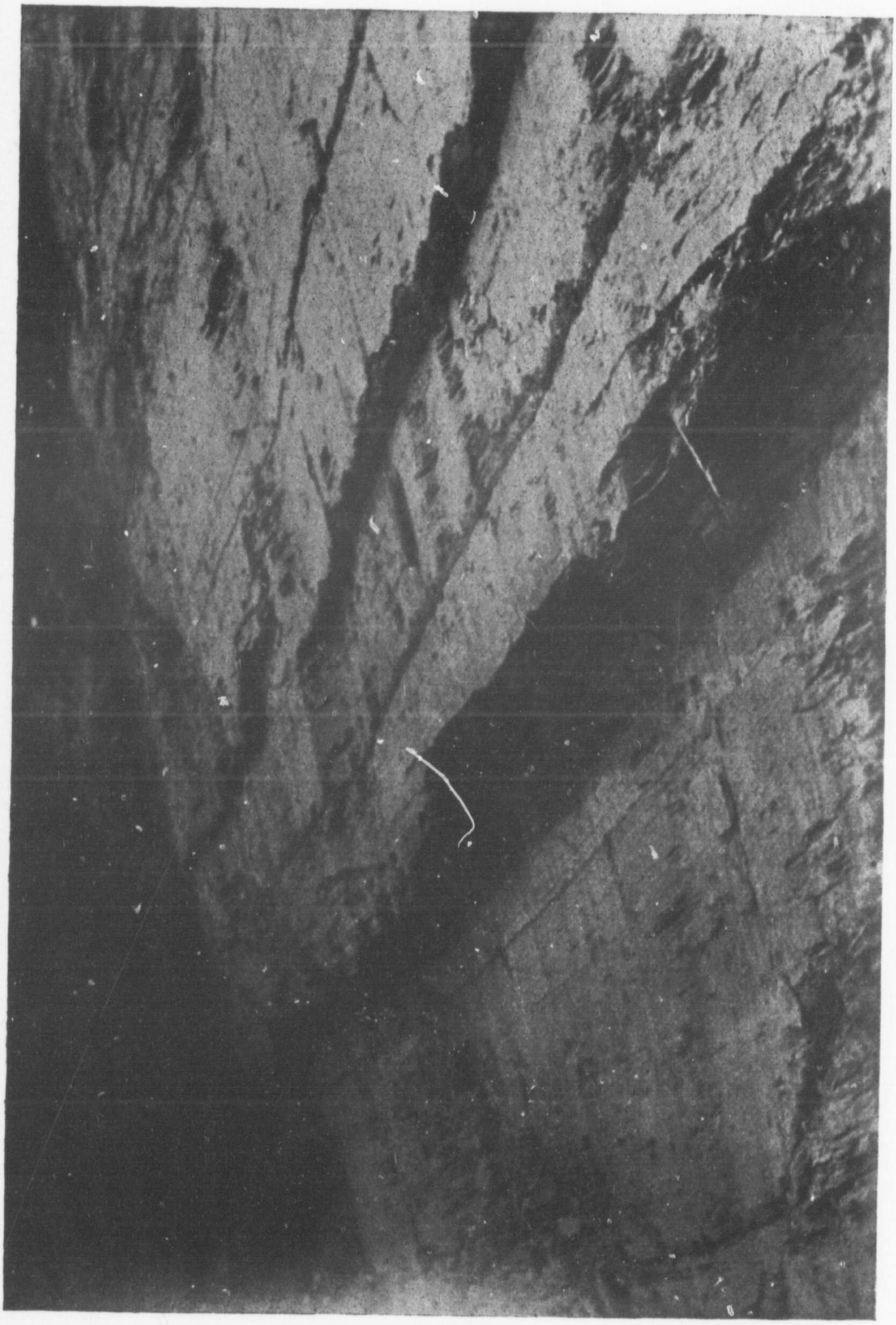

POST-GLACIAL FAULTS AT ST. JOHN.

See Page 34.

BULLETIN

OF THE

NATURAL HISTORY SOCIETY

OF

NEW BRUNSWICK.

No. XII.

PUBLISHED BY THE SOCIETY.

SAINT JOHN, N. B.:
BARNES & CO., 84 PRINCE WILLIAM STREET.
1894.

BULLETIN

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NATURAL HISTORY SOCIETY

OF

NEW BRUNSWICK.

ARTICLE I.

AN OUTLINE OF PHYTOBIOLOGY.

WITH SPECIAL REFERENCE TO THE STUDY OF ITS PROBLEMS BY LOCAL BOTANISTS AND SUGGESTIONS FOR A BIOLOGICAL SURVEY OF ACADIAN PLANTS.

BY W. F. GANONG, M. A.

Read May 1st, 1894.

First Paper.

It is clear to all botanists who note the signs of the times that the study of local Botany must take a new direction in the near future. Up to the present, under the favoring influences of intrinsic æsthetic interest, abundance everywhere of easily-handled materials, accurate terminology and excellent manuals, the systematic study of flowering plants has been the department of natural history most cultivated by those of scientific tastes, who must work without special training and away from the great centres. Hence has arisen the great class of local botanists. Their relationship to the science, however, has been one of reciprocal advantage, for not only have they derived from it an occupation of elevated pleasure, of high educational value, and of radiant good influence, but it in turn has profited greatly by their thorough explorations of local floras.

But this mutually beneficial adjustment is becoming unbalanced. Not only on the one hand are the local botanists by their very devotion exhausting their field of systematic usefulness, but as well on the other, through the consequent narrowing of opportunity for original investigation and loss of its stimulating charm, the subjective value of the science to themselves is being impaired. Discoveries of real worth and studies in pursuit of new truth can now, for the most part, be made only at the expense of journeys from home often longer than time or means justify. The question, then, is forced upon us: In what direction lies a new field for local botanists such as will yield them intellectual profit for themselves, and in which their enthusiasm, opportunities and local knowledge can be utilized for the advancement of botanical science?

Happily there need be no hesitation as to the answer. Through the studies of the younger professional botanists, particularly of Europe, there is being developed the new department, almost the new science, of Phytobiology.* It offers in the highest degree opportunities for great usefulness, and it is to be moreover the leaven of the botany of the future.

In the three provinces of Acadia we possess rich material for phytobiological study, skilled and earnest workers, and scientific societies for the correlation and

*I am not aware that this term has hitherto been used. It seems to be our nearest possible equivalent for the generally used German "Pflanzenbiologie." and is far better than the simple word "Biology," which is now employed in several senses, or than the word "Oekologie," which many recommend, but nobody uses.

communication of results. Under these favoring conditions we can enter with confidence upon the new work. And it is a fortunate coincidence, which we must not overlook, that its pursuit under the auspices of this Society will distinctly further the highest object of the Society's existence, the collection of data for a true natural history of Acadia. We have therefore a double stimulus to the careful consideration of the subject before us.

I.—The Relationship of Phytobiology to the other Departments of Botanical Study.

In order to thoroughly comprehend the scope of Phytobiology it is needful to examine briefly its relationship to the other departments of Botany. It will be useful also incidentally to note where to the latter the local botanist can be of service. It is of course understood that the advancement of knowledge in all departments must depend upon the specialists, who alone can command the requisite training, libraries and collections.

The vastness of the range of botanical study has made needful its division into departments. These, based mainly upon convenience, cannot be logically distinct and must merge often one into another. As they have practically segregated themselves, they are about as follows:

I. Systematic Botany, the study of the relationship of plants to one another. Its ideal is to construct the real genealogical tree of plants. Based in the past chiefly upon anatomy, its future advance must be through aid of morphology, which alone affords a true guide to genetic relationship. As hitherto, the local botanist can assist by exhaustive local explorations and communication of his results to the specialists.

II. Phyto-Anatomy (Vegetable Anatomy), the study of the actual present structure of plants and their parts, apart from causation. In its larger aspects it is rarely studied apart from Systematic Botany, but in its microscopic phases, the anatomy of cells and tissues, (HISTOLOGY) it is a distinct division of importance, studied at its best upon morphological principles. The local botanist cannot serve it.

III. PHYTO-MORPHOLOGY (VEGETABLE MORPHOLOGY), the study of genetic origin underlying adaptive form in plants. By penetrating the disguises imposed by special function, and laying bare real history it becomes the chief reliance of the modern systematic botanist, and is most closely bound up with the higher phases of Phytobiology. Its chief auxiliaries are TERATOLOGY, the study of monstrosities; EMBRYOLOGY, the study of the unfolding of the plant from its earliest germ; and COMPARATIVE ANATOMY the comparison of graduated series of structures. It is the philosophical basis, or as Darwin calls it, the soul of natural history. The local botanist can serve it by collecting and noting the conditions of monstrosities.

IV. PHYTO-PHYSIOLOGY (VEGETABLE PHYSIOLOGY), the study of the "vital" processes of the plant. It has to deal chiefly with questions of Chemistry and Physics, requires for its advancement unusually special training and cannot be served by the local botanist.

V. PHYTO-PATHOLOGY (VEGETABLE PATHOLOGY), the study of plant diseases. Of these by far the greater number are caused by parasitic Cryptogams, the practical difficulties of the study of which have caused them, together with the non-parasitic lower plants, to be grouped together for study under the department of CRYPTOGAMIC BOTANY. As it likewise includes the systematic study of these forms, local botanists can render great service by the collection and communication to the specialists of all Fungi and Algæ, with the most careful observations of the conditions of their occurrence.

VI. ECONOMIC BOTANY, the study of the relationship of plants to man's good and injury. Up to the present this department has been in the hands of practical men, has had no principles and no scientific status. Its discoveries have been far oftener the result of accident than of research, a natural corollary of the fact that the usefulness of a plant to man is usually a matter of accident and not of adaptation, some feature developed in and for its own economy happening to accord with some need or peculiarity of his. In the future it is to become an organized scientific study. The local botanists, by careful observation of effects of plants upon other organisms, may gain hints revealing new uses.

VII. BOTANICAL GEOGRAPHY, the study of the distribution of plants over the earth's surface. Upon the largest scale it deals with the great floras of the earth, the relationships of which are solvable only by aid of Palæontology and geological history. The special phase of it dealing with distribution within limited areas, belongs rather in the consideration of locomotion and competition in Phytobiology proper. To the former the local botanist can be of use by making his lists as full, accurate and discriminating as possible; to the latter he can be of the greatest service, as we shall later discover.

VIII. Phyto-Palæontology (Vegetable Palæontology), the study of fossil plants. The local botanist can be of service by the collection of the fossil plants of his district, if any, and their communication to the specialists, not forgetting that there are valuable late clay, bog, and lake-bottom, as well as earlier rock-fossils.

IX. Folk-Botany, the study of plants in their relationships to folk-lore, folk-uses, superstitions, traditions, history. It includes the study of all aboriginal and other unwritten lore, knowledge and names of plants. It has contributed many, and may be made to contribute more, facts of importance to Economic Botany, Ethnology, Philology, History. The local botanist can be of the greatest service by the careful collection and publication of all Indian and other local plant-lore and names.

X. Philosophical Botany, the study of origin and causation in the development of plants. Its principles, the same as those of Philosophical Zoology, we are accustomed to group together as aids to the study of "Evolution." Its advancement requires the highest possible qualities and opportunities, and the local botanist can hope only to follow, not to further it.

XI. Phytobiology, the study of the immediate relationship of plants to their environment. It views plants not only as living, but also as plastic beings, moulded in the past and in the present by their surroundings, and to some extent reciprocally affecting them. It has primarily to do with *adaptation*, or fitting of form and structure to function. When it traces the structural history of an adapted part, it employs morphology, which is thus inseparably connected with it; and where it considers that history causatively or dynamically, it approaches Philosophical Botany. It investigates the use or meaning of form, color, size, position, and the like in plants and their parts. It is therefore the most living and generally interesting department of Botany, and is destined to expand enormously in the future. The potential relationship to it of the local botanist has been indicated already, and will now be traced more fully.

II.—The Nature and Methods of Phytobiological Study.

Phytobiology, as we have seen, is the study of adaptations, that is of the arrangements by which plants and their parts are brought into responsive contact with external influences. It investigates in all degrees the effects upon plants of the external phenomena of the world, that is, force in all its forms and matter in its various states; and considers as well the utilization of these by plants in their organic necessities, *i. e.*, nutrition, locomotion, protection, reproduction, competition. From the most general relationships of influences and necessities, resulting in the formation of the primary organs of plants, it proceeds through all grades to the most minute analysis of details, explaining the most superficial characteristics of form, size, color, position.

The study of the reaction of the plant to the conditions of its environment would be comparatively simple were we concerned but with the present, and a completely plastic plant. But in fact all of the complexities of relationships of the past, the resultant effects of which we are accustomed to designate *heredity*, together with a little-understood *internal constitution*, of which variation is the most important phase, and which may or may not be included with heredity,—these two impose great restrictions upon the operation of the present environment. Every plant, and every part of it, represents the resultant of an enormously complex inter-operation of the influences of these three conditions—heredity, internal constitution and present environment, and each of these plants and its parts is in a state of unstable equilibrium, and readily alterable through movements in the environment. The delimitation of the effects of these influences upon plants is the ideal of Phytobiology in its most philosophical phases.

Viewed in this light, Phytobiology certainly does seem the most difficult of the departments of botany. So in its higher branches it is, but like all other branches of science, it has three grades: first, the observation of facts; secondly, the correct interpretation of the immediate meaning of these; third, the composition of knowledge thus gained into the principles of a science. It is in the first and second, but especially in the first, that the local botanist can render invaluable service. The first great need of Phytobiology, that upon which its progress depends, is accurate observation of fact in the field; for it must be remembered that it deals with living things in action and the laboratory or herbarium can help but little. Field study of how plants behave in relationship to the external world is the great aim which the local botanist should keep clearly before him.

Limiting ourselves now to the subject from the point of view of the local botanists, we have to consider first of all certain general principles.

The first pre-requisite for active work in Phytobiology is an acquaintance with what has already been learned, and some idea of the problems to be studied. The best single work upon the subject is unquestionably the admirable "Pflanzenleben,"* by Kerner von Marilaun, of course in German, as are the other very important works by Gœbel, Schimper, Warming, Stahl, Volkens, Kihlman, and others. Unfortunately there is no such work in English, and it is to supply in some measure this want for Acadian students, that a series of articles upon the subject will follow the present one.

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* While this paper is in press I learn that Kerner's work is to be translated into English under the title "Natural History of Plants.

The other great pre-requisite is a proper training in the three scientific faculties—observation, experiment, judgment.

We have already but just referred to field study, and the local botanist's opportunities for it. It cannot be emphasized too often, nor too strongly, that just here is his true field, and that his greatest triumphs will come from his observation of nature in action. It is under the extreme conditions of nature that her adaptations are best seen, and in all seasons and times and weathers the observer should be abroad, alert, persistent, sympathetic. The effects of storms on the branches, of rain on the flowers, of heat on the leaves, of birds on the fruits, of innumerable other external agencies, can be learned only by seeing them in operation, and they make clear the responsive adaptations in plants. The observer, indeed, is greatly aided by this dual nature of his problems,—the operations of agencies upon the plant, and the adaptations in the plant to the agencies; either may form a guide in the search for the other. The field observer can settle what the indoor worker can but guess at, and make discoveries of which the latter would never dream. But the more concrete treatment of this most important matter belongs under the special sections to follow.

The great adjunct of observation is apt experiment, and for Phytobiology this of the simplest and most direct sort. The mere cutting away of a branch, the isolation of a flower by a muslin cover, the pinning of a leaf to a fixed position are types of simplicity of experiment which, when tried in test of a definite question, have made clear some of the deepest principles. By what simple methods great truths can be laid bare is illustrated by Darwin's phytobiological work, particularly upon Insectivora, fertilization and seed-dissemination, and the student cannot possibly do better to prepare himself for similar work than to study these classical models. We shall have much more to say upon this subject under the special divisions to follow.

The training of the judgment, axiomatical for all good scientific work, has a particular application to our present more limited topic in connection with the nature of adaptation. As we have seen, not all the characters of a plant are adaptive. Some are simply inherited and of little or no direct use; and others are incidental to something else. The line separating inherited or genetic characters from those adaptive or immediately useful, is extremely shadowy and shifting, and the relationship of the two is of the most varied degrees. In general, the student may feel sure that the most superficial characters —form, color, size, position, etc., are immediately adaptive to readily-observable agencies, while the deeper seated characters are either adaptive to more general agencies or are inherited and not now of vital importance. One may obtain a rough measure of the immediateness of adaptation by noting how far the given character runs throughout the relatives of that plant. If only specific, it is probably easily discoverable; but if generic, or tribal or ordinal, it becomes proportionally deep-seated and more difficult to detect. But ever there comes in also the third term of the life-equation, which is almost unknown, hence making it so difficult to solve it to the fourth. Heredity, environment, internal constitution are the three; use or reason for being is the sought-for fourth.

Again, the student is often misled by what seems to be adaptation, but in reality is not, which teaches that conclusions cannot be safely drawn from a single line of observation. Thus the presence of the sexual organs upon the *under* side of the prothallia of Ferns seems to be a distinct adaptation for placing them where the water necessary for their fertilization is most abundant. Yet experiments show that they seek not the wettest but the darkest side, and if light be thrown up upon them from below, these organs develop upon the upper surface. Indeed, very few facts can be settled from observation alone; it is always better to confirm observation by experiment. Again, one must be on the watch lest he take single individual adaptations or accidents or sports, as characteristic of the whole species. The power of individual response to certain special conditions is in some plants remarkably great, and it may accidentally or intentionally be brought about. The result may be extremely valuable for some purposes, but it is not a safe guide to the real cause of adaptation in a state of nature. Numerous observations under varying conditions in the field, with concise control-experiments—these, we repeat, are the tools of the local phytobiologist.

It remains in this connection but to point out that there are three phases of phytobiological study to be applied to every plant. There is first the investigation of the *raison d'être* of the characteristics of its individual parts; secondly, the consideration of it as a member of a biological group; and thirdly, its consideration as a member of a climatic group. The Sundew catches insects in one way, Nepenthes in another, thus showing individual adaptations; both have characteristics in common as members of the biological group Insectivora, while the former has yet other characteristics in common with its neighbors in cold northern bogs, the latter with other epiphytes in damp tropic forests. Salicornia and a Cactus have habits different enough, yet they have many characters in common as members of the biological group of succulents (water-holders), while yet, again, the former has much in common with other sea-shore plants, and the latter with other dwellers in the desert. So there are groups within groups in adaptation, and the student has to take account of generalization as well as details.

III.—The Phytobiological Study or Survey of Acadian Plants.

The three Acadian provinces offer to the student of phytobiology a field of unusual attractiveness. It is true we do not possess those extremes of physical conditions which give us such extremes of adaptations as are found on deserts, high mountains, or in the damp tropics, but we have approaches to them all. The great diversity of surface of Acadia, rich forest lands and intervales, salt-marshes and sand-dunes, bare hill-tops and wind-swept cliffs, together with the richness of its flora, comprising, as it does, more than a third of all the many species found north of Tennessee and east of the Mississippi; and the great climatic changes of past times, all combine to make the plant life of Acadia of great interest, and of much promise in phytobiological results. And this is true not only of questions of individual adaptations, but the presence of all of the great biological groups, Insectivora, Succulents, Parasites, etc., with their problems, and the unusual variety of climatic groups, add to our advantages.

To proceed now to the treatment of the subject from the point of view of the Acadian student, we must first make some classification of the great subject. As elsewhere in nature none can be made which will be strictly natural and give exclusive divisions, and that to be outlined below is based largely upon convenience of treatment in this series. Under each division we shall discuss, (*a*) its most general principles, (*b*) their application to Acadian plants, (*c*) present knowledge as to Acadian plants, (*d*) problems requiring solution. We are to confine our attention in the main to flowering plants. The divisions are as follows:

A. The Adaptations of Plants to Inorganic Nature. This includes the relationship of living matter to the very physical and chemical nature of the world, and to the laws of Physics and Chemistry. It traces how, as a resultant of all these external influences, the higher plant has been produced, with its peculiar nutrition and its three primary organs, leaf, root, stem. It further considers the response in these organs to variations in the external conditions — notably meteorological conditions with varying degrees of moisture, heat, etc., and forces brought to bear upon the plant, including, with others, gravity, wind, weight of snow, beating of rain, water currents, etc., or, in a word, all the variations of the external inorganic world. Here comes the treatment of the origin of climatic groups, and of the main causes of plant-form and size, and the structural phenomena of life-cycles.

B. The Adaptations of Plants to other Organic Beings. This includes their relationship to animals, protection from them by spines, chemicals, etc., and utilization of them for defence against other animals, and of their powers of locomotion for the transfer of pollen and scattering of seed. It includes also their relationship to plants of the same and other kinds, under the former treating the little known subject of competition and development of new races, and under the latter competition upon a larger scale, with its consequent forcing of groups into parasitic, water, and other special habits originating the biological groups. It includes also symbiosis of living together of organisms for mutual advantage. In this division the whole subject of competition is most important, for the Darwinian hypothesis of evolution hinges thereupon, and very little of positive knowledge has yet been gained about it.

C. Adaptations of Plants to Reproduction. This includes the origin of the flower and its biological significance as an organ for securing the co-operation of two parents in the production of offspring. This introduces also the subject of cross-fertilization and the utilization of locomotive agencies for securing pollen transfer. Meaning of colors, shapes, time of flowering, clusters, etc., in fact, all floral phenomena belong here, together with sexual reproduction and hybridization.

D. Adaptations of Plants to Locomotion. To prevent overcrowding and to secure the advantages of development under somewhat different conditions of soil, etc., plants, like animals, must have the power of locomotion at some period of their lives. Being incapable of it directly, they have utilized the seed stage as most practicable and adapted it to be moved by the ordinary locomotive agencies of the world about them —wind, water-currents, animals, etc. The varying modes and degrees of perfection of the power thus acquired, together with the operations of man, produce important results in the distribution of plants within limited areas, and some such problems of unusual interest we have in Acadia.

E. The Biological Groups of Plants. These include the groups modified to a common special habit by influences other than those of climate, such as the Parasites, Insectivora, Water-plants. Though all of them present, they are none of them conspicuously developed in Acadia.

F. The Climatic Groups of Plants. As already mentioned Acadia does not possess extremes of climate, and hence has not extremely-adapted groups. But it has a great variety of conditions producing the following floras:

Strand,	Fresh-water,	Hard-wood upland,
Salt marsh,	Salt water,	Dry sea-cliff,
Sand-dune,	Intervale,	Hill,
River-bank,	Barren,	Field and open place.
Bog,	Soft-wood upland,	Weeds.
Swamp,		

The characteristics of these, and their common response to their common environment is a most important division of our subject. Here must be considered also the causes which allow of the persistence of northern and southern colonies within our borders.

G. A Summary of the Biological Characteristics of the Vegetation of Acadia, correlating our previous studies, and bringing them into touch with other departments of Botany, principally Botanical Geography and Botanical Philosophy. Here we must consider recent changes in the flora, and the causes of the introduction of northern and southern colonies, and finally the general phytobiological status of the Acadian flora.

So much for a general view of our subject. We have now to enter upon the special treatment of its divisions, one of which I hope to present each year to this Society. I have every confidence that Acadian Botanists and Phytobiology will prove reciprocally adaptive.

The University, Munich, Germany, March, 1894.

ARTICLE II.

THE CRYSTALLINE ROCKS NEAR ST. JOHN, N. B., CANADA.

By William D. Matthew, Fellow in Geology, Columbia College, N. Y.

(Read May, 1894.)

Among the many attractions which St. John offers to an intelligent visitor, the variety and interest of the rocks in and around it, is by no means the least. Few places, if any, afford a greater number of geological formations within so limited an area, and the scanty soil, which is the despair of the farmer, is hailed with delight by the student of lithology. Yet, on account of its distance from the great centres of learning in the United States and in Canada, the details of its geology have been worked out chiefly by local students, and their excellent work is perhaps not as well known elsewhere, as it otherwise would be. The complicated structure of the neighborhood has made it impossible to get satisfactory results without the most careful and accurate study, and this cannot so well be made in the less settled districts at a distance from the city. But it may, I think, be safely said that southern New Brunswick has been as carefully surveyed as is practicable until it becomes more thickly settled, and hence more accessible.

In the present paper I do not propose to deal much with the structural geology of the country, but rather to discuss to some extent the character of the various rocks around the city, and especially the igneous ones. The facilities for the study of these have in late years been greatly increased by the use of thin sections of the rock, which can be examined under a polarizing microscope; thus bringing to light many interesting structures, imperfectly, or not at all seen in the opaque specimen.

The pioneer geologist in New Brunswick was Dr. Abraham Gesner, who conducted between 1839 and 1843, under the Provincial Government, a geological survey, which published a number of reports on the geology of the province, dealing chiefly with its economic aspects, the prospects for mining and agriculture. After the union of the provinces, a second and more thorough survey was made under the Dominion Government, and the results of this survey in southern New Brunswick were published in the Report of 1871, and later ones. The structural geology of this paper is mostly summarized from these reports. The field-work for this part of the province was done by Dr. L. W. Bailey and Dr. G. F. Matthew, President of this Society, joined later by Dr. R. W. Ells. The map accompanying this paper will more fully show the geology of the vicinity of St. John, being on a larger scale than that published by the Canadian Geological Survey.

Saint John is built on the upturned edges of grey Cambrian slates, which underlie most of the peninsula forming the city proper, and the "Valley" to the north of it. At the end of the peninsula is a small remnant of very similar slates of Devonian age, separated from the Cambrian by a band of older trap rock. The face of the hill back of the Valley is composed of hard and fine-grained flinty felsites, very much cracked up and jointed; and behind these lie limestones, quartzites and gneisses, forming a rough, broken country which extends to Kennebecasis Bay. Across this broken country stretch a number of bands of solid and massive granite rock, in ridges and hills covered by a thin growth of stunted firs and spruces, or often turned into desolate barrens by repeated forest fires. Northwestward towards Boar's Head is a small area covered by coarse red conglomerate and sandstone, of Carboniferous age.

All these formations have a general strike approximating north-east and south-west. Following them south-west, at the mouth of the harbor, we find the Devonian slates continuing along the "Bay Shore," where the well-known "Fern Ledges" have afforded beautiful specimens of ferns and insect wings. On this side of the harbor the igneous rock is found to increase in width, forms most of Carleton Heights, and appears in several hills along the shore. The Cambrian slates of the city cross to Carleton, but are cut out beyond the Falls by a faulting which has caused the felsites and limestones to the north to encroach on them, and to the south-west of the Falls everything is buried under ridges of glacial drift. The limestones and gneisses continue across the river and extend to the west and south-west for a long distance. One of the bands of granite crosses over from Indiantown to Pleasant Point, and makes a high, round-topped ridge on the west side of the river along the the Narrows. Other masses of granite appear beyond, but have been less carefully studied.

The succession of the stratified rocks in point of age is as follows:

1. Limestones, quartzites and gneiss.
2. Felsites and trap.
3. Cambrian slates.
4. Devonian slate and sandstone.
5. Carboniferous conglomerate and sandstone.

Overlying all these are deposits which have not yet been consolidated into rock. These are :

6. **Glacial debris, or "drift," covered in places by gravels.**
7. **Marine clays, or "Leda-clay," formed when the land was lower than at present.**
8. **Marine sands, "Saxicava sand," formed in a shallow sea.**
9. **River alluvium and salt marsh, (the land at or near its present level, and) the deposit still forming.**

It is only with the first two members of the series of stratified rocks that I propose to deal at present. The later rocks, showing clearly their original character of sand and mud, and yielding unquestionable evidence of their age in the form of fossils, are of interest chiefly to the palæontologist. But the pre-Cambrian rocks contain practically no direct evidences of life, and are, besides, so much changed that it is often difficult to tell what they originally were.

The Metamorphism of Rocks.

One is apt to think of a rock as something fixed and unchangeable — and so indeed it is, if we measure by our own short span of life. But in the time-scale of the geologist, rocks, like living forms, are seen to change with changing conditions.

To go back to the beginning, the first crust of the earth must have solidified from a molten mass, or "magma," as it is called, much like the lavas of modern volcanoes. Whether this crust formed over a liquid interior, or one mostly solid, is a matter of conjecture, though the weight of evidence tends to show that now, at all events, the earth is solid throughout, and molten areas, if they exist, are only of local extent. The rock of the original crust would be composed of minerals formed at a red or almost white heat. As it cooled down, these minerals become *unstable*, that is, they tend to change chemically into other combinations, and this change is greatly assisted by exposure to air and rain. Part of their substance is dissolved away, the rest left as loose grains, or changed to new minerals, which are usually softer than the original ones, and are not in large and solid crystals, but in a fine, loose powder, or mud, so that they are easily washed away by the water and carried down by streams to the sea, where they are deposited as sediment. This chemical change, or weathering, is one to which all rocks are subject, and it is the great agent by which they are worn away, the grinding and battering action along sea-coasts playing but a subordinate part.

If the sediments are deposited in a place where the earth's crust is slowly sinking, more and more material is piled up on top of them, weighing them down with an enormous pressure, and they gradually settle into a campact mass. The water contained in this mud is under a very heavy pressure as well, and as the mass sinks deeper it comes more and more within the influence of the earth's internal heat. By this combination of heat and pressure the solvent power of water becomes much greater, and it dissolves out a considerable part of the rock. As the mud settles downward and becomes more compact, it is evident that the water will work its way upward, so that throughout the mass there will be relatively a continual, slow, upward seeping of water, charged with all the dissolved rock it can carry. This water will come into zones of less heat and pressure as it rises, and must then deposit some of its mineral matter, cementing the compacted sediment into a solid rock.

As the sinking continues, the heat and pressure increase, and the remaining water has a more powerful influence, enlarging the old crystal grains and changing the surface-formed minerals into new ones, which are much more crystalline and harder. Finally the rock passes into a state in which it is only kept from melting by the enormous pressure from above, which, by preventing the slight expansion which rocks undergo in becoming fluid, compels it to remain solid.

The Origin of Igneous Rocks.

If now this pressure be relieved, as it would be if a crack should form at the surface and extend down into the buried rock, the whole mass liquifies and squeezes up through the crack, pushing apart the walls as much as it can, part of it perhaps reaching the surface and pouring out over it, part solidifying on its way up. This molten magma contains the one or two per cent of water that still remained in the sediment after it had progressed far down into the region of internal heat; and this water greatly assists in keeping it fluid.

The part that reaches the surface cools quickly, and much of its contained water escapes as steam, being now released from the pressure that had kept it liquid. This steam blows up the lava into scoria and pumice, or shatters it into fragments, which are thrown from the mouth of the crater by the ascending steam, and scattered far and wide over the country round. The coarse fragments will fall near the opening, making a volcanic breccia, so called; the finer material will travel further and form beds of volcanic ashes or tuff. Some may fall into the sea — all indeed, if the volcano be sub-marine,—

and will then be worked over by waves and currents like ordinary sediments. The solid lavas will have cooled at their surface, too quickly for crystals to form, and will be glassy rocks or obsidians. Away from the surface, if the lava stream be thick enough, crystals will have had time to form, and the rock will be full of small crystals.

The part of the magma which failed to reach the surface will cool very slowly, so that its crystals will be comparatively large. They will finally interfere with each other's growth, and their boundaries will not be smooth faces, but irregular surfaces, the rock being made up of more or less roundish grains of different minerals. This structure is called *granitic*, as being best shown in the granites. But suppose the rock is interrupted while it is cooling, when some large crystals have formed, but before they have begun to interfere with each other; and pushing up to the surface, cools there. The still liquid part will solidify as a mass of minute crystals, or a glass, and through this will be scattered large ones. It has then a *porphyritic* structure, an extremely common one in volcanic rocks.

It is evident that a large mass of molten matter cooling slowly at a considerable depth will have great influence on the surrounding rocks, not by its heat alone, but especially on account of the highly heated water it contains. As it crystallizes, much of this water will escape, and, intensely heated and loaded with dissolved material, will work out into the surrounding beds, producing new minerals and re-crystallizing old ones. These contact effects will be most conspicuous next the granitic rock, and will gradually decrease as we go away from it.

EROSION AND FOLDING.

Let us now suppose that in the area we are discussing the slow sinking of the crust stops, and a slow elevation begins. The sediments last deposited will be raised out of water, eroded by air and rain, and carried off by the streams to some other region. As the elevation and erosion continue, strata will be exposed at the surface, which are more and more altered. In the course of time the rocks overlying our granitic intrusion will be all swept away, and we will have the granite (with a zone of altered rocks around it) brought to the surface. As time went on, yet more of the surface rock would be carried off, till finally we would have brought to light the most highly altered rocks, scarcely distinguishable from the granite itself. As all these rocks successively come to the surface their minerals are altered and destroyed by air and rain, and the new minerals formed, with the remnants of the old, are swept away, carried off and deposited as sediments in some other area, there to undergo the same cycle of change that has been already outlined.

From causes which as yet are not well understood, the upper crust of the earth has been folded and wrinkled —like the skin of a dried apple, to use an old comparison. The immediate cause of this folding seems to be a side thrust or pressure coming from that part of the crust which underlies the great oceanic areas. The crests of the folds are first exposed above water and are rapidly eroded; the hollows are slowly worn away, or, if under water, are filled up by later sediments, which in their turn are folded and squeezed together by the ocean thrust. The strata are thus exposed more or less on edge, instead of flat-lying; and this up-tilting is most marked in general, in the earliest rocks, where the action has been going on the longest.

Composition of Igneous Rocks.

Since an igneous rock is a mixture of minerals, we do not expect to find a definite or unchanging composition in any one variety. The minerals present depend on the chemical composition of the molten magma from which it cooled ; and within certain limits this composition may have varied indefinitely. But this variation is governed by certain rules.

All igneous rocks contain a large proportion — from thirty to seventy-five per cent — of silica. But those especially rich in silica contain the largest amount of potash and soda, and very little lime, magnesia, or iron ; on the other hand, those poor in silica contain a large amount of lime, magnesia and iron, almost no potash, and not much soda. The former are called *acid*, the latter *basic* rocks. Alumina is present in considerable amount, averaging ten to fifteen per cent, in all rocks except the extremely basic ones, in which it is sometimes almost wanting.

Corresponding with the chemical change is a change in minerals. The common minerals in igneous rocks are almost all silica compounds. We have first *quartz*, which is pure silica. Then the *feldspars*, which are silicates of alumina with some other basic oxides. *Orthoclase* feldspar contains potash and a little soda. *Plagioclase* feldspar contains soda and lime in varying proportions. These are the chief light-colored minerals. The dark minerals are *mica*, *hornblende*, *augite*, *hypersthene* and *olivine*. *Mica* is a complex silicate, containing alumina, potash, magnesia and iron. There are two species; one, *muscovite*, is a potash-alumina silicate, and the other, *biotite*, is a magnesia-iron alumina silicate. The first is rarely seen in igneous rocks, except a few very light colored granites. The second, which is much darker in color, is a common constituent of them. *Hornblende* and *augite* are silicates of alumina, lime, and magnesia and iron. *Hypersthene* and *olivine* are magnesia-iron silicates. Orthoclase feldspar, and some varieties of plagioclase, contain a very large proportion of silica, while hypersthene and olivine contain less than the rest. All these minerals are of definite composition, but one basic oxide may replace another to a certain extent. *Magnetite*, an oxide of iron, is found in noticeable amount in the more basic rocks.

We name the rocks according to the minerals most abundant in them, and also according to their structure, which is granitic in those which have cooled at a considerable depth, porphyritic, or glassy, in surface-cooled masses. Among the granitic rocks we have a series from acid to basic, as follows: *Granite*, composed of quartz, orthoclase, and usually some plagiolase, and a small amount of mica, or hornblende, or both. This grades into *Quartz-diorite*, composed of quartz, plagioclase, and often some orthoclase, and with rather more hornblende, or mica. By the quartz decreasing and hornblende increasing, we get a plagioclase-hornblende combination, or *diorite*. This, again, by augite replacing the hornblende, becomes a *gabbro*, and the gabbro, with incoming of hypersthene and olivine, becomes an *olivine-gabbro*. This, finally, by decrease of the feldspar, grades into a *peridotite*, composed of olivine with hypersthene, or augite, or both.

Corresponding to these intrusive rocks we have different volcanic rocks, which are not so easy to distinguish, as the minerals are not well crystallized. The porphyries and felsites correspond roughly to the most acid intrusives, the porphyrites to the intermediate ones, and diabase to the more basic.

Segregation.

A curious, and for a long time unexplained fact about volcanic rocks is that lavas erupted from the same centre often differ markedly in composition, some being more basic, some more acid. Correspondingly, we find with intrusive rocks that one part of the intrusion often differs much from other parts. This variation follows closely the rule already noted, that the potash and soda go mostly with a high silica percentage, the lime, iron and magnesia with a low one. Hence, it can scarcely be due to accidental differences in the original melted mass, and it is believed that the cause lies in a tendency in all molten magmas to split gradually into acid and basic divisions, the potash and soda having a greater chemical affinity for the silica than have lime, iron, or magnesia.

The Rocks About St. John.

There are around St. John almost all of the different kinds of rocks whose origin we have discussed, and some are of considerable interest.

Metamorphic Rocks.— To begin with the oldest, we have the "Laurentian" series, of limestones, gneisses and quartzites.* These are very highly altered rocks, but were once sediments probably very like those of the present day. The quartzite was once a sand, composed of loose rounded grains of quartz, but now all the spaces between the grains are filled up with quartz similar to

* The reader may observe the areas occupied by these and the following divisions of the rocks at St. John, by referring to the accompanying map.

the grains themselves, so that they cannot be distinguished except by examining a thin section with the microscope. The limestone, probably once fine grained, or made up of small fragments of the skeletons of low organisms, is now crystalline, and shows (with a few exceptions) no traces of its former condition. The gneiss was probably once a sandy shale, but all of its original mineral grains have disappeared, and we have in place of them a rock composed of far larger grains of quartz, feldspar, mica and hornblende, as densely packed as in a granite. The original bedding of the rock is still quite plain, however, as the sandier layers have been converted in a more quartzose rock, and the more clayey ones into micaceous bands. In Quebec and northern Ontario are vast areas of gneissic rocks which are much more metamorphosed even, than those around St. John, and are extremely massive and coarsely crystalline. They are everywhere cut through by granite intrusions, and it is thought doubtful whether they ever were ordinary sediments of the modern type. But there can be little doubt about the original nature of the gneisses near this city.

Granite — Cutting through the Laurentian rocks north of the city there are several granite intrusions. The granite is fairly coarse-grained, showing that it solidified at a considerable depth; but it contains large porphyritic crystals of orthoclase feldspar, which must have formed at a still greater depth. In the mass of the rock there is more plagioclase than orthoclase, hence it is not properly a granite, but rather a quartz-diorite, except in a few places where the orthoclase predominates. The different areas of the rock differ considerably in appearance, the wider ones being more coarsely crystalline, and with more of the porphyritic crystals. But as all have in common a number of peculiarities, they were probably injected from the same molten magma, and approximately at the same time, the variation being due to segregation. The dark minerals in the granite are biotite and hornblende in about equal amounts in the fresh parts of the rock. But the biotite is an unstable mineral when near the surface, and tends to alter to hornblende, or epidote, so that we often find these minerals replacing it and still retaining the outward form of their original. These, in turn, when at the surface, are acted on by rain and changed to soft green aggregates of chlorite, calcite, etc. Scattered in small quantity through the rock are minute crystals of the rare zircon, which can be separated by crushing and "panning out," and show under the microscope very perfect crystal forms.

The contact between the granite and surrounding rocks is usually hidden. Near King's mill, Fairville, it is exposed by a small quarry in the limestone, and here the lime is whiter and more crystalline near the granite, and close to it contains great numbers of garnet crystals. Besides these evidences of contact-metamorphism, there is between the lime and the granite a narrow band of a peculiar rock like a "vein-granite," which was probably deposited by the heated water around the edge of the intrusion. Further east, near Pleasant Point, the river has left some remnants of the surrounding rock clinging to the side of the granite cliff; and here, too, the limestone and gneiss are coarser than usual, and garnet is developed, sometimes forming entire layers of the rock.

Gabbro.— Another type of intrusive rock appears in two little knobs at Indiantown, and in a larger one making the hill just north of Dolin's Lake, back of Rothesay.

This is a basic rock, very coarse grained, black and heavy. It is composed of plagioclase feldspar, hypersthene, olivine and augite in variable quantities, and is therefore to be called an *olivine-gabbro*. The last three minerals, all unstable ones, have been changed more or less to hornblende. By taking different specimens, all stages of this change can been seen, some parts being almost fresh, others completely changed to a hornblende-plagioclase rock, which for the sake of distinguishing it from an igneous rock, *originally* composed of these minerals, is called an epi-diorite, or gabbro-diorite. The olivine and hypersthene were not of the right chemical composition to change to hornblende, had they been alone. But wherever they came in contact with the feldspar, the necessary alumina and lime was supplied, and a hornblende crust or rim formed between the two, and enlarged itself at the expense of both minerals. In thin sections this gives a very pretty effect; the pale brown olivine is surrounded by a rim of bright green needle-like crystals of hornblende, radiating out into the colorless feldspar.

The little area at Indiantown, close to the end of Main street, and south along the water-front, furnishes a very good example of segregation. At its south end it is composed chiefly of feldspar, with very little of the dark colored silicates, and is a greyish white rock, with dark spots. As we go toward the north end, the dark silicates increase in amount and the feldspar decreases, till finally the rock is made up almost entirely of olivine, hypersthene and augite, and is of a dense and glistening brownish black color.

The Volcanic Rocks.— Between the Laurentian limestones and the Cambrian slates lies a rather narrow band of felsite of intermediate age. Its original nature is rather doubtful, but it has been considered to be most probably a consolidated volcanic ash. The series to which it belongs is greatly developed to the north-east, in the Quaco hills, and there is made up of ancient lavas, volcanic breccias and ashes. The lavas are usually more or less porphyritic, and some show, when sectioned, indications of having once been partly made up of glassy matter.

It seems that in pre-Cambrian times southern New Brunswick was part of a great volcanic region, which extended down to the south-west at least as far as the Carolinas. From the St. John volcanoes were thrown out great quantities of lava and ashes, some on land, some under water. The centres of eruption appear to have been some miles to the east of the city, so that only the finer ashes reached this far west, and formed the fine felsite band.

The parts of the lava flows next the surface would cool suddenly and be glassy. Those farther from the surface would be fine-grained, with usually some porphyritic crystals, which had formed in the depths of the earth from which the molten rock had come. Along with the solid lavas vast quantities of pumice, broken fragments of rock and fine ashes were cast up, the finer ash drifting some distance with the wind.

In the course of time these volcanoes became extinct, were partly worn away, partly covered up by the sinking of the land, and later sediments deposited on them. The ashes and breccias were consolidated into a hard rock, metamorphosed so as to be almost unrecognizable; the harder lavas suffered less change, but their glass was converted into a felsitic mass, made up of exceedingly minute crystalline grains of different minerals. Then, through later folding and erosion, these altered rocks were once more brought to the surface, as we see them now.

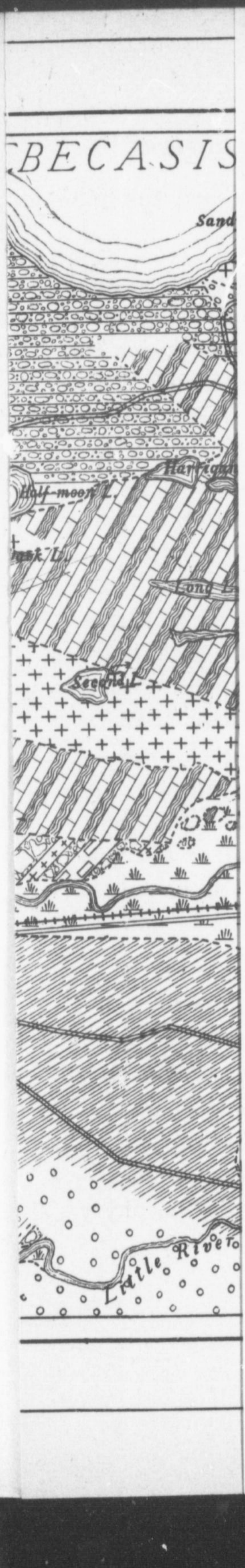
Characteristic Structures of Volcanic Rocks. — In modern glassy lavas we usually see imperfect forms of crystallization, one common type of which is composed of a quantity of minute needles of crystalline quartz and feldspar, radiating out from a centre and forming a little ball, called a *spherulite.* These spherulites are still preserved in some of our ancient lavas, and give one proof of their original character. Again, in modern lavas, or slags, we often see a series of wavy parallel lines, produced by the flowing of one part of the viscous fluid over another. These "flow-lines" are often to be seen in some of the old New Brunswick lavas. In the upper part of a lava flow, the contained water, relieved from pressure, bursts into steam and fills the lava with little cavities, or vesicles. So, too, in parts of these old volcanic flows we find vesicles abundant; but they have subsequently been filled in with quartz and calcite by the mineral-bearing solutions which contrive to seep into the rock during its metamorphism. Such are some of the proofs of the volcanic origin of these rocks.

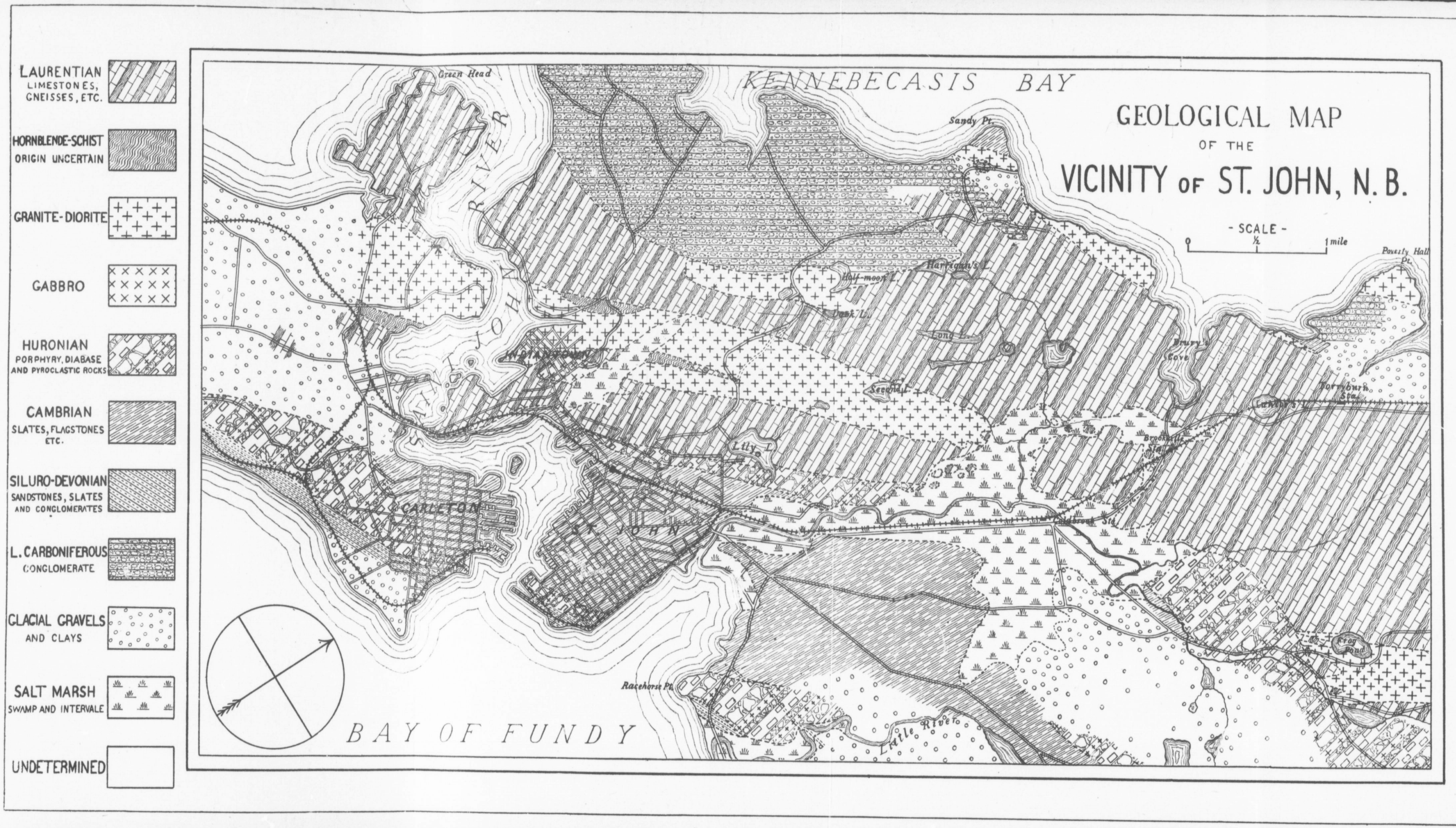
The breccias are seen to be made up of angular fragments of rock of all sizes and lying "every which way." The whole mass at the same time is flinty, and breaks in the same way as the felsites. In thin sections we can see that it is made up entirely of pieces of lava, large and small, which often show some of the characteristic structures of which I have spoken.

Some of these rocks have been so much metamorphosed that they have taken on a schistose structure, and almost nothing is left of their original character, which can only be assumed from their association and the finding of intermediate stages of alteration.

Basic Volcanic Rocks.—A more basic type of volcanic rocks is to be seen in a series of knobs along the southern side of the Cambrian slates. The heights on which the Martello tower is built are of this material, and to the east of the city it crops out on the shore south of the alms-house, and again back of the penitentiary. This rock is a plagioclase-augite mixture, or diabase—one of the rocks commonly called "trap." It is often very full of vesicles, which are filled in with white quartz. At the shore, by the alms-house, it outcrops as a heavy dyke in green and red slates, instead of a surface flow; in all probability part of the fissure is exposed, through which the magma found its way to the surface. It is interesting to note that as far back as 1840 Dr. Gesner pronounced this to be a dyke, though he was not able to find its edges, and supposed it to graduate into the surrounding slates. By a careful examination, however, the edges may be traced on both sides; but with some difficulty, because the igneous rock has baked the slate near by into a hard flinty mass, very like itself.

Dykes.—Great numbers of small dykes are to be found cutting across all the older rocks near St. John. Most of them, probably, were formed about the same time as the great volcanic surface flows, which they closely resemble, though wanting the special characters which have been mentioned as distinguishing surface flows. Almost all are diabase, dense, sometimes porphyritic, more generally fine grained. A very few porphyry and porphyrite dykes are also known.


BECASIS
Sand
Half-moon L.
Little River


GEOLOGICAL MAP
OF THE
VICINITY OF ST. JOHN, N. B.
- SCALE -
0
½
1 mile
LAURENTIAN
LIMESTONES, GNEISSES, ETC.
HORNBLENDE-SCHIST
ORIGIN UNCERTAIN
GRANITE-DIORITE
GABBRO
HURONIAN
PORPHYRY, DIABASE AND PYROCLASTIC ROCKS
CAMBRIAN
SLATES, FLAGSTONES ETC.
SILURO-DEVONIAN
SANDSTONES, SLATES AND CONGLOMERATES
L. CARBONIFEROUS
CONGLOMERATE
GLACIAL GRAVELS
AND CLAYS
SALT MARSH
SWAMP AND INTERVALE
UNDETERMINED
KENNEBECASIS BAY
BAY OF FUNDY
ST. JOHN RIVER
Green Head
Sandy Pt.
Poverty Hall Pt.
Half-moon L.
Harrigan's L.
Long L.
Drury's Cove
Torryburn Sta.
Brookville Sta.
INDIANTOWN
CARLETON
ST. JOHN
Lily L.
Frog Pond
Racehorse Pt.
Little River

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SUMMARY.

To sum up, finally, we have represented at St. John, besides the ordinary sedimentary strata, the following types of rock:

1. A varied series of metamorphic or crystalline stratified rocks.
2. Intrusive rocks, both acid and basic, showing well the phenomena of contact-metamorphism and segregation.
3. A great and varied series of volcanic rocks—lavas, breccias and ashes—all of pre-Cambrian age.
4. Dykes, mostly trap (diabase) and with some exceptions also of pre-Cambrian age.

EXPLANATION OF THE MAP.

I am indebted to the courtesy of the New York Academy of Science for permission to use the plate for this map, which first appeared in connection with my article, read before that body, on April 16th, 1894.

The reference column in the margin will sufficiently show the meaning of the various markings used in the body of the map. No attempt has been made to distinguish the bands of limestone in the Laurentian rocks, as this would necessitate a more detailed survey of the district than it has been possible to make. Areas where the limestones have been found are not specially distinguished here, but are designated in a general way on the map of the Canadian Geological Survey.

ARTICLE III.

MOVEMENTS OF THE EARTH'S CRUST AT ST. JOHN, N. B., IN POST-GLACIAL TIMES.

By G. F. Matthew, D. Sc., F. R. S. C.

Read 6th November, 1894.

A year ago, when passing through City Road, St. John, in an electric car, the writer caught sight of a sloping ledge of slate, which appeared to show evidences of faulting. On re-visiting the spot afterward he found that the appearance was not illusory, but that there had been uplifts of these slates along old fault lines since Glacial times.

An examination of the rock surfaces at other points showed that this was not a solitary instance of displacement, but all along this hillside—for a distance of half a mile—great numbers of these faults could be seen. Though the individual displacements were generally slight, yet owing to the great numbers that exist the change of level is very considerable, and the importance of these faults is greater that at first sight would appear.

Their influence on the structural geology of this district seemed of sufficient importance to make a more careful examination desirable, and the writer accordingly undertook a rough measurement of the faults at the more important exposures.

At City Road, just under the City Hospital hill, are some ledges on the south side of the street which project above the street level, the street having been partly excavated from the solid rock at this point. These ledges have a thin covering of soil, but in some places the covering has been removed, and the smooth, glaciated surface of the slates is visible.* (See plate).

The glacial striæ here have a course south, five degrees east, which is more than the usual easting, because the crest of the Hospital ridge slopes downward to the north-east near here. The slates are full of fault planes, running in several directions. The prevailing ones are parallel to the hillside and have a course north, sixty degrees east. It is along this line of fault planes that the principal displacements have occurred. Movement has also occurred along a set of planes having approximately a south-west (south, thirty-five degrees west) course.

The rough measurement of the spaces between the faults, and the amount of displacement, gave the following results, beginning at the City Road:

Estimated Distance.		Displacement at the Fault.
Feet.	Inches.	Inches.
0	6	¼
1	0	¼ to ½
1	0	2
1	6	4
1	6	1 to 2
1	0	¼ to ½
1	4	¼
0	9	¼
3	0	¼
11	7	10

In the half nearest the road, toward the western end of this exposure, there is a diagonal fault, course south, thirty-five degrees west, of about one inch, having a hade of seventy degrees to the south-east, and having the downthrow on the north side.

Other measurements were taken at Rock Street. Back of Fowler's mill on this street, there are quite distinct faults, some with a throw of three to five inches.

*I am indebted to Mr. Gilbert Van Ingen of Columbia College, New York, for the photographic view from which the accompanying plate has been made; it shows the faults described in the first of the tables given above.

Further along the street, eastward, but off it to the south, there is a space about two hundred and forty feet from north to south, going up the hill where the slates are well exposed. For about one hundred and fifty feet of this space the glacial striæ and faults are well shown; beyond this, higher up the hill, the rocks are too much weathered to give trustworthy results.

The striæ at this locality have a course of south, five degrees west, and the fault planes along which the principal displacements have occurred, have, as at the City Road locality, a course of north, sixty degrees east.

The following faults were observed here, beginning at the north side of the exposed ledges:

	Feet.	Inches.		Inches.
Distance,	4	0	Displacement.	2½
"	1	0	"	2¼
"	2	6	"	3½
"	0	5	"	1½
"	4	2	"	4¼
Surface of the rock concealed.				
Distance,	2	0	Displacement,	1
"	1	2	"	1¾
"	0	1	"	1
"	0	9	"	1¼
"	1	2	"	0¾
"	0	10	"	1
"	1	4	"	1
"	1	2	"	1
"	0	2	"	½
"	1	2	"	2
"	0	10	"	½
"	0	10	"	½
"	0	10	"	1
"	1	8	"	1¾
"	3	6	"	1¼
"	2	6	"	1
"	1	2	"	½
"	3	0	"	½
"	1	3	"	1½
"	0	10	"	½
"	2	6	"	½
"	0	2	"	1¼
"	0	10	"	1
"	1	4	"	¾
"	1	3	"	1½
"	1	2	"	2

	Feet.	Inches.		Inches.
Distance,	1	0	Displacement,	½
"	5	0	"	½
"	0	8	"	1
"	1	2	"	½
"	2	0	"	½
"	3	0	"	½
"	1	3	"	1
"	0	4	"	¾
"	4	0	broken surface.	
"	1	0	Displacement	1¾
"	2	6	"	½
"	2	6	"	5
"	1	4	"	½
"	3	0	"	3
"	2	6	"	1
"	2	0	"	1
"	0	6	"	¼
"	0	2	"	¼
"	0	1	"	¼
"	2	0	"	¼
"	0	4	"	¼
"	0	8	"	1
"	2	0	"	1
"	3	0	"	½
"	0	2	"	½
"	2	0	"	½
"	2	0	"	¼
"	7	0	"	1
"	9	0	"	2
"	4	0	"	1
"	2	0	"	½*
"	15	0	broken surface.	
	156			68 in.

* Down-throw on south side, all other down-throws on north.

In this space of one hundred and fifty-six feet, with sixty faults, all the down-throws were on the north side, with one exception, marked with an asterisk, where the down-throw is on the south side.

For spaces of forty feet, four feet and fifteen feet, respectively, in and beyond this space, the ledges were either covered by soil, or so worn and broken that the faults could not be traced. There were diagonal faults at this Rock street exposure, but not being well shown, they were not measured.

Further along this hillside, at the east end of Charles street, there are other ledges exposed. Here the striæ run south, fifteen degrees west. The principal set of fault planes has a course of north, sixty degrees east, and a steep hade south-west. The down-throw, as at the two former places, is at the north side of the fault. The diagonal faults are well shown here; one set has a course from east to west and a hade of about fifty degrees to the south; along these fault lines the down-throw is on the north side.

From Charles street westward to Sewell there are no good exposures, partly owing to the land being covered by buildings, and partly to the fact that there has been considerable filling in at Garden and Dorchester streets.

Proceeding toward the west end of the "Valley" the slate ledges are again exposed along the hillside south of Sewell street, at the north end of Peel street. This is at the junction of the fine black shales of the Bretonian division of the St. John Group with those coarser, lighter coloured slates of the Johannian division. The exposures are of small extent, but there are several of them. The glacial striæ here run south, twenty-five degrees west, and the fault planes along which the uplifts occur have the usual course. East of the end of Peel street, in a width of eight feet, four faults were noticed, varying in throw from one-quarter of an inch to one inch. The down-throw was on the north side. West of the end of Peel Street are several small exposures. At one the fine, dark slates are exposed for a breadth of fifteen feet. Here are twelve faults, varying from half an inch to one inch, and one fault with a throw of five inches. All have the down-throw on the north side. The striæ here have a course south, twenty-five degrees west. Further along the hillside, opposite Pond street, there are several faults with down-throws to the north. These are in black slate, and so worn by the weather that they could not well be measured. Here the striæ have a course south, thirty degrees west, a greater westing than at the other localities named above, because the ridge bounding the valley to the south here begins to descend westward toward the sea level.

A few observations outside the city limits have been made, which show the presence of these post-glacial faults at other points. Thus, at the north-east corner of the Church of England burying-ground, at the eastern border of the city, there is a glaciated ledge exposed, showing two slight post-glacial faults, of one-quarter of an inch each, having the down-throw on the south side. At the head of Courtenay Bay, on the eastern side, the ledges at the shore, and near by on the highway, show several post-glacial faults, with down-throws on the north side.

The excellent preservation of the pre-glacial faults in the "Valley" at St. John is due to various causes. In the first place the rock along the hillside consists of the fine shales of the Bretonian division of the St. John Group, which are well adapted to receive the finest striæ, and they are on the "stoss" side of the hill, and so are very distinctly grooved. Owing to their sheltered position behind this hill the surf did not reach them, when the country was submerged after the glacial period; and being non-calcareous, they were not affected by percolating surface water when the country was again elevated above the sea.

It will be noticed that the down-throws along the lines of fault are almost universally on the north side of the fault planes, which in the case of these planes is also the under side, for the hade of these faults varies from vertical to seventy degrees inclination to the south-east. We may suppose, then, that the appearance of these faults is due either to a failure of support beneath, *i. e.*, a weakening of the foundations of the earth's crust along the line of this valley; or to lateral thrust from the south-east, sustaining or lifting the rock along the south side of the faults.

The former cause has some color of support from various considerations. The valley along the south side of which these faults occur is one of great antiquity, and is itself, in part at least, due to a sinking of the rocks along the course of the valley in ancient times. This sinking between Mill street and the Falls, along the Straight Shore amounted to three thousand or four thousand feet in past Geological ages. The wearing of softer rocks will not account entirely for the scooping out of the valley, as the hard flags of the Johannian division are found in the bottom of it, and the soft slates of the Bretonian division crown the Hospital hill on its south side. But though there are thus plausible reasons for supposing the faults may have been produced by a sinking of the earth's crust beneath the valley, those that favor the view that the faults were produced by lateral pressure from the south, seem more weighty.

This lateral pressure has been shown to exist at Monson, Mass. In the quarry at that place it has been found that after the removal of a block of stone, the rock on each side of the space from which this block was taken, would, in the course of a few hours, creep together considerably, showing that there was a tension of the rock in this quarry, indicating a pressure from the south.* The well-known case of the flexures on a gigantic scale in the Carboniferous and pre-Carboniferous rocks of the Alleghany ranges show that such a pressure has been in active operation from a south-east direction in the middle states since the Carboniferous period. The prevailing south-east dip, and the numerous monoclines, dipping in that direction, among the pre-Carboniferous rocks of Southern New Brunswick, all point to the former action for intense pressure from the south-east. And it seems probable that the continued action of the force, to which this pressure is due, in a milder form, is responsible for uplifts on the south side of these pre-glacial faults.

The force which has produced these post-glacial faults appears to correspond in its action to that which caused the tension in the Monson quarry, only that in the case of the St. John locality it seems to have operated from a somewhat different direction. At St. John the greatest throws, and the most frequent, have a north-east to south-west course, and the more the joints depart from this course the less is the rock on their sides displaced; so that at right angles to this course a fault is quite rare.

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* The above was written from memory. I think the "Phenomena observed in quarrying," by Prof. W. H. Niles, described in American Journal of Science, March, 1872, refers to this occurrence. Among other peculiarities it was mentioned that a block split off with wedges 354 feet long, eleven feet wide, and three feet thick, freed at one end, but not at the other, was observed soon after being split to have lengthened one inch and a half; the expansion was not due change of temperature.

As the hade of these faults have more or less inclination to the south-east, the tendency of a force acting from the south-east (by lateral pressure) would be to elevate the mass on the south-west side of the fault and depress it on the opposite side. By continuous action of this kind a series of faults with an up-throw on the south side would be produced, which, in the width of this hillside, must amount to several feet.* Looked at in this view this whole hillside is a mass of shattered slate, seamed with joints, and ready to yield to pressure when applied; and when we consider that these post-glacial faults have been seen at other points, we realize that a stupendous power is still at work crushing and squeezing the rocks along this Atlantic coast, and ready to inaugurate afresh the process of mountain building when opportunity is afforded.

That this region is not perfectly stable and at rest may be inferred from the slight earthquake shocks felt here from time to time. Some of these shocks have had their area of greatest intensity at the mouth of the St. Lawrence river, and appear to have been propagated from there. The earlier records mention shocks of considerable violence, but the later ones have been slight.

The most complete list and description of these earthquakes which the writer has seen is that compiled many years ago by Sir William Dawson for the Canadian Naturalist, and is a record of about eighty-eight occurrences of this kind which have effected Eastern Canada and New England.† Of these at least twenty were probably felt at St. John, N. B., but only four are recorded in this list as having actually been felt here.

* A further test of the source of this movement might be obtained by examining steep hillsides sloping to the north-west, and noting if the faults are more prevalent there than in other situations.

† Can. Nat. and Geol., October, 1860, Montreal.

Two later earthquakes are recorded by Sir William as having affected the Maritime Provinces.* These are said to have been powerful enough to shatter walls, throw down chimneys, and do other similar damage. Other earthquakes of slight intensity have occurred in this region since 1870, but I have not at hand the record of the time of their occurrence, or the areas affected by the shocks.

As collateral to this subject I may mention the existence of two objects in the museum of the Natural History Society of New Brunswick which appear to show earth-movements since the glacial period: One is a glaciated boulder from the Grand Falls of the St. John river, collected and presented by R. Chalmers, that since its entombment in the boulders clay has been broken apart, the pieces somewhat displaced and then re-cemented. The other, which indicates more recent fracture, is a stone lance-head of felsitic material found at Grand Lake, which, since it was originally lost in the debris of a camp site of the stone age, was broken apart, the pieces slightly displaced, and the lance-head again cemented so as to be as perfect as before, except for the line of the crack and the slight displacement where the pieces are joined.

A short notice of these pre-glacial faults has been communicated to the American Journal of Science. It is to be hoped that the members of the Society will examine the surfaces of ledges in other localities to find out whether the phenomenon of glacial faults is of common occurrence in other parts of the province.

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* Can. Nat. and Geol., 1891, also November, 1870.

ARTICLE IV.

THE OUTLETS OF THE ST. JOHN RIVER.

By G. F. Matthew, D. Sc., F. R. S. C.

Read 13th November, 1894.

INTRODUCTORY.

Among the many rivers of the Atlantic seaboard of North America none have the peculiarities which serve to give especial interest to the St. John.

It is difficult to find a river four hundred and forty miles long and only two hundred feet wide at its mouth,† or with the peculiar tidal rapids which give such constant variety to the appearance of the gorge at the narrow outlet of this river.

The St. John differs from the majority of rivers in having no marine delta; the mud which it pours into the sea being swept up and down the Bay of Fundy by strong tides, until it mostly finds a resting place in the deep waters of the bay, off Grand Manan and the Western islands. The actual delta of the St. John is inland, between Belleisle bay and Oak point, and of the Kennebecasis at Perry's point, where these rivers discharge into lake-like expansions of brackish water.

The St. John combines within its basin three different river systems, once independent of each other, but now con-

† Between Split Rock on the eastern side and the limestone point under the Cantilever bridge on the western side, according to W. D. Matthew, the width is about 212 feet.

tributing their waters to the stream which discharges at the harbour of St. John. The rivers of the Middle and Southern States flow with a rapid course from mountain ranges to the plains, where they enter the sea by broad estuaries; those of the New England States descend from a broken country to enter the sea by fjords, or by shallow estuaries; the Hudson alone dividing these two groups of states has physical features which may be compared with those of the St. John. These streams are alike in their long, navigable courses, and in the fact that each drains a flat, interior region and forces its way to the sea through obstructing ranges of hills. The St. John, however, flows through a rolling and elevated country before it reaches the interior plain, while the Hudson gathers its waters off the low plateau or plain of Central New York, and then passes directly through the hills to the sea.

I do not propose to discuss this evening all the features of this remarkable river, but rather to try, if possible, to throw some light on the question of earlier outlets of the St. John than that which now exists, and to sketch the genesis of the several valleys which now form the channel by which the waters of the interior are poured into the sea at St. John.*

INCEPTION AND GROWTH OF THE VALLEYS NEAR THE OUTLET.

To trace the history of the valleys which give passage to the St. John, near its mouth, will carry us back to the remotest period of geological history, almost to the dawn of life, quite to that dawn as measured by the standard of fifty years ago.

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*J. W. Bailey has lately published a little book on "the St. John river, specially intended for sportsmen and tourists, in which the physical geography of this stream and its affluents is graphically presented. ("The St. John river in Maine, Quebec and New Brunswick," Cambridge, Mass., 1894.)

Let us take up this history at the close of Huronian time. At this period only the simplest organisms existed, viz., the Protozoa and Sea-weeds, with, perhaps, marine worms. The Protozoa had developed several types, as Sponges and Radiolarians with siliceous shells or skeletons, and the Foraminifera with calcareous shells, and these, no doubt, were accompanied by soft-bodied animals which have left no trace of their existence in the solid rocks. These animals that we speak of are known to have existed as early as, and probably before, Huronian time.

Huronian time in this region was too troublous to admit of the peaceful existence of these minute and delicate creatures. It was here a time of great physical disturbance. The solid crust of the earth, perhaps then more unstable than now, was broken up in many places and gave passage to great eruptions of volcanic matter. All the coast region of New Brunswick was overspread with vast sheets of scoria and ashes, poured forth from numerous volcanic vents.

Very noticeable among these volcanic ranges are the Kingston hills, now sunk to four hundred or five hundred feet above the sea level, but once towering above the surrounding country. Usually the rocks of this old volcanic range are so twisted and folded, or broken up, that it is impossible to trace the order of succession in which they were laid down; but at New river, in Charlotte county, they are more regular, and there a succession has been traced amounting to ten thousand feet in thickness. This means an accumulation of more than a mile and a half in thickness of lavas.

But the peculiar feature of this Kingston range is that while it has a longitudinal extent of about seventy miles, from Beaver harbor to Norton, where it is covered by later deposits, it is only four or five miles wide; and it is bounded by nearly straight lines throughout. This tells us that there were profound faults or breaks in the earth's crust along each side of this range, with probably a sinking area between, into which and on which the lava streams were poured. These faults were the initial lines of valleys which continue to exist to the present day.

A glance at the condition of these valleys, as they were developed during the passage of the ages, may be of interest. But we can only refer to a few of the more important epochs, taking up first their aspect at the close of the Cambrian time.

The Huronian epoch, previously referred to, was marked by the existence of animals of low organization — the Protozoans; now an advance had occurred, and we find the seas were tenanted by Crustaceans and Molluscs of various kinds, as well as many soft animals which have left tracks on the surface of layers of sand and mud of which the rocks are made up. The volcanic fires had died out, the sea had covered the land in the region of which we speak, except, perhaps, a few projecting hills; and over the lava beds, sunk beneath the ocean, was spread layer after layer of sand and mud, charged with the cast off tests of trilobites, the shells of molluscs, and the rod or net structures of hydroids.

The Saint John Fault.

The muds in which these were buried accumulated to a thickness of four thousand feet, and subsequently were crowded and folded together by a resistless pressure from the south, until the whole series was at one point doubled over on itself. This over-folding has revealed the existence of another profound fault in the earth's crust within the city limits: it runs along the Marsh and Valley, and the upper part of the harbor, from Mill street past the Straight Shore to the Lunatic Asylum, and beyond. (See map on page 56).

On the south side of this great fault the earth's crust has sunk down to the depth of three-quarters of a mile; or, *vice-versa*, the crust on the north side has risen to that extent, and the covering of Cambrian rocks with its entombed trilobites, molluscs and graptolites, or hydra-like animals, has been completely swept away by the vast denudation of subsequent ages. The weakness of this fault line helped to produce the valley which now exists along the City Road, and the upper part of the harbor which here forms a part of the outlet of the St. John.

Denudation as well as Faulting has helped to form these Valleys.

Another part of the outlet is more clearly the result of denudation or wear of the rocks. In the Laurentian rocks which cross the river at the "Falls," or rapids, there are some bands softer than others. One of the soft bands is that of shales, etc., which contains the graphite beds; this band is enclosed between limestones on the south and quartzites on the north, and being softer than the enclosing bands has given rise to the basin between the Upper and Lower "Falls." The quartzites on the north, form the ledges which obstruct the passage of the water of the river at the "Upper Falls," and the limestones on the south form cliffs on each side of the gorge at the "Lower Falls." On the west side of the river no rocky ledges show between these points, but the shore consist of Boulder clay and other surface deposits.

More complex agencies have been at work in producing the undulating shore lines at and opposite Indiantown, chiefly the denudation of rocks of unequal hardness, and the movement of rocks along fault lines. The bold hill at Pleasant point is a mass of granite which has fault lines and softer beds on the south, and softer strata also on the north, and to these owes its prominence; and the deep indentation of Marble cove is clearly due to the softer limestones and slates which lie between the harder quartzites on the south, and the granite, quartz-diorite and gabbro of Indiantown itself.

In the Narrows above Indiantown the rocks are of so uniform a texture that denudation cannot have been the chief agent in producing this somewhat tortuous passage. We shall have to appeal to cross-faults here for an explanation of the inception of this passage, though subsequent wear by water-action no doubt enlarged and deepened it.

The formation of caves and subterraenan water courses in the limestone beds in distant ages, (as suggested further on) are also probably in part responsible for the opening up of this passage.

Enlargement of the Valleys by Deformation of the Earth's Crust.

The occurrence of these faults leads us to speak of the enlargement of the valleys above the Narrows, to which we have already referred, as being due to profound faults produced in Huronian and post-Cambrian time in the earth's crust. We may now take a step onward in time and look at this region at the close of the Devonian period.

Important physical changes had taken place; the comparatively peaceful condition of the region in the Cambrian ages had been followed by volcanic disturbances, not however on the vast scale of those which took place in the Huronian age. But though the volcanoes were less active the tangential pressure from the ocean became more intense, and finally culminated in the extrusion of extensive areas of granite. These movements were complicated with the production of new fault-lines and changes of level along the old ones.

In Cambrian times the movement along the two great faults that bound the old volcanic range of the Kingston rocks was reversed from what it had been in Huronian time, and the valleys which were thus formed on each side of the Kingston ridge were filled with Cambrian sediments. Another fault line had formed along the northern rim of the valley on the north of the Kingston ridge, producing a parallel valley in which Upper Silurian muds were deposited.

It was probably at this period, that is to say at the close of Devonian time, that the great cross fault was formed, which extends from the granite in the Nerepis hills to the Narrows of the river above Indiantown.* This fault, enlarged into a valley, of which the Nerepis intervals, the Short Reach and Grand Bay form parts, serves to catch the waters of the rivers coming down the long valleys to the eastward and convey them to Indiantown.

Growth of the Kennebecasis Valley.

One more stage in these profound earth movements may be referred to. If we pass on to the close of Carboniferous time, although there are proofs of comparatively mild volcanic action in the interior of the Province of New Brunswick at this time, no physical change

*The continuity of this fault line is broken by the granite ridge of Pleasant point, opposite Indiantown; but W. D. Matthew informs me that this granite is traversed by numerous trap dykes (diabase), parallel in their course to the Short Reach fault.

occurred in the region that can be compared to the vast volcanic outbursts of the Huronian, or the great pressure and metamorphism of Devonian time. Nevertheless, there are proofs of some important movements along these old fault lines. I should especially refer here to that which bounds the south side of the Kingston hills, and therefore the north side of the Kennebecasis valley.

At this time the chain of hills between this valley and that of Loch Lomond was of much greater height than it now is, and perhaps was glacier-covered. From these highlands a vast body of material was swept into the valley below, and with the wash from other sources accumulated to a depth of several thousand feet. At the Joggins, in Nova Scotia, this Carboniferous formation, or terrain, has a thickness of fourteen thousand feet, but in our region the thickness probably was not so great. Whatever it was, however, the weak line of the crust along the foot of the Kingston hills could not sustain it, and it sank gradually its whole thickness along this fault-line. Subsequent denudation scooped out a good deal of these soft beds and produced the present valley.

There are indications that the great cross fault of the Short Reach yielded somewhat at this time, sinking on the East side; for while the Carboniferous deposits show considerable bulk at Boar's Head and Kennebecasis island, they are hardly represented on the west side of the river. The Cambrian sediments also east of this fault, in the Long Reach valley, are much better developed, that is, have been less eroded, than they have west of it.

Estimates of Geological Time.

As yet, however, there was no St. John river; the changes in, and denudation of the earth's surface which I have endeavored to describe, were simply the stages which led to the production of the valleys which this river, in a later period of the earth's history, utilized for its outlet.

The principal features of this river basin were chiselled during a vast space of time, of which no record remains in this region, except the worn and corroded surface of the earth, exposed to the action of the elements during a succession of ages. Geologists have attempted to estimate what the extent of this time was, or at least the relative length of its different parts. The space of time, from that when the Huronian volcanoes ceased to pour out their vast floods of lava until the close of the Carboniferous age (Permian included), is called the Palæozoic ages, and it is represented by nearly consecutive deposits in this region, which give us the history of geological changes occurring here during this time.

The next grand division of time includes the Mesozoic ages, and so far as the St. John river is concerned is an utter blank, no vestige of a formation or terrain remains on the banks of this river, to tell of the changes which then occurred.

The third great division of Geologic time includes the Cainozoic ages, and is also a blank as regards these Maritime provinces, except its closing period, represented by the deposits of the Glacial and subsequent times.

Some of the leading American geologists have given time ratios, to mark the proportionate lapse of time during these geological ages, as follows:

	Palæozoic.	Mesozoic.	Cainozoic.
J. D. Dana, ...	12	3	1
A. Winchell, ...	9	3	1
H. S. Williams, ...	15	3	1
C. D. Walcott, ...	12	5	2
Average, ...	12	3½	1¼

Williams' and Dana's estimates were based largely on observations in the eastern United States; Winchell's, on studies in the north-central States; Walcott appears to have given more weight to the evidence obtained in the western States, where the Mesozoic and Cainozoic rocks prevail. I should be inclined to think his proportions nearer the truth, as they accord better with European estimates of the comparative length of the several great divisions of geological time.

Walcott has gone further and given us an estimate by years of these several great divisions of time, allowing nearly one and a half millions of years to each unit of the time ratios. Taking his estimate we may say that for ten millions of years, during which vast changes in the life history and physical conditions of the globe took place, the record here is a complete blank. During most of the time it probably was for this region a period of continental elevation, when the rivers cut deep canons and valleys into the earth's crust, and when the ocean margin was far off to the south, along the outer banks which exist on the Atlantic coast, from Nantucket to Sable Island. This was the period of the carving out of valleys by flood and storm in preparation for the needs of the St. John at a later time.*

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*The Continental border at this period in New England is indicated by beds of sand, gravel and clay of considerable extent and thickness in Long Island, Martha's Vineyard, Nantucket, and the shoals eastward of this island; and though thinner deposits in shallower estuaries and lakes were no doubt formed contemporaneously further to the north, they have been comparatively thin and have been almost entirely swept away by subsequent sub-ærial erosion. Small patches of sediments of the Cretaceous period have been found in Massachusetts, of the Tertiary in Vermont, and again of the Cretaceous in Wisconsin and Minnesota, on the borders of this Continental area. But on the whole it would be safe to assume that during the long Secondary and Tertiary ages (Mesozoic and Cainozoic) that elapsed after the Trias and before the Glacial period, New England and all Eastern Canada was above the sea, and at times of greater extent and height than now.

DRAINAGE AREA OF THE ST. JOHN.

Showing the portions of other river-systems that have become tributary to it:

Boundary of the Restigouche basin.

Portion which has become tributary to the St. John.

Boundary of the Miramichi basin.

Portion made tributary by the St. John.

Water-shed between the St. John and Miramichi rivers.

Portion of the Petitcodiac basin now tributary to the St. John.

THE RIVER SYSTEMS WHICH COMBINED TO FORM THE ST. JOHN.

I have said that the St. John was a combination of three river systems. (See map on page 53.) Of these the northern is that of the Restigouche, and embraces a large area in the north of New Brunswick and Maine, which was a sound of the sea in Silurian times. In later Devonian times the sea had withdrawn nearly to the present Baie Chaleur, but it again invaded the valley along its southern side as far as the Aroostook valley, at the beginning of the Carboniferous period. The deformation or change of level of the surface of this valley, which drew off the waters of its western part in a southerly direction, which now are tributary to the St. John, probably took place during, or after, the Carboniferous period.

Between the Silurian age, when this valley was filled with marine sediments, and the beginning of the Carboniferous period, the strata were folded and uplifted along this valley, and through the hills on its southern side ridges of granite were brought to the surface. The depressing of the south side of the valley was subsequent to this, and went so far as to carry this side beneath the sea again.* Scattered areas of red sandstone and conglomerate in this area were deposited at this time.

The middle river-system may be regarded as that of the Miramichi, since this river now drains away to the eastward, the principal waters of this system. As it existed at the close of Carboniferous time, this system included all the central part of New Brunswick, a wide plain, opening and descending to the eastward, and its western border is now marked by the Carboniferous rocks which extend westward to, and include Oromocto lake.

The third river system which the St. John made tributary to itself, or of which, perhaps, it would be more

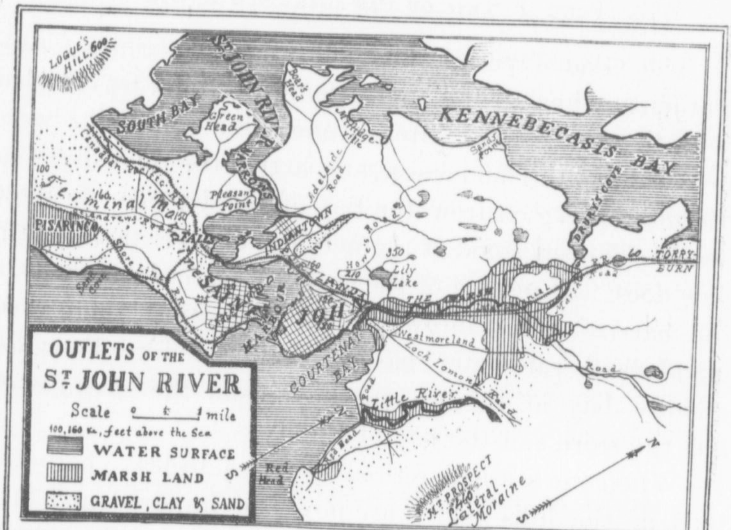
* See the triangular area on the map, divided off by a line of dashes.

correct to speak as the original St. John, is that which flows in the Kennebecasis and Petitcodiac valley. It is one which apparently, in the early part of the Carboniferous age, had its discharge eastward; but which, after the long period of continental uplift, if not earlier, through the breaking down of the land barriers near St. John, found an outlet to the south.

Thus we see that the St. John river has attained its present magnitude by the breaking of mountain or hill-barriers which once separated its three river systems, and is not a simple valley of continuous growth like the Mississippi. Great changes of level of the earth's surface were required to bring about this condition of things, and these changes were to a large extent affected during the period of continental elevation to which I have referred. Not all of them, however, for very important ones were produced when the former warm-temperature climate was exchanged for one of arctic cold, and glaciers of wide extent overspread the land.

Action of Glacial Agencies Upon the River Courses.

The long period of continental elevation, coupled with the warm temperature which prevailed during the greater part of it, had decomposed the rocks to a great depth, and when glaciers invaded the land they found it an easy task to remove great masses of this loose covering. This debris was carried along by the moving ice and eventually deposited at the sides and at the foot of the glaciers, across many of the valleys and ravines, and left there when the ice melted away. These deposits were modified during a period of submergence, but not greatly changed, and as the land again arose to its original level, first beds of sand and gravel and then beds of clay were deposited in all the valleys, forming a luting which made water-tight the numerous basins formed by the transverse moraines and gravel ridges that existed in these valleys. In this way innumerable lakes were produced, and it became the business of the rivers, as the land emerged from the sea, to unite the various lakes together, to erode the barriers, drain the depressions and restore the river systems again.



It sometimes happened that these gravel and boulder-clay barriers were so extensive and high that the river was forced to seek a new channel, and usually a rocky one, often removed to a considerable distance from the one it had occupied before the Glacial period. Such was the case with the St. John, both at Grand Falls and at its present outlet.

The conformation of the land between South bay and Pisarinco cove renders it highly probable that this was the course by which the river discharged its waters into the sea before the Glacial period. The shores are low around both these indentations, and only a few ledges come to the surface in the intervening area, which is occupied by Boulder clay and gravel ridges, with a covering of Leda clay in the hollows. Every indication points to the existence of a buried channel of the river somewhere between the Asylum ridge and Robinson's inn, on the St. Andrew's road.

FOUR OUTLETS OR PASSAGES ONCE EXISTED.

The Glacial period was followed by a time of submergence when all the land around St. John was buried beneath an icy sea. After a time these conditions were reversed and the land rose again, so that the ridge dividing the interior region from the Bay of Fundy began to show itself. The sea stood at a much higher level then than it now does, and instead of the brackish-water basins within the barrier at Indiantown, which now exist, there were land-locked salt-water basins, sheltered like Passamaquoddy bay at the present day, from the ocean-swell and the storms of the bay of Fundy.

When the sea had retired so far as to leave bare the tops of the hills which are now one hundred and fifty feet above its present level, the existing outlet of the St. John began to be defined by a wide estuary, extending from Logue's hill in Lancaster (600 feet high *) to Mt. Prospect (the "Cottage Hill") in Simonds (440 feet high). The inhabited part of the city was still beneath the waters of the bay of Fundy when the opening of this estuary was dotted with numerous islands, now the tops of hills, in the peninsula between the harbor and the Kennebecasis, etc. Beside the present outlet of the river there would at this time have been three others. The most westerly of these passed out from South Bay by way of the valley of

* For the heights given in this paper I am indebted to Wm. Murdoch, C. E. Engineer for the Board of Works of the city of St. John.

Spruce Lake stream to Pisarinco cove, and was about fifty feet deep; another on the opposite side of the estuary passed through Torryburn valley and was nearly a hundred feet deep; and a third, a deeper, but narrower strait, existed at the present site of Drury's cove.

As the land continued to rise the depth of water in these passages diminished, until two of them were entirely closed and only the present passage and that at Drury's cove remained. This cove is a deep indentation of the Kennebeccasis river, here a lake-like expansion connected by a deep water channel with the St. John, and filling the lower part of the valley in which the former river runs. The cove is enclosed by rocky shores, but at its head there is a low pass — only about fifteen or eighteen feet above high-water mark—and floored by limestone ledges. This pass connects the cove with a long narrow valley, now filled with marine alluvium called the "Marsh," which has its termination at Courtenay bay, east of the city, and thus connects with St. John harbor.

When the land rose so that the sixty feet beach was formed, the Torryburn passage would have been closed, but there would still have been a channel forty feet deep at Drury's cove and one of equal or greater depth at the present passage.

From the condition of the Marsh valley it seems probable that the Drury's cove outlet continued to exist for some time after this, as the land continued to rise; this it did until the sea-water was entirely excluded from the Kennebeccasis and St. John rivers. When nearly excluded a tidal flow of considerable importance would have existed at Drury's cove as well at the main passage at the falls, and only the rocky floor at the former outlet and the narrowness of the pass would have prevented this passage from being as important an outlet as the other. From this acuse, however, if from no other, the passage at the falls would gain the preponderance and finally become the sole discharge of the river.

Not only was the sea-water thus excluded from the river by this rising of the land, but the harbor itself was probably drained so that an outer fall appears to have been formed to the eastward of Partridge island.* At this time the Drury's cove passage was closed, and peat and marsh mud began to fill in the valley of the Marsh. The land then began to sink again, but very slowly, until it reached its present level, and the tidal falls were re-established as we now see them.

Marine alluvium is, as we know, one of the latest of the geological deposits, and is in process of accumulation at the present day. The growth of this deposit in the Marsh valley has been stopped by dyking the outlet of the valley, but the deposit where it has been tested shows a very considerable depth at several points, and occupies the place of an old water channel that has been silted up in comparatively modern times. It no doubt had its origin in the period of continental elevation, or at least was enlarged at that time and very likely was in connection with some old water-way, possibly subterranean, that crossed the limestone ridge which separates this valley from the Kennebecasis. Indications of old subterranean channels in this ridge are found at several points. I may instance two.

* The former existence of this fall is shown by a rocky depression which exists south-east of Partridge Island and is indicated by the soundings there; outside of this the old submerged channel of the river has been filled up by the silt which is swept up and down the Bay of Fundy by the heavy tides.

SUBTERRANEAN WATER-WAYS.

The first I shall refer to was along and beneath the valley in which the Intercolonial railway runs, and is marked by limestone sinks at several points. One of these is west of Torryburn station, the next is Lawlor's lake. It is difficult to account for the deep cup-like form of this lake, surrounded by steep hills of limestone, on any ordinary theory of erosion by surface-wear, and we suppose it to be due to the undermining of the rock along pre-glacial subterranean water-courses. A third sink on this line is south-west of Lawlor's lake. The present drainage of the two western sinks of this valley is discharged by a spring at the head of the "Marsh," at the level of the marine alluvium, the spring being blocked at this level by the marshy deposit.

The other instance of an old abandoned channel in the limestones is Oliver's cave, on Howe's road. No stream runs near this cave now, but close by, to the north-east, lying in a valley opening north-eastwards to the Kennebecasis, occupied by several lakes, is a small pond, called Dark lake, which discharges by an underground passage into the valley of Simond's marsh. The stream through this valley enters the St. John river just above Indiantown. The valley of this stream is considerably lower than Dark lake and the outlet of Oliver's cave, opposite those places, and is filled at this lower level with an alluvial deposit, probably resting on Leda clay. Oliver's cave consists of a descending passage and two chambers, and terminates in a well, filled with water to the depth of the surface of the alluvium in the valley adjoining. It is evident that the water-channel formed through the limestone rock at Oliver's cave is a very old one and has been blocked during a period of submergence by the deposit formed in this valley.

I refer to these two instances to show the possible existence of buried subterranean channels in the limestone ridge which may have given passage to more or less of the river-water of the Kennebecasis, and of the St. John valley, in pre-glacial times.

Changes of Level Due to Post-Glacial Faults.

But there is an element of uncertainty as to the comparative importance of the passage at Drury's cove and that at the present outlet, due to a cause which we only lately been led to appreciate. This cause, which may have operated at only a late date to close this channel, would have acted by an uplift of the solid rocks at the Drury's cove pass, such as undoubtedly has occurred in the city of St. John itself since the Glacial period.

Is is but recently that we have observed the obvious evidence of such movements which exist around us. At our last meeting I called attention to the existence of post-Glacial faults in and near St. John by which very considerable changes of level in the surface of the land had been effected since the glaciers disappeared from this region. In one case a change of level to the extent of over five feet can be shown to have occurred in a space of one hundred and fifty feet. This movement was effected by a number of small faults or breaks in the rocks, amounting in all to the displacement above referred to. If the solid rocks could thus be lifted to the extent of five feet in the short space of one hundred and fifty feet, it is quite possible that between the sea and Drury's cove they may have been raised to the extent of fifteen or twenty feet. A rise of the ledge at that cove to this extent would prevent the escape of the river waters at that point and turn the whole into the present outlet.

In the preceding remarks I have not mentioned another cause which, no doubt, operated to deepen the present outlet at the expense of the one at Drury's cove when once the preponderence of the discharge at the former was established, namely, the erosion of the rocks at the "Upper Fall." I know of no evidence of this erosion which, nevertheless, is in progress at the present day; but it will be difficult to distinguish it from the effects of the slow subsidence of the land which has been going on in modern times, without special observations having this end in view.

Conclusions.

To sum up the whole matter we may say that—

1st. The St. John River is built up of three river systems, once independent of each other.

2nd. That the river has availed itself of several very ancient valleys for its present outlet.

3rd. That the pre-Glacial discharge was probably by a buried valley on the line of South Bay and Pisarinco Cove.

4th. That there were four post-Glacial outlets.

5th. That the post-Glacial outlet by way of Drury's Cove and the Marsh, to Courtenay Bay, persisted longer than two others of the four, but now only one of the four remains open.

APPENDIX A.

Thirty-second Annual Report of the Council of the Natural History Society of New Brunswick.

The Council of the Natural History Society of New Brunswick beg to submit the following account of the condition of the Society and the work done during the past year:

Membership.

Addition has been made to the membership roll, as follows:

Ordinary members,...	4
Associate members,...	11
Junior member,...	1
Corresponding member,	1
Total increase,	17

Finance.

The Treasurer's report shows the following receipts and expenditures:

Balance on hand from last year,...	$205 09
Receipts from dues,...	103 00
Bulletins sold,...	1 05
Duplicate specimen sold,...	10 00
Provincial grant,...	125 00
Miscellaneous items,...	6 34
	$450 48
Expenditures for year,...	435 69
Balance on hand,...	$14 79

SECRETARY.

The Secretary reports that during the year 119 communications were received and 145 sent. Communications received and forwarded have been filed and indexed in a book kept for that purpose.

All the old papers and documents of the Society have been collected, arranged in a large blank book and indexed. Many manuscripts of papers, read before the Society in its earlier years, have been placed for preservation in large envelopes and labelled.

LECTURES AND ESSAYS.

Nine regular meetings were held, at which the following papers were read :

1893.

Feb. 7. (1) Geography and Natural History of the Tobique. By Geoffrey Stead. (Published in Bulletin No. XI.)

(2) Spring Flowers about Fredericton. By F. G. Berton.

Mar. 7. (1) Notes on the Introduction of the Pickerel into New Brunswick. By Samuel W. Kain.

(2) The Black Bass Introduced into the Waters of New Brunswick. By Samuel W. Kain.

April 4. Constellations and the Planets. By Geo. U. Hay, M. A.

May 2. Sir James Alexander and his Survey from the Bend to Boistown. By Geo. U. Hay, M. A.

June 6. Report of Delegate to Royal Society.

Oct. 3. Account of Summer Camp held in August at French Lake. By Geo. F. Matthew, D. Sc., F. R. S. C.

Nov. 7. Geology and Mines of Eastern Cape Breton. By Geoffrey Stead, C. E. (Printed in *Progress* of November 13th, 1894).

Dec. 5. General Business — resolution on death of the Patron of the Society. No paper.

1894.

Jan. 2. The Red Indian of Newfoundland. By Dr. H. G. Addy. (Abstract given on page 71).

The Society also carried on its usual course of Elementary Lectures in Science, which was well attended and very successful. The subjects were selected with special reference to the work of the Summer Camp, held in August at French Lake. Nine lectures were given, at which the following subjects were treated:

1893.

Feb. 14. Land and Fresh-water Molluscs. By Geo. F. Matthew.

21. On the Palæolithic Age, or Age of Chipped Stone. By Geo. F. Matthew.

28. On the Neolithic Age, or Age of Polished Stone. By Geo. F. Matthew.

Mar. 14. French and Indians on the River St. John. By Rev. W. O. Raymond.

21. The Structure and Habits of some of the Lower Forms of Fishes. By Philip Cox.

28. The Common Smelt. By Philip Cox.

April 11. Some Observations on Plant Life. By G. U. Hay.

18. Some Observations on Plant Life (continued). By G. U. Hay.

25. History of Architecture. By G. Earnest Fairweather.

Library.

The Librarian reports that the number of exchanges received is in excess of any previous year. Special note is made of the receipt of thirty-seven numbers of the publications of the Manitoba Scientific and Historical Society.

Dr. John Baxter, of Chatham, donated a copy of Roderick McKenzie's "Miramichi Wild Flowers"—a desirable addition to our botanical works.

A new book case has been placed in the library, and has been utilized to hold the many scientific publications of the United States Government.

Botany.

The Botanical Committee report that a handsome Herbarium case has been obtained during the year and placed in the library.

The work of arranging our large collection of plants in this new case is progressing, and a catalogue is being prepared. When this is completed the Society will have a collection in which it may well take pride.

Museum.

Some work has been done in the museum, but much remains. Additions are constantly being made by donations from members and otherwise. The Society is indebted especially to Messrs. W. M. McLean and P. Cox for the large addition made to our collection of fishes.

The collection of insects is the only collection in the museum that is catalogued, and the importance of having the other collections catalogued cannot be over-estimated. It is a considerable task, but if done in sections by the various committees, could be accomplished before the next annual meeting.

The rooms are open to the members on Tuesday and Friday evenings, and the museum to the public on Tuesday evening and on Saturday afternoon. Members are invited to come, as occasion offers, and study the collections. About one hundred and fifty persons visited the museum during the year.

Publications.

Bulletin XI. has been issued and placed in the hands of members and sent to the various societies, with which exchange is made. Many calls have been received from abroad for back numbers, and it is a matter of regret that the stock of earlier numbers has been exhausted. Any one who could supply copies of Bulletins I. to III. would confer a favor.

Summer Camp.

In the earlier part of the year it was determined to hold a summer camp in August for the study of nature in the field, and the course of elementary lectures was arranged largely with that work in view.

In August the party, numbering about twenty-three, proceeded to French Lake, some by sail boat and some by steamer to McGowan's wharf, and thence by carriage to Lakeville Corner. Tents were erected and ten days were spent in studying the surrounding country. Excursions were made in all directions, and very satisfactory results were obtained in archæology and botany. The party secured many specimens of the implements and weapons of the unknown people who, in the Pre-historic period, dwelt in that section of the province, and the additions thus made to the museum furnish good material for students of this most interesting subject. By vote of the Society the President has been requested to edit an account of the camp for future publication.

General.

The University Extension movement has been continued, and in the latter part of the year Dr. Bailey, one of our honary members, gave an interesting course on Zoology in the rooms of the Society.

The Committee on Invertebrates report an addition to the museum of a collection ot Pacific Coast shells. This collection will amount to at least eighty species, and will be a valuable acquisition, illustrating, as it does, the marine shell fauna of the western shores of our Dominion. Some other shells have also been received as donations. A preliminary list of our native land and fresh water shells is being prepared by Wm. D. Matthew and G. Stead.

The Press Committee report that the press of St. John have granted free insertion of preliminary notices of meetings, and by excellent reports of the lectures have materially aided in disseminating information about the Society and its work. For those courtesies the hearty thanks of the Society are due.

At the last annual meeting some amendments were made to the constitution — enlarging the duties of the Secretary and giving the Associate members power to elect a President and Secretary of their branch.

The Council consider that the year now closing has been a prosperous one, and hope the members of the Society will continue to interest themselves in promoting the objects for which it was founded.

Respectfully submitted,

SAMUEL W. KAIN,
Secretary to Council.

Natural History Rooms, Market Building,
St. John, N. B., January 16th, 1895.

REPORT ON BOTANY.

Since the somewhat large list of plants recorded in the Bulletin of 1893 was published, very few plants have been found that are new to the province. The researches of Mr. M. L. Fernald, of Cambridge, Mass., in Northern Maine and New Brunswick have brought to notice some plants new to the province. Others, which Fernald found only in Northern Maine, may be looked for in New Brunswick. Mr. Fernald suggests that New Brunswick botanists are in a place to be of great service to him in his Maine work, particularly when they note (as he has done) things on "the other side of the line." Our New Brunswick botanists will, no doubt, readily accept this offer of reciprocity, if opportunity should occur. Among the interesting plants discovered by Mr. Fernald are the two varieties of *Nuphar advena; Oxytropis Lamberti*, Pursh, var. *sericea*, at Van Buren, Me., ("its first appearance east of Montana"); *Pyrus sambucifolia*, "growing with and as common as *Americana; Myriophyllum alternifolium, M. verticillatum, M. ambiguum, M. tenellum; Epilobium adenocaulon; Potamogeton nitens* ("a very rare plant, having been found but once before in America, should be looked for about Edmundston,") *Carex interior; Panicum nitidum; Glyceria grandis; Equisetum littorale, Woodsia obtusa* (Van Buren).

Mr. Vroom reports *Lobelia cardinalis* on south branch of Oromocto, near Fredericton Junction—farther east than before noticed.

ADDITIONAL REPORT.

Mr. Brittain reports *Lysimachia lanceolata*, found near St. Stephen in 1891 by Mr. G. A. Inch. Mr. Brittain also reports receiving a specimen of *Aster linariifolius*, found by Mr. Edward Jack at Boiestown, in Sept., 1894.

Mr. Hay reports *Cuscuta epithymum*, var. *trifolii*, a very injurious weed from Europe. Found at Ingleside, near Westfield, October, 1894, twining about clover, very abundant in one corner of a field belonging to Mr. Finley, who ploughed it under.

G. U. HAY,
Chairman of Committee.

THE RED INDIAN OF NEWFOUNDLAND.

(Abstract of a paper read January 2nd, 1894, by H. George Addy, M. D.]

Dr. Addy, in introducing his subject, gave extracts from the writings of the early explorers of Newfoundland referring to the aborigines of that country.

A graphic picture was drawn of the happy and primitive life of these people when the Cabots visited Newfoundland, and the sad story of their cruel extermination was briefly told.

Mr. Cormack was the first white man to cross the island, and he reported these Indians to be a fine, hardy race of men, subsisting by the chase and living a simple life.

Richard Whitbourne, in his work on the island, (published 1622) thus describes them: "The natural inhabitants of the country, as they are but few in number, so are they a somewhat rude and savage people, having neither knowledge of God nor living under any kind of civil government. In their habits, customs and manners they resemble the Indians on the continent, from whence, I suppose, they came. They live altogether in the north and west part of the country. The French (who resort thither yearly for the whale fishing and also for the codfish) report them to be an ingenious and tractable people, being well used."

After quoting in detail various authorities to account for the origin of the Red Indian, he summed up the evidence to show that they were the vanguard of the Algonquin tribes, driven to the extreme eastern coast by succeeding waves of immigrants from the shore of Asia and the islands of the Indian Archipelago.

The territory occupied by these Indians was then described. It contained about 4,000 square miles, and embraced the region bordering on and between the Exploits and Humber Rivers.

An account was given of their ingeniously constructed fences for entrapping deer, their dwellings, mode of preservation of food for the winter, and their canoes and weapons.

Dr. Addy concluded his interesting paper with an account of their burial customs.

DONATIONS TO THE MUSEUM.

DATE.	DONOR'S NAME AND DESCRIPTION OF ARTICLE.
1893.	
Jan'y	W. F. BEST, Esq.—Asbestos and the rock in which it occurs, from the Black Lake Mines, Quebec.
Feb.	EXHIBITION COM.—Bamboo from Demarara.
May.	JOHN S. MACLAREN, Esq.—Scales of Tarpon.
	JOHN S. MACLAREN, Esq.—Large grooved stone axe found at St. Leonard's Flat, Madawaska County, N. B.
	HAZEN J. DICK, Esq.—Lizard from Luzon, Phillippine Islands.
June.	JAMES CLERKE, Esq.—Unfinished maple shoe-last, with full grown insect enclosed (*Clytus speciosus*).
	J. MORRISSEY WHITE, Esq., Bathurst.—Blue Heron.
	MR JOHN. V. ELLIS, JR.—Eider Duck (mounted).
	GEOFFREY STEAD, Esq.—Archæozoon Acadiense, three specimens from Douglas Road, St. John, N. B.
August.	DAVID PELMAIN, Esq., Indian Point, Grand Lake.—Three stone spear heads, four arrow heads, and one piece of Indian pottery.
	DUNCAN LONDON, Esq., Lakeville Corner, Sunbury Co.—Small stone axe, carved arrow point and flaked knife blade.
October.	SUMMER CAMP PARTY.—A large number of stone axes, arrow heads, sinkers, skinning knives, spear heads, and other articles of stone; also fragments of Indian pottery; stone implements mostly from French Lake and vicinity; pottery from Indian Point, on Grand Lake. (105 articles of stone, 97 pieces of pottery).

DONATIONS TO THE MUSEUM — (*Continued.*)

DATE.	DONOR'S NAME AND DESCRIPTION OF ARTICLE.
1893.	
October.	MRS G. A. HAMILTON.—Fifteen species of tertiary fossils, four specimens of phosphate, and an electric swamp-bug, from Ocala, Fa.
	J. T. MORIARITY.—Squid from St. John Harbor.
	W. E. STEVENS.—Great spotted Salamander from Lily Lake, St. John, N. B.
	DR. GEO. A. HETHERINGTON.—Harbor Seal (mounted).
	W. R RAYMOND, ESQ.—Moose bone.
	FRED PICKETT, ESQ., Greenwich Hill, Kings Co.—Cray Fish (*Cambarus Bartonii*).
Nov.	DR JOHN BAXTER, Chatham, N. B.—Seventeen specimens of Mollusca from Tracadie Beach, embracing nine species.
	GEOFFREY STEAD, ESQ — Fossils from coal measures of Eastern Cape Breton, consisting of ferns, calamites, fish scales, bivalve crustaceans, *Naiadites elongata*, etc. Twenty-one specimens in all.
	W. J. WILSON, ESQ , Ottawa.—A fine collection of Devonian fossils from the Fern Ledges of Lancaster, consisting of ferns, fruits, *Asterophyllites*, etc.
	GEOFFREY STEAD, ESQ — Concretions from recent clay found in bank of St. John River, four miles above Fredericton. Fresh-water Clams (*Unio* and *Anodon*) from Grand Cane, La., U. S. A. Twenty-eight specimens, embracing twelve species.
Dec,	GEO ROBERTSON, ESQ , Mayor of St. John.—Six Bamboos, fifteen feet long and from three to six and a half inches in diameter, from Jamaica.

DONATIONS TO THE LIBRARY.

Date.	Donor's Name and Description of Book.
1893.	
Jan.	Director Experimental Farms, Ottawa.—Reports 1887 to 1892. Bulletins 1 to 18.
Feb.	Ottawa Field Naturalists' Club, Ottawa —Proceedings, Vol. VI, Nos. 10, 11; Vol. VII, Nos. 1–9.
	Department Marine and Fisheries, Ottawa.—Twenty-fifth Annual Report. Report on the Oyster Fisheries of Canada, 1892.
	Hon. L. J. Tweedie, Surveyor General of New Brunswick.—Report Crown Lands Department, 1883 to 1892. Map of New Brunswick (Loggie's).
	Feuilles des Jeunes Naturalistes, Paris.—Nos. 268 to 278.
	American Museum of Natural History, New York.—Bulletin, Vol. IV., 1892.
	Inland Revenue Department, Ottawa.—Bulletins 31 to 33.
	Russian Geological Survey, St. Petersburg.—Bulletins, Vols X. and XI.; Memoires, Vols. XI.–XIII.
	Public Museum of City of Milwaukee, Milwaukee.—Tenth Annual Report.
	U. S Department of Agriculture, Washington.—Circulars 8 and 9. (Forestry Division). Bulletins 1–6. Annual Reports, 1886–1891 (Forestry Division). Hawks and Owls of the United States, by A. K. Fisher. Bulletin No. 4. The Prairie Ground Squirrels, 1893. North American Fauna, No. 7, Part II, 1893.
March.	U. S. Fish Commission, Washington, D. C.—Report for 1888. Bulletin, Vol X, 1890.
	Edward Gilpin, Esq., Halifax—Quarterly Journal Geological Society of London, 1893
	Academy of Natural Sciences, Philadelphia.—Proceedings, 1892–1893.

DONATIONS TO THE LIBRARY — (*Continued.*)

DATE.	DONOR'S NAME AND DESCRIPTION OF BOOK.
1893. *March.*	BELFAST NATURALISTS' FIELD CLUB, Belfast, Ireland.—Annual Report and Proceedings, 1892.
	DIRECTOR GEOLOGICAL SURVEY OF CANADA, Ottawa.—Contributions to Canadian Palæontology, Vol. I., Part IV. Catalogue of Section 1 of Museum of the Survey. Catalogue of Stratigraphical Collection of the Rocks of Canada, 1893. Annual Report, Vol. V., Parts 1 and 2.
April.	BUREAU OF ETHNOLOGY, Washington, D. C.—Bibliography of the Algonquin languages, by James C. Pilling.
May.	NEW YORK MICROSCOPICAL SOCIETY, New York.—Journal, Vol. IX., Nos. 2-4.
	CALIFORNIA ACADEMY OF SCIENCE, San Francisco.—Laying the Corner Stone, 1880. Proceedings, Vols I.-III.
	JOHNS HOPKINS UNIVERSITY, Baltimore, Md.— Circulars, 102-107.
	SOCIÉTÉ SCIENTIFIQUE DU CHILE, Santiago, Chili.—Proceedings, etc. Vols. II. and III.
	SOCIÉTÉ ROYALE MALACOLOGIQUE DE BELGIQUE, Brussels.—Proceedings, 1892.
	SMITHSONIAN INSTITUTION, Washington, D. C.— Circular concerning Hodgkin's Prize Fund. Smithsonian Report, 1890.
	U. S. NATIONAL MUSEUM, Washington. Proceedings, Vol. XIV. Bulletins 39 and 40.
	CORNELL UNIVERSITY, Ithica, N. Y.— Bulletins 48-59. Library Bulletins, Nos. 4-5.
	DIRECTOR MISSOURI BOTANICAL GARDENS, St. Louis, Mo.—First, Second and Third Annual Reports.
	UNIVERSITY OF MICHIGAN, Ann Arbor, Mich.—Morphology of the Carinæ upon the septa of Rugose Corals, by Mary E. Holmes. Peach Yellows, by E. F. Smith, 1888. Latitude of Detroit Observatory, by Ludovic Ester, Ph. D. Organic Contamination of Soils, by J. F. Eastwood, M. A.

DONATIONS TO THE LIBRARY—(*Continued.*)

DATE.	DONOR'S NAME AND DESCRIPTION OF BOOK.
1893.	
June.	CINCINNATI SOCIETY OF NATURAL HISTORY, Cincinnati, O.—Journal, Vol. XVI., Nos. 1-3.
	ROYAL SOCIETY OF CANADA, Ottawa, Ont—Proceedings, Vol. X
	LIVERPOOL BIOLOGICAL SOCIETY, Liverpool, G. B.—Proceedings and Transactions, Vols. V. and VI.
	MANCHESTER GEOLOGICAL SOCIETY, Manchester, G. B—Transactions, Vol. XXII.
	GEO. U. HAY, M. A., St. John, N. B.—Proceedings and Transactions of the Nova Scotia Institute of Science, Vol. V., Part II.
	DR. JOHN BAXTER, Chatham, N. B.—Miramichi Wild Flowers, by Roderick Mackenzie.
	NOVA SCOTIA INSTITUTE OF SCIENCE, Halifax, N. S.—Proceedings, Vol. I., Part IV. (Second Series).
July.	ESSEX INSTITUTE, Salem, Mass.—Bulletins, Vols. XXIV. and XXV. Memoir of Dr. Henry Wheatland.
	U. S. GEOLOGICAL SURVEY, Washington.—Flora of the Dakota Group. by Lesquereaux (Monograph XVII). Gasteropoda and Cephalopoda of New Jersey (Monograph XVIII.) Geology of Eureka District, Nevada, (Monograph XX.) Atlas of Geology of Eureka District, Nevada. Mineral Resources of the United States, 1891. Bulletins of U. S Survey, Nos. 82-86, 90-06. Eleventh Annual Report, 1889-1890, Parts I. and II.
	U. S. COAST AND GEODETIC SURVEY, Washington.—Report, 1890.
August.	GEOLOGICAL SOCIETY OF LONDON, G. B.—Abstract of Proceedings, 1892-1893. List of Members.
	DIRECTOR ROYAL GARDENS, Kew, G. B.—Bulletins, Nos. 76-81, 1893. Appendix I., 1894.
	CONNECTICUT ACADEMY OF ARTS AND SCIENCES, New Haven, Conn.—Transactions, Vols. VIII. and IX.
	CANADIAN RECORD OF SCIENCE, Montreal.—Vol. V.
Sept.	COLORADO SCIENTIFIC SOCIETY, Denver.—Proceedings, 1893. Four Parts.

Donations to the Library—(*Continued.*)

Date.	Donor's Name and Description of Book.
1893.	
Sept.	From the Author.—Height of the Bay of Fundy Coast in the Glacial Period, etc., by Robert Chalmers.
	Colonial Museum, Wellington, New Zealand.—Manual of New Zealand Coleoptera.
	Trustees Australian Museum, Sidney, New South Wales.—Annual Report for 1892. Hints for the Preservation of Specimens of Natural History. Catalogue of the Australian Hydroid Zoophytes. Guide to the Contents of the Australian Museum. Catalogue of Australian Birds, Parts I.-III. Catalogue of Australian Mammals. Records of the Australian Museum, Vol. II, Nos. 1-5. Catalogue of Marine Shells of Australia and Tasmania, Parts I.-III.
	The Author.—Observations on Shell-heaps and Shell-beds, by E. J. Statham, Assoc. Inst. C. E., New South Wales.
Oct	New York Academy of Sciences, New York—Transactions, Vols. X., XI. and XII.
	Hamilton Association, Hamilton, Ont.—Journal and Proceedings, No. 9.
	Canadian Institute, Toronto.—Fifth Annual Report on Archæology. Transactions, Vol. III., No. 6, Part II.
	Rochester Academy of Sciences, Rochester, N. Y.—Proceedings, Vols. I.-II.
Nov.	Boston Natural History Society, Boston.—Proceedings, Vol. XXVI., Part I.
Dec.	Natural History Society of Glasgow, Glasgow, G. B.—Proceedings and Transactions, Vol. III., 1889-1892.
	Royal Academy of Sciences, Stockholm.—Proceedings, twenty volumes; Bulletins 46-49.
	Entomological Society, London, Ont.—The Canadian Entomologist, 1893. Twenty-fourth Annual Report, 1893.
	Manitoba Historical and Scientific Society, Winnipeg. Transactions, thirty-seven numbers.

APPENDIX B.

SOME EVIDENCES OF A GLACIAL EPOCH.

BY CHARLES R. FISHER.

(Read October 9th, 1894.)

This evening it is purposed to give some account of that comparatively short, but remarkable, recent geological time, known as the Glacial Period, or Great Ice Age. The immediate reason for giving this description is because we have before us a quantity of the material, accumulated by ice action during that period. These specimens were found in England, not in Canada, although in many respects, the northern portion of America is undoubtedly one of the finest fields extant in which to study the phenomena resultant upon Glacial action, and especially is this the case in the vicinity of St. John. Above your Canadian Drift you often find clays of a more or less grey or reddish color, known as the Leda Clay, so called because amongst other marine shells, the Leda Glacialis is found extensively in it. Examples of this clay are to be found along the coast of the Bay Shore, near Fort Howe, in the valley between St. John and Portland, (St. John North) along the Red Head Road, in the Horticultural Grounds at Seely Street, and elsewhere. This clay is undoubtedly of sedimentary origin, and one which accumulated very quickly, probably at the time when the immense amount of glacial ice was re-converted into water. I am not aware that the equivalent of this is found in England, though some of the Eastern Counties' Boulder Clay contains many broken portions of marine shells.

Our President, Dr. Matthew, is such an authority upon all connected with geology in this city and province, that I will not attempt to give any account of the evidences in the immediate vicinity of St. John, which tend to prove that at one time this entire region was covered with ice, perhaps to a depth of from one to two thousand feet. My work in this special field has been very desultory, not so much, I hope, from want of inclination as from absence of opportunity. For many interesting facts in connection with your local formations, I am much indebted to the kindness of my friend Mrs. Bowden.

Ice action has been the formative agent of various deposits. During the Pleistocene age, accumulations were laid down upon the older rocks, without any apparent order, often ending very abruptly, and in a manner which indicates the work of quite a different force from any which built up the more ancient strata. The evidences of this action are found in the Boulder Clays, Tills and Gravels of the early Pleistocene Period. The clay sometimes has one or more layers of sand, peat, or fine clay, sandwiched in, showing either the action of water, or the accumulation of a vegetable deposit. The interlayers must have been caused by an intermittingly warmer climate. The peat deposit shows that a considerable period of warm weather must have intervened, for such an accumulation to accrue, as that found in this particular stratum.

Where sand or gravel is found, it is probably consequent upon the depression of the land to below the point of submergence; this portion becoming subsequently re-elevated and subject to re-glaciation. The great weight and power of the moving ice has in some places crumpled the shales and other rocks over which it passed, in the line of their lamination. The Glacial Clays partake largely after the nearest rocks over which they passed, with regard to color.

The geographical extent of the ice in the northern hemisphere was, roughly speaking, bounded by the 50th degree north latitude in Europe, whilst in America it was bounded by parallel 39. It England it does not seem to have reached further south to any extent, than the north of the Thames Basin. During this time the British Isles were united with the European Continent by a vast ice sheet, the whole of the land surface, both in Europe and America, being then, probably, of considerably greater elevation than at present. South of parallel 50 in Europe, immense glaciers would be produced on the Alps, Carpathians, and Pyrenees. In fact, the present Swiss and Pyrenean glaciers are the pigmy remains of once immeasurably larger ice fields. In Asia we find proofs that far larger glaciers existed in the Himalaya Range than those of the present day, occupying the southern slope even, down to within some 2,500 feet of the sea level. Similar evidences of large glaciers in New Zealand are obtained, whilst traces of proof of former glacial action are found in both Australia and South America.

Geological exploration has, as yet, been confined to so comparatively few regions, that anything like a complete knowledge of the range of ice during the glacial age, has not been attained. One fact should be very clearly borne in mind, that the occupation of a certain area by ice does not necessarily imply that that particular district has a so much lower mean temperature, than other places in the same latitude where no ice exists. Through local causes, the precipitation of moisture in the form of snow is so much greater in some districts than in others, that the supply so far exceeds the melting power of the atmosphere as to cause such an accumulation that a glacier is the result. We know that there are districts where moisture seldom or never falls, in cold, as well as in hot districts. Take Siberia as an instance. If any very large quantity of snow fell over that immense territory, it would become one huge glacier, and be totally uninhabitable. Most certainly would this be the case north of parallel 60; yet at Yakutsk it is possible to live, notwithstanding the fact that the ground is permanently frozen to a depth of 700 feet.

Some geologists consider that there has been a succession of Glacial Ages, ranging from Cambrian Times, onward through the Devonian, New Red Sandstone, Lias, and Cretaceons, to the Pleistocene. The evidences, however, are not definite enough to be considered conclusive; although Sir A. C. Ramsey and other writers, hold the opinion that there are traces of glacial action in some of the deposits of those ages.

The ice age which wrought upon so considrable a portion of the earth's surface, such important and remarkable changes, that often the entire contour was altered, took place at a comparatively recent date. Various causes have been assigned for the lowered temperature of the globe at that time. In many places the land was much higher than now, and high ridges of land would act as condensors of the moisture, causing it to fall as snow, in sufficient quantities for glacier building.

The astronomical deductions made by Herschel, Arago, and later by Croll and others, have been of much value to geologists, by giving them data which shews that a much lower temperature was probable at the time assigned for the Glacial Period. This, at any rate, would be the case in the northern hemisphere. Then we have the suggestions that the warm ocean currents were so deflected from the countries whose climatic rigors they now so much modify, that a great change of temperature would ensue. As an instance :—If the Gulf Stream were to have its course turned, say into the Pacific Ocean through an opening in the Isthmus of Panama, London would have a mean temperature about 40 degrees below the present one.

The prevalence of certain winds might prove another possible factor; though these would probably be the result of a changed temperature, rather than the producer of it.

I have, of course, only touched upon the possible causes which might aid in bringing about the epoch of frigidity; to attempt even to sketch out the different theories, would need much more time than I now have at my disposal.

The particular specimens brought to illustrate the subject of this paper, came from what is known as the Upper Glacial Boulder Drift. They were collected from that deposit during the excavations made for a new railway tunnel, which was being constructed in Bedfordshire, East Mid-England.

The organic remains, of which some 55 species were found, belong almost entirely to the Mesozoic Period, and consist of fossils derived principally from the Lias, Oolitic and Cretaceous Formations. These are in a much more perfect condition than fossils of the Drift usually are. Cephalopoda, especially Ammonites, of which some 20 varieties were collected, were abundant. A piece of wood was found in good preservation; it was probably a portion of some Pilocene Conifer. One specimen of Trigonia Pulchella was unearthed; this bivalve has only before been found in the Upper Lias Clay near Lincoln, some 70 miles north of the tunnel. Quite a heterogeneous collection of rock fragments were gathered, igneous, metamorphic, and sedimentary, with numbers of septaria.

Such a mass of debris has sufficient internal evidence to show that it was not laid down in the ordinary stratified form; either by the action of denudation, or by the aid of the remains of a marine or a terrestrial flora or fauna, as is the case with the rocks of the Laurentian age, leading onward through all the Palaeozoic, Mesozoic, and Tertiary periods, and still upward to the immediate Preglacial age, represented by such beds as that of the Norfolk Forest deposit of East Anglia.

Some of the earliest geologists considered such accumulations to be the result of ice action, in the form of bergs. To this theory there are weighty objections. These are the two most important :—

1st. There is no trace of stratification in the deposit.

2nd. There are no remains of the inhabitants of the sea in which the ice would float when it deposited its gleanings, as all fossil remains belong to clearly defined strata of a much more ancient date; so much so, that we may speak of the Ice Age as belonging to yesterday, by comparison with the deposits from which the fossils were derived, which in that case, might be spoken of as pre-historic. The one exception, is the fossil wood which was found, but this is terrestrial, not marine.

It seems from all the evidence that can be adduced, that the vast accumulations of clay, known as the Upper Glacial Boulder Drift, must have been deposited by the direct action of moving ice upon the land. Today the same force may be seen at work in

Switzerland, the Canadian Rockies, and in other localities. In fact, wherever glaciers exist, some such deposits must be made to a greater or less extent. The moraines of the Swiss glaciers being the modern equivalent of the ancient ice deposits.

Undoubtedly England, at the time of the Glacial Period, was united to Scandinavia, and probably to Ireland also. One immense glacier moved southward, being fed by ice-streams branching out, both east and west, in the manner of river tributaries. You may ask "How is this proved ?"

Why, by the contents of the clay. The Bedfordshire Drift Clay is undoubtedly obtained in a great measure from the Liassic and Oolitic Argillaceous deposits, which lie comparatively near at hand. In fact, both are found in various localities not far distant, the Oxford Clay lying in the immediate neighborhood to the north and north-east. These facts are important, as the number of fossils found in this particular drift, which are characteristic of either the Oolitic or Liassic clays, show that the bulk of the material must have been obtained from these sources.

Those fossils and rocks derived from material lying at a greater distance, are naturally much fewer in number, although some must have been brought a long way, as for example the Trigonia Pulchella, whilst some of the rock fragments would seem to be of Scandinavian origin.

There has been much speculation as to the chronology of the Glacial Period. Sir Charles Lyell and his disciples gave a practically unlimited time to life, as we know it in geology.

More modern geologists, guided in a great measure by astronomers and physicists, have arrived at conclusions strikingly different from those of the older school of writers. Here is the contrast, if figures of such magnitude can be sufficiently grasped to appreciate their import.

500,000,000 years ago the Eozoon would be flourishing, according to Sir Charles Lyell. Of course, it is very possible that you do not accept the evidence as sufficient to show that any organism existed, prior to the reign of the Trilobites. Anyway, that is the age given when the Laurentian rocks were being formed.

Young and Wallace, two more modern mathematical geologists, give about 30,000,000 years only, as the time of the "Dawn of Life."

Dana, in his geology, gives this proportional ratio: Palaeozoic, 22; Mesozoic, 6; Tertiary, (together with the Post-Tertiary) 2. From this you will gather that the whole of the deposits ranging from the Lower Eocene to the Pliocene, onward through the Pleistocene to the present time, is only 1-15 of the geological life period. Some authorities give a much less proportionate time value than this even, for the Kainozoic Age. Out of this time, only a small portion can be taken for the Glacial Period, occurring, as it does, after all the great deposits of the Tertiary Age were laid down. Prestwich gives about 25,000 years, as the time for the existence of the Age of Ice.

Next arises the question: How much time has elapsed since the close of the Glacial Epoch? From cumulative evidence a fairly near date can be attained.

The Niagara Falls form, perhaps, the best geological clock in existence, for the purpose of giving the approximate date when this period ended. It took years to work out a satisfactory result, and such men as Sir Charles Lyell, James Hall, and Woodward all aided in solving the problem. It is a very well authenticated fact that the river Niagara is of post-glacial date, as is also Lake Erie, and a large number of the Canadian lakes. Lake Ontario was probably pre-glacial, the Grand River and its tributaries being the means by which the whole of the valley which is now Lake Erie was drained. This river course was completely diverted by ice-action, as be-for the ice age, it entered Lake Ontario at its western extremity at the point where Hamilton now stands.

The calculations as to the length of time since the Glacial Period, are based upon the wearing away of the rock at the Falls of Niagara. The yearly loss of rock by denudation is, roughly speaking, some three or four feet, or even more, as it does not wear evenly, hence its horseshoe form. Take this length and divide into the length of the gorge, and we have a quotient giving from 8,000 to 10,000 years as the age of the river, in other words, as the river is an outcome of the Ice Age, it must be that length of time since the glaciers disappeared from the Niagara district. Undoubtedly we must assume in this case that the same continuity of the volume of water has existed since the Glacial Age.

In the upper part of the Mississippi River is another post-glacial gorge, which forms a valuable indicator as to the time of the Glacial Age. The results here about coincide with those arrived at with regard to Niagara. Other similar cases of denudation give approximately the same results.

The silting up of lakes, whose beds were formed by the agency of ice, show that the Glacial Era could not have been much more remote.

Take your own lakes near St. John, which are all of glacial origin. They are small, and receive a quantity of mineral and organic matter, brought down from the hills by the various streams, and deposited in them, by which means they gradually become filled up. Both Lily and Ashburn lakes have already become nearly filled with silt, in their shallower portions. In a comparatively short time, geologically speaking, both will become swamps, while only a little while afterwards they will be flat grass-land, just as the old rifle-range land now is. That ground was undoubtedly a lake at one time, but became filled up with mineral and organic matter, brought down by the streams from the hills around.

You may ask, "What has this to do with the Glacial Age?" Well, simply this : A computation of the amount of silt there is in the lake, before the hard rock-bed is reached, will give the age of the lake, if the average yearly deposit can be obtained. Calculations based upon such data, approach very nearly in results to those deduced from the erosion of rivers.

It is a moot point amongst geologists whether the age we are now speaking of, was really a time when whole continents were under glacial ice, or whether local climatic influences, coupled with changes of land elevation, would be sufficient to produce this phenomenon. Further, Sir William Dawson has shown that a species of Drift Deposit is being accumulated at the present time in some of the openings of the Canadian Coast, this deposit being formed by the agency of floating ice, in the shape of either bergs or drift-ice. Moreover, the rocks are often much striated. It will be well to remember the fact here, that an iceberg has only about an eighth of its entire mass above the water, the rest being submerged. You can imagine at what a depth some would be in the water, when I mention that I have, myself, seen icebergs some 200 feet high, in and near the Straits of Belleisle. So soon as such a mass of ice gets into comparatively shallow water even, it would run aground, and be swayed about by either the wind or current, in some particular direction, when any stones sticking underneath would be scraped across the sea-floor, by which means they would become striated. Notwithstanding the proofs that in particular instances floating ice may lay down Drift Beds, the consensus of opinion shows that such a deposit as the one particularly described tonight, must have been laid down by glacial action, and for the reasons already mentioned, but which it might be well now to recapitulate.

1st. The formation is completely devoid of stratification.

2nd. The striated stones are very often elongated in shape, showing that they were worn by being pushed along by some solid force.

3rd. The character of the whole of the contents of the clay—both organic and inorganic, point to the fact that some land force must have been at work, to glean such a heterogeneous mass of debris together.

4th. The manner in which the accumulation was laid down, shows a difference in the method employd, from that used to produce the sedimentary deposits.

5th. No marine life remains are found in the clay, of the age in which it was formed.

6th. Similar deposits are now actually in process of formation in some parts of the world, being laid down by Glacial Agency.

In conclusion, it may be remarked that it is still a debatable question, as to whether man's existence was coeval with the Glacial Period. It probably depends upon what is meant by coeval.

If it means with the later ice age, which occurred after the warm Interglacial Period, then, perhaps, the query may be answered in the affirmative, as considerable evidence has been collected which tends to show that man was in existence then, but no trace of his remains were found in the Bedforshire Drift. The Cave and other deposits contain evidences, such as chipped flints and stones, which seem to indicate that he may have retreated before the advancing ice which produced the Upper Boulder Clay.

If man's advent did not occur until after the drift was deposited, yet the men who chipped palaeolithic stones or polished neolithic flints must have lived at a period very remote from us, if we gage the time of their existence simply by the measure of historic chronology.

Natural History Society of New Brunswick.

Appendix C.

THE MOUNTAIN SYSTEMS OF AMERICA.

A Comparative Study.

Synopsis of a Paper read before the Society
January 2nd, 1895,

By LORING W. BAILEY, M.A., Ph D.

After referring briefly to the part which mountains play as elements in the earth's physiography (helping to determine climatic differences, the distribution of rain fall, the size and flow of rivers, the limitation of floral and faunal areas) beside directly affecting human affairs by their influence on national characteristics, on religion, poetry and art, on wars and commerce, and finally as being the chief source of mineral wealth, Dr. Bailey went on to give a comparative description of the three great mountain systems of America: the Laurentian, the Appalachian and the Cordilleran, or Rocky Mountain, systems.

Of these the Laurentian was described as being at the same time the oldest and the lowest, including the belt of broken land which, in the form of a gigantic V, stretches from Labrador to Ontario, and thence to the Arctic Sea, enclosing between its arms the depression of Hudson's Bay. It thus forms the backbone of this Canada of ours, and is especially interesting as being one of the earliest of the centres from which the continent began to grow, and as having been probably continuously above the ocean from the earliest times. Thus, through unnumbered ages, it has been the theatre of atmospheric denudation, and what we now see of it is but the remnant of what it once was. Indeed, a close study of its denuded folds and of the great faults or dislocations by which it has been affected, alike prove the extent of its degradation, and lead us to believe that originally the system may well have borne comparison with the loftiest of existing chains.

The Appalachian or Alleghany system was next referred to as stretching from Gaspe to the Carolinas, and forming the eastern wall of the continent. Though hardly so long as the Laurentian system, it embraces a far greater number of subordinate chains (such as the Shickshocks of Gaspe, the Notre Dame range of Quebec, the Green and White Mts. of New England, the Highlands of New York, the Blue Ridge of Virginia, etc.) and includes some much higher summits, such as Mt. Washington in New Hampshire. It is also more complex in structure, involving the results of many mountain-making movements, but not completing its history until after the deposition of the coal-beds, these (in Pennsylvania) being included in the folds and faults by which the region was raised into mountain form. Since that time its history, like that of the Laurentian, has been one of waste and removal.

Lastly we have the great Rocky Mountain system, better known as the Cordilleran system, for the Rockies proper form only one element in the system as a whole, the latter properly embracing all the high land lying between the region of the Great Plains and the Pacific coast. This region, nearly 1,000 miles in width, was somewhat minutely described as seen, first along the Union Pacific R. R., or 40th parallel, and secondly along the line of the C. P. R. In each case it was shown to embrace a number of approximately parallel chains, including basins or plateaus between, and each exhibiting features peculiar to itself. Thus, on the line of the 40th parallel, the eastern ranges, constituting the Rockies proper, were described as rising abruptly from the region of the Plains to heights of 10,000 to 14,000 feet; while upon their western side they look down, with almost equal abruptness, upon the Green River and Colorado Basins, the two being separated by the east and west chain of the Uintahs, and together making up what, from a geological point of view, has been well styled the Plateau Province. This name is suggested by the fact that everywhere around the borders of this relatively low and flat tract are found great masses of horizontal strata, arranged in steps or plateau, one above another, the descent from one to the other being often precipitous and hundreds or even thousands of feet in amount; while near the edge of the successive terraces are numerous outlying masses or buttes, which were evidently at one time continuous with the adjacent terraces, but have since been separated as the result of wear and removal. It was then shown that a similar removal of rock, to a thickness of nearly *two miles*, had taken place over an area of at least 100,000 square miles, the terraces or plateaus, representing successive formations of different ages and degrees of hardness, being only the remnants of what once covered the whole region. Further, in the centre of the basin, this process of erosion was described as finding still grander illustration in the great canon of the Colorado River, a profound trench cut by the river across the whole Plateau Province, and having a vertical depth, with nearly precipitous sides, from 2,000 to 6,000 feet. This canon was described as one of the greatest of nature's wonders and its history fully detailed, while increased interest was given to the descriptions by the exhibition of numerous plates and a large number of photographs taken by the various exploring expeditions sent out by the U. S. government. On the west the Plateau Province, embracing a large part of the State of Colorado, is again abruptly met and walled in by the lofty range of the Wahsatch Mts., separating the Colorado Basin from what, ever since Fremont's time, has been known as the "Great Basin." This is the flat, treeless and almost utterly desert tract, including the region around Great Salt Lake, which at one time proved such a barrier to the tide of westward emigration, and which is still uninhabitable except where, as at Salt Lake City, fertility has been partly restored by artificial irrigation. The waters of Great Salt Lake are so dense that the human body is sustained on them without exertion and becomes, after bathing, encrusted with salt. Several rivers, such as the Humboldt, Carson and Truckee, traverse portions of the desert, being fed by melting snows from the mountains, but, unlike most streams, become smaller as we recede from their sources and are finally swallowed up in "sinks." So lakes, many square miles in surface, sometimes appear after heavy rain fall, and vanish a few hours after the latter has ceased.

This great desert is 100 miles wide, and on the west is again abruptly terminated by the lofty snow-clad range of the Sierra Nevadas, 500 miles distant from the Rockies, and rivalling the latter in elevation, as they exceed them in the grandeur and diversity of their scenery. Their greatest altitude is upon the eastern side, where they form an abrupt wall facing the Great Basin, and rise to a height of 14,000 feet. But to the west the slope is more gradual, descending slowly to the low land of California, which, however, is again separated from the Pacific by the chain of the Coast and Cascade ranges.

From the description of the physical features of the Cordilleran system the lecturer passed on to sketch its geological history, which is truly wonderful.

It was first pointed out that, alike in the Rockies, the Wahsatch and the Sierra Nevada ranges the core of the mountains is composed of the most ancient or Archæan rocks, and that these, prior to Cambrian times, formed a sort of semi-continent in the far west, the land being mostly of a mountainous character, and involving peaks and precipices miles in height, which, in magnitude, are now only rivalled by the topography of the moon.

In the Palæozoic ages which succeeded the Archæan, this lofty western land mass would seem to have slowly subsided until about 30,000 feet of sedimentary beds, of marine origin, had been deposited upon it, burying all but its highest summits. The immensely long period of time required for such deposition seems to have been unattended with any greater physical disturbances, but from its close and onward the evidences of such disturbances are frequent and upon a scale of unequalled magnitude. Thus, at the close of the Carboniferous period, or end of the Palœozoic ages, we find a movement occurring by which western Nevada, with portions of Oregon, previously dry, sink far below the sea level, while, simultaneously, eastern Nevada, western Utah and Idaho rise above it. The movements occurred along lines of fault, one of which, now forming the eastern wall of the Sierras, is 300 miles long, and marks a dislocation by which the Nevada country has been relatively dropped 3,000 to 10,000 feet.

The next great movement was at the close of the Jurassic era, and after 20,000 feet more of sedimentary beds had been deposited over the areas which were in a position to receive them. Again we find a change in the disposition of land and water. The Oregon-Nevada basin now disappears by the rising of its bed, and simultaneously the Pacific coast subsided beneath the waves. So in the early Cretaceous or chalk era there was a renewal of disturbance, in this instance so violent that over an area embracing thousands of square miles the rocks were so shaken and shattered that the fragments produced do not on an average exceed a hen's egg in size. The Coast and Cascade ranges also date their beginnings from this time.

Still later, at the close of the Cretaceous, came other movements resulting in the partial subsidence of the Coast Range, reducing it to a chain of islands, while east of the Wahsatch and thence to the Rockies the land rose from 30,000 to 40,000 feet, thus completing the "Pacific slope," at the same time that to the eastward of the Rockies the region of the Great Plains became for the first time dry, and, by the disappearance of the old Inter-American ocean, eastern and western America became united into one great continental land mass.

From this time onward we find no further depression of the west below the sea level. There were, however, frequent movements and a continuation of the old system of dislocation, further breaking up the surface, while in the hollows thus formed were produced a series of great inland lakes, bordered by extensive forests, whose shades gave shelter to vast numbers of gigantic mammals and other forms of life. But in time this condtion also passed away. The lakes were drained off as the mountains rose—aridity followed upon excessive humidity—the rivers dried up or became shrunken to narrow defiles, like that of the Colorado, and indescribable deserts began to take the place of what before had been a region of universal verdure. At the same time, along the lines of fracture, great floods of lava welled up from below, to spread in molten torrents over vast areas, and helping still further to make uninhabitable the already sterile wastes.

But, with this disappearance of all that would tend to make the surface suitable for tillage and for man's habitation, came also the storing of the fissured rocks with mineral veins, making the region the most productive mineral region in the world. For, from the same region, up to the year 1880, there had been removed, in gold, lead, silver and quicksilver, a total product of not less than 2,000 *millions* of dollars. The lead and silver are chiefly found along the line of the old Wahsatch fault—a fault by which the western half of the chain had been dropped some 40,000 feet, while the gold belt of California lies along the western flank of the Sierra Nevada, where a similar displacement of many thousands of feet has been shown to have taken place. Lastly, the great quicksilver deposits, without which the gold could hardly have been discovered, lie nearer to the coast, and undoubtedly owe their origin to the powerful movements and accompanying igneous phenomena by which the latter had been affected.

The lecture closed with some further comparisons in the character of the movements distinguishing the three great mountain systems of the continent, and the belief was expressed that, as regards the Rocky Mountain system, these movements were still in progress, and that volcanic outbursts, upon an extensive scale, might at any moment renew in that region the events which at no distant period marked its history.

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