourishing within the polar circles. Many ingenious hypotheses have been proposed to account for the warmer climate of earlier times, but are at best unsatisfactory, and it appears to me that the true solution of the problem may be found in the constitution of the early atmosphere, when considered in the light of Dr. Tyndall's beautiful researches on radiant heat. He has found that the presence of a few hundredths of carbonic acid gas in the atmosphere, while offering almost no obstacle to the passage of the solar rays, would suffice to prevent almost entirely the loss by radiation of obscure heat, so that the surface of the land beneath such an atmosphere would become like a vast orchard-house, in which the conditions of climate necessary to a luxuriant vegetation would be extended even to the polar regions. This peculiar condition of the early atmosphere cannot fail to have influenced in many other ways the processes going on at the earth's surface. To take a single example: one of the processes by which gypsum may be produced at the earth's surface involves the simultaneous production of carbonate of magnesia. This, being more soluble than the gypsum, is not always now found associated with it; but we have indirect evidence that it was formed and subsequently carried away, in the case of many gypsum deposits, whose thickness indicates a long continuance of the process under conditions much more perfect and complete than we can attain under our present atmosphere. While studying this reaction I was led to inquire whether the carbonic acid of the earlier periods might not have favoured the formation of gypsum; and I found, by repeating the experiments in an artificial atmosphere impregnated with carbonic acid, that such was really the case. We may thence conclude that the peculiar composition of the primeval atmosphere was the essential condition under which the great deposits of gypsum, generally associated with magnesian limestones, were formed.

The reactions of the atmosphere which we have considered, would have the effect of breaking down and disintegrating the surface of the primeval globe, covering it everywhere with beds of stratified rock of mechanical or of chemical origin. These would now so deeply cover the partially cooled surface that the amount of heat escaping from below is inconsiderable, although in earlier times it was very much greater, and the increase of temperature met with in descending into the earth must have been many times more rapid than now. The effect of this heat upon the buried sediments would be to soften them, producing new chemical reactions between their elements, and converting them into what are known as crystalline or metamorphic rocks, such as gneiss, greenstone, granite, etc. We are often told that granite is the primitive rock or substratum of the earth, but this is not only unproved, but extremely improbable. As I endeavoured to show in the early part of this discourse, the composition of this primitive rock, now everywhere hidden, must have been very much like that of a slag or lava; and there are excellent chemical reasons for maintaining that granite is in every case a rock of sedimentary origin—that is to say, it is made up of materials which were deposited from water, like beds of modern sand and gravel, and includes in its composition quartz, which, so far as we know, can only be generated by aqueous agencies, and at comparatively low temperatures.

The action of heat upon many buried sedimentary rocks, however, not only softens or melts them, but gives rise to a great disengagement of gases, such as carbonic and hydrochloric acids, and sulphur compounds, all results of the reaction of the elements of sedimentary rocks, heated in presence of the water which everywhere filled their pores. In the products thus generated we have a rational explanation of the chemical phenomena of volcanoes, which are vents through which these fused rocks and confined gases find their way to the surface of the earth. In some cases, as where there is no disengagement of gases, the fused or half-fused rocks solidify *in situ*, or in rents or fissures in the overlying strata, and constitute eruptive or plutonic rocks like granite and basalt.

This theory of volcanic phenomena was put forward in germ by Sir John F. W. Herschel thirty years since, and, as I have during the past few years endeavoured to show, it is the one most in accordance with what we know both of the chemistry and the physics of the earth. That all volcanic and plutonic phenomena have their seat in the deeply buried and softened zone of sedimentary deposits of the earth, and not in its primitive nucleus, accords with the conclusions already arrived at relative to the solidity of that nucleus, with the geological relations of these phenomena as I have elsewhere shown; and also with the remarkable mathematical and astronomical deductions of the late Mr. Hopkins, of Cambridge, based upon the phenomena of precession and nutation; those of Archdeacon Pratt; and those of Professor Thompson on the theory of the tides; all of which lead to the same conclusion—namely, that the earth, if not solid to the centre, must have a crust several hundred miles in thickness, which would practically exclude it from any participation in the plutonic phenomena of the earth's surface, except such as would result from its high temperature communicated by conduction to the sedimentary strata reposing upon it.

The old question between the plutonists and the neptunists, which divided the scientific world in the last generation, was, in brief, this—whether fire or water had been the great agent in giving origin and form to the rocks of the earth's crust. While some maintained the direct igneous origin of such rocks as gneiss, mica-schist, and serpentine, and ascribed to fire the filling of metallic veins, others—the nuptunial school—were disposed to shut their eyes to the evidences of igneous action on the earth, and even sought to derive all rocks from a primal aqueous magma. In the light of the exposition which I have laid before you this evening, we can, I think, render justice to both of these opposing schools. We have seen how actions dependent on water and acid solutions have operated on the primitive plutonic mass, and how the resulting aqueous sediments, when deeply buried, come again within the domain of fire, to be transformed into crystalline and so-called plutonic or volcanic rocks.

The scheme which I have endeavored to put before you in the short time alloted, is, as I have endeavoured to show, in strict conformity with known chemical laws and the facts of physical and geological science. Did time permit, I would gladly have attempted to demonstrate at greater length its adaptation to the explanation of the origin of the various classes of rocks, of metallic veins and deposits, of mineral springs, and of gaseous exhalations. I shall not, however, have failed in my object, if, in the hour which we have spent together, I shall have succeeded in showing that chemistry is able to throw a great light upon the history of the formation of our globe, and to explain in a satisfactory manner some of the most difficult problems of geology; and I feel that there is a peculiar fitness in bringing such an exposition before the members of this Royal Institution, which has been for so many years devoted to the study of pure science, and whose glory it is, through the illustrious men who have filled, and those who now fill, its professorial chairs, to have contributed more than any other school in the world to the progress of modern chemistry and physics.

REVIEW.

"MANUAL OF THE BOTANY OF THE NORTHERN UNITED STATES."

By ASA GRAY, Fisher Professor of Natural History in Harvard University. New York, 1867.

A fifth edition of this very useful manual has been recently issued. The author has, to a great extent, re-written the work, and, in the elaboration of some parts, has received active co-operation from some other American botanists, prominent among whom are Dr. George Engelmann and Prof. D. C. Eaton. Important changes in the arrangement of some of the orders and genera have been embodied in this edition; the geographical range of very many species has been extended; naturalized as well as indigenous plants—some familiar as Canadian—not previously known to occur within the Northern United States (as limited by the author) have been recently discovered and are now included; and to the work have been added not a few new species.

In the present edition there are many points of considerable interest to Canadian botanists.

Among the orders several noticeable changes occur. The Cabombeæ are treated by the author as constituting a sub-order of Nymphæaceæ, and the Limnantheæ, Balsamineæ and Oxalideæ as sub-orders of Geraniaceæ. This comprehensive view of Geraniaceæ is that originally entertained by Jussieu, the founder of the order, but regarding which difference of opinion has existed among later botanists. The irregular, unsymetrical flowers, the usually fewer sepals, petals, and stamens, the spur or sac on the posterior sepal, the simple leaves, as well as other distinguishing characters of the Balsams, seem to entitle, at least, them to rank as a distinct order. The Parnassiæ, which in many respects approach the Hypericaceæ, but the flowers of which are, as indicated in former editions of the Manual, sometimes clearly perigynous, and the Grossulariæ are removed by the author to Saxifragaceæ. The Halorageæ, formerly regarded as a sub-order of Onagraceæ, he now considers to have characters sufficient to constitute an order. Under Liliaceæ, as here extended and re-arranged, are included the Trillideæ, Melanthieæ, and Uvularieæ.

Among the genera there are not many changes to note. Atragine, distinguished by the presence of petals which gradually merge into stamens, is included in Clematis. Iodanthus and Turritis are referred to Arabis, and Alsine, Mœhringia, and Honkenya, also considered by some authors, as well as in former editions, as genera, and of which the last named has considerable claims to generic distinction, are comprised in Arenaria. Further, among endogens, the older genus Habenaria, distinguished from Orchis by its naked and exposed separate glands or viscid disks, is revived in this edition, and the Gymnadenia and Platanthera of former editions referred to it. Whilst on the subject of genera, it may be added that it admits of grave doubt whether an author when changing a species from one genus to another should wholly suppress the name of the original describer.

Mr. Paine's new Water Lily, *Nymphæa tuberosa*, from Oneida Lake and other parts of the Union, and which has been recently observed near Belleville by Mr. Macoun, is fully described. *Arabis petræa* Lam., which occurs on the Canadian side of Lake Superior, appears now as a United States plant, having been found on Willoughby Mountain by Mr. Horace Mann. *Oxytropis campestris* DC., it will interest Quebec and New Brunswick botanists, is to be looked for about the Maine boundary line. The other species, *O. Lamberti* Pursh, an interesting local plant of the Province of Quebec, is another noticeable addition to Dr. Gray's work. Such are also *Parnassia parviflora* DC., one of our Anticosti plants, which has been observed on the north-west shore of Lake Michigan, and *Sedum Rhodiola* DC., a rather boreal plant of Anticosti, Labrador, and Newfoundland, which has been met with in Maine and, curiously enough, in Pennsylvania on cliffs of the Delaware River above Easton. Among other recent additions of interest to the flora of the Northern United States there may be mentioned, as species previously known to occur in either Quebec or Ontario, *Matricaria inodora* Linn., a native of the far-west, introduced from Europe into Maine; *Senecio pseudo-arnica,* Less., a plant of Anticosti and northward, detected on Grand Manan Island, off the coast of Maine; *Polemonium cæruleum* Linn., and *Corispermum hyssopifolium* Linn., both western plants, the latter apparently extending eastward; *Rumex patientia* Linn., a stray introduction into both countries from Europe, and *Sagittaria calycina* Engl., also a recent addition to our flora from Grand Manitoulin Island, where it has been collected by Dr. John Bell.

A hasty enumeration of the number of genera and species shows that, numerically, considerable additions have been made. Of Exogenous plants there are 627 genera and 1842 species, and of Endogenous plants 174 genera and 716 species. The increase has chiefly taken place in the orders Leguminosæ, Compositæ, Naidaceæ, Cyperaceæ, and Graminæ.

Six lithographic plates, illustrative of the genera of the Cyperaceæ, have been added to the fourteen illustrating the Graminæ and Filices. These will prove useful aids to the young botanist.

A. T. D.

Mr. Eaton's elaboration of the ferns is painstaking, able and thorough. Four sub-orders are represented within the limits, Polypodiaceæ, Schizæaceæ, Osmundaceæ and Ophioglossaceæ. The second of these contains the genera Schizæa and Lygodium which have not yet been detected in Canada. Some changes have been made in the arrangement of the genera composing the Polypodiaceæ. Phegopteris has been seperated from Polypodium and put next to Aspidium, its proper place, as was long ago indicated by Roth (who included it in his genus Polystichum, the equivalent of Swartz's Aspidium) and by Fée, who founded the genus. Struthiopteris has been removed from Pterideæ to Aspidieæ and placed next to Onoclea, but not included in that genus, chiefly because of its different venation. Pellæa has been seperated from Allosorus, the only species which retains the latter name being *Allo. acrostichoides*, an inapt section, inasmuch as Bernhardi's name is not appropriate to any other genus than Cheilanthes of Swartz, and moreover, Robert Brown's well named and well defined genus, Cryptogamme, was constituted expressly for this species. Sir William Hooker held (probably correctly) that our North American plant was identical with the European *C. crispus;* Mr. Eaton appears to consider them distinct. Mr.

Eaton has here cleared up the confusion which existed among our species of the genus Cheilanthes. He has confirmed the Abbé Brunet's observations that *Neph. lanosum* of Michaux is the "*Ch. vestita* Willdenow" of former editions and of American botanists generally, – the "*Ch. vestita* Swartz" of the present edition of this work. It is matter for regret that Michaux's name has not been respected, but, having been continued through so many editions and now confirmed in this one, and being probably applied to the plant which the founder of the genus had in view, the name *vestita* must now stand; it is, however, noteworthy that Swartz misunderstood Michaux's plant—he believed it to be an Aspidium, and that Sir William Hooker and other European botanists have applied *vestita* to the plant here named *Ch. lanuginosa*. *Ch. vestita* has been found by Mr. Denslow, as far north as the island of New York, and his specimens appear to be as vigorous as those of more sourthern latitudes. *Ch. tomentosa* of Link (Lindheimer No. 743; *Ch. Bradburii*, Hook. Sp. Fil.) is not stated to be rare, and yet specimens of it appear to be very scarce in the herbaria of American botanists. The third species of Cheilanthes which occurs within the geographical limits is here named *Ch. lanuginosa*, a MS. name given by Nuttall; this must give place to Riehl's earlier name *Ch. gracilis* which has been adopted by Fée and by Mettenius: this plant is the *Ch. vestita* of Hooker's Species Filicum. In Asplenium one new species has been admitted, *A. ebenoides* R. R. Scott, which is only an abnormal form of *A. ebeneum*. In Woodsia, Mr. Eaton has receded from the position assumed in his paper on the genus contributed to this journal, having readmitted *W. glabella* to the rank not merely of a good species but of a purely American species. The truth would appear to lie between his two extremes; those glaberous Lapland plants, named *W. hyperborea* by Scandinavian botanists, are certainly identical with our *W. glabella*, and are possibly what Liljeblad had before him when describing his *Acros. hyperboreum*, and also what Wahlenberg named *Polypodium hyperboreum* in "Flora Lapponica." Our plants are, however, certainly distinct from the *Acros. alpinum* of Bolton (*W. hyperborea*, R. Br., Hook. etc.) which is very near to *W. Ilvensis* if, indeed, it be separable from it. In Botrychum, *B. simplex* is admitted as a species, as is also *B. lanceolatum*, neither of which have much claim to that rank. With his views of generic limits, Mr. Eaton might very fairly have seperated Dryopteris from Polystichum; he has, however, following

Swartz and Mettenius, combined them in Aspidium. Leaving out *Aspl. ebenoides*, there are described fifty-six good species and six well-marked ("black-letter") varieties. Of these the following were not recognized in the second edition:—*Ch. lanuginosa*, *Allo. acrostichoides*, *Aspd. Filix-mas*, *Woodsia Oregana*, *Botrychium Lunaria*, *B. simplex* and *B. lanceolatum*. Twenty species are marked with the contraction "Eu." as being common to Europe and America, and from three it has been accidentally omitted (*B. simplex*, *B. lanceolatum* and *B. virginianum*); to these I would add for the reasons above stated *Allo. acrostichoides*, *Woodsia glabella*, and also probably *Aspd. fragrans* (which appears to extend all round the Arctic circle), which would increase this number to twenty-six. But the remaining thirty species are not all of them confined to America; *Adiantum pedatum*, *Pellæa gracilis*, *Aspl. thelypteroides* and *Onoclea sensibilis* are also Asiatic and *Aspl. ebeneum* has been collected in Africa. Of the sixty-two species and varieties forty-nine are known to me as Canadian, in addition to which the following may be looked for within our boundaries with good prospect of success,—*Ch. vestita*, *Woodwardia areolata*, *Aspl. Ruta-muraria*, *Aspd. Filix-mas* (about Lake Superior), *Woodsia obtusa*, *W. Oregana* (about Lake Superior), and *Lygodium palmatum*; on the other hand, *Polypodium incanum*, *Ch. tomentosa*, *Ch. gracilis*, *Aspl. montanum*, *A. pinnatifidum* and *Schizæa pusilla* are pretty surely beyond our reach. We have left to us but two Canadian ferns not noticed by Mr. Eaton, *W. hyperborea* R. Brown, and *Aspl. viride* Hudson, but as the first-named has been found on Willoughby Mountain by Mr. Horace Mann, and the latter is most probably a native of the northern parts of Maine, etc., Mr. Eaton might as well have included them and thus had the opportunity of fully revising his former views on the genus Woodsia. *Aspidium spinulosum* has been split up into four varietal forms—dilatatum, intermedium, verum, and Boottii, the var. intermedium (*Aspd. intermedium* Willd.) being our common narrow form; this would seem to be a somewhat too minute subdivision. The large broad form of *A. cristatum* which we have been calling var. *majus* is here named var. *Clintonianum*, in compliment to Judge Clinton of Buffalo. The var. *Braunii* of *A. aculeatum* is hardly entitled to "black letters," it being merely a form of the var. *angulare*—the *A. angulare* of Willd. etc.—unless on the supposition that this latter is a good species. The plates being unaltered, the genera Allosorus and Phegopteris are not illustrated; the figures of *Ch. vestita* and *W. glabella* are very indifferent, the latter particularly so.

The following extracts from the preface are of interest:—

"This work is designed as a compendious Flora of the Northern portion of the United States, for the use of students and of practical botanists.

"The first edition (published in 1848) was hastily prepared to supply a pressing want. Its plan, having been generally approved, has not been altered, although the work has been to a great extent twice rewritten, and the geographical range extended. The second edition, much altered, appeared in 1856. The third and fourth were merely revised upon the stereotype plates, and some pages added, especially to the latter.

"The *Garden Botany*, an Introduction to a Knowledge of the Common Cultivated Plants, which was prefixed to this fourth edition in 1863, is excluded from the present edition, and is to be incorporated into a simpler and more elementary work, but of wider scope, designed especially for school instruction, and for those interested in cultivation,—entitled *Field, Forest, and Garden Botany.*

"In the present edition, it has been found also expedient to remand to a supplementary volume the *Mosses* and *Liverworts*, so carefully and generously elaborated for the previous editions of this work by my friend, Wm. S. Sullivant, Esq. It is hoped that the *Lichenes*, if not all the other orders of the Lower Cryptogamia, may be added to this supplementary volume, so that our students may extend their studies into these more recondite and difficult departments of Botany.

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"There is abundant reason, I doubt not, for me to renew the request that those who use this book will kindly furnish information of all corrections or additions that may appear to be necessary, so that it may be more accurate and complete hereafter, and maintain the high character which it has earned.

"Geographical Limitation, Distribution, etc. As is stated on the title-page, this work is intended to comprise the plants which grow spontaneously in the United States, north of North Carolina and Tennessee, and east of the Mississippi. A Flora of the whole national domain, upon a similar plan (the issue of which I may now hope will not be delayed many years longer), would be much too bulky and expensive for the main purpose which this Manual fulfils. For its purposé, the present geographical limitation is, on the whole, the best,—especially since the botany of the states south of our district has been so well provided for by my friend, Dr. Chapman's *Flora of the Southern States*, issued by the same publishers. The southern boundary here adopted coincides better than any other geographical line with the natural division between the cooler-temperate and the warm-temperate vegetation of the United States; very few characteristically Southern plants occurring north of it, and those only on the low coast of Virginia, in the Dismal Swamp, etc. Our Western limit, also, while it includes a considerable prairie vegetation, excludes nearly all the plants peculiar to the great Western woodless plains, which approach our borders in Iowa and Missouri. Our northern boundary, being that of the United States, varies through about five degrees of latitude, and nearly embraces Canada proper on the east and on the west, so that nearly all the plants of Canada East on this side of the St. Lawrence, as well as those of the deep peninsula of Canada West, will be found in this volume.

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"Distinction of Grade of Varities. Vain is the attempt to draw an absolute line between varieties and species. Yet in systematic works the distinction has to be made absolute, and each particular form to be regarded as a species or a variety, according to the botanist's best judgment. Varieties, too, exhibit all degrees of distinctness. Such as are marked and definite enough to require names are distinguished here into two sorts, according to their grades: 1. Those which, I think, cannot be doubted to be varieties of the species they are referred to, have the name printed in small capitals. These varieties make part of the common paragraph. 2. Those so distinct and peculiar that they have been, or readily may be, taken for species, and are some of them not unlikely to establish the claim: of these the name is printed in the same [black letter] type as that of the species; and they are allowed the distinction of a seperate paragraph, except where the variety itself is the only form in the country."

The whole work is a model of accurate description, correct orthography and typographical excellence. W.

Published, Montreal, 1st January, 1368.