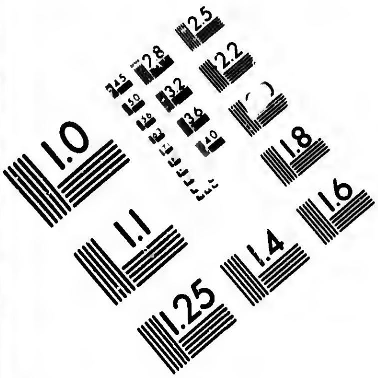

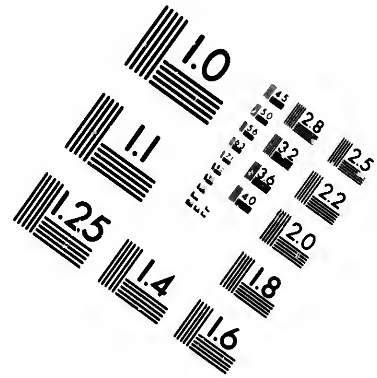

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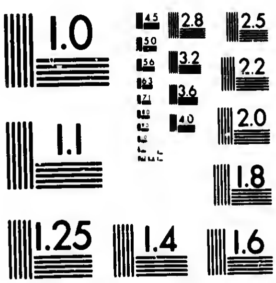

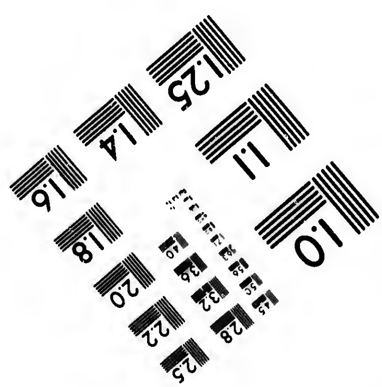

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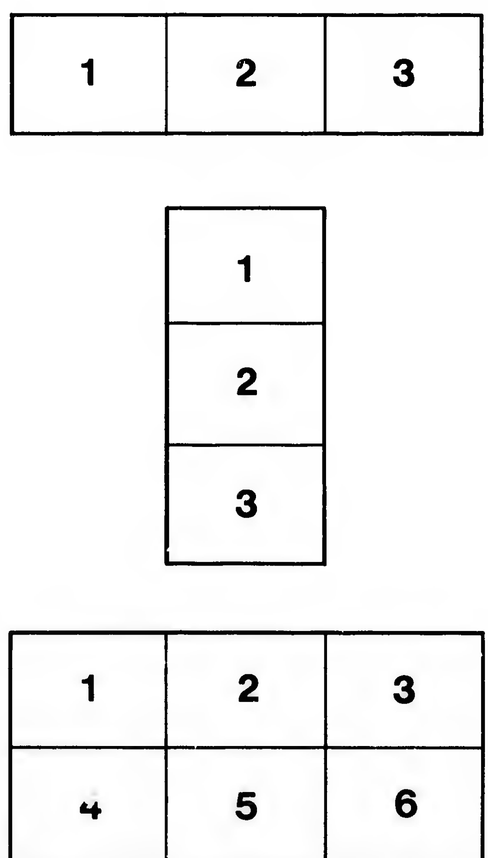
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# THE LAURENTIAN AND HURONIAN SYSTEMS IN THE REGION NORTH OF LAKE HURON

BY

**ROBERT BELL, B.A. Sc., M.D., LL.D.,**

*Assistant Director of the Geological Survey.*

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(FROM THE REPORT OF THE BUREAU OF MINES, ONTARIO).

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*PRINTED BY ORDER OF THE LEGISLATIVE ASSEMBLY.*

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1892.

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# THE LAURENTIAN AND HURONIAN SYSTEMS NORTH OF LAKE HURON.

By Dr. Robert Bell, Assistant Director of the Geological Survey of Canada.

This paper is intended to give a brief account of the geology of the country represented on the accompanying map extending from lake Huron northward to lake Temiscaming and from lake Nipissing westward to the Spanish river. It will aim at giving a summary of the various reports of the Geological Survey referring to that region in the light of the most recent views in regard to the rocks of the district, and will cover ground already described by the writer in the annual reports of the Survey for 1865 and 1866, 1875 to 1877 and from 1887 to 1890, by the late Mr. Alexander Murray of the same service in the reports of 1847 to 1857, and by reports made at various times by officers of the Department of Crown Lands.

The geological coloring of the map is compiled by the Director of Surveys in the Department of Crown Lands from the maps and descriptions of Mr. Murray, the geological map of the Basin of Moose River, 1883, and that of the Sudbury Mining District, 1890, by the writer, and also the maps accompanying Sir William Logan's Geology of Canada, 1863, as well as from the descriptions contained in the various reports above referred to. As these reports and maps are not very accessible to the public, and some of them are out of print, it is felt that a short summary of their contents, with suitable explanations, arranged in convenient form for reference and illustrated with a geological map, would be found useful at the present time. The colors used are made to harmonize with those at present adopted by the Geological Survey. The topography is compiled from the surveys of the Department of Crown Lands and of the Geological Survey.

With the exception of the larger islands on lake Huron, and possibly a tract in the Sudbury district, the area represented on this map is occupied almost exclusively by rocks of the Laurentian and Huronian systems. Descriptions of these rocks in general and of their relations to each other by the writer are contained in the Section devoted to Geology in the Report of the Royal Commission on the Mineral Resources of Ontario, 1890. But it is now proposed to give a more detailed and local account of the rocks belonging to these systems which are met with in the area represented on the map.

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## THE LAURENTIAN SYSTEM.

The Laurentian system may be divided into an upper and a lower formation. The latter consists almost entirely of primitive or fundamental gneiss, which is supposed by many geologists to have been originally of an igneous nature, but to have undergone alteration which has produced its more or less foliated character. The upper Laurentian appears to consist of metamorphosed sedimentary strata to some extent at least, while the Huronian rocks are undoubtedly largely sedimentary, but mingled with a varying proportion of igneous rocks, both of which have undergone more or less metamorphism.

### METAMORPHISM.

By this term is meant those changes in rocks which have been produced by pressure and heat, and possibly electricity, acting slowly or through a very long time, and producing molecular or chemical interchanges in their constituents, and causing them to become in a greater or less degree crystalline. The original composition of some rocks is more favorable to metamorphism than that of others

With a change of conditions, rocks may undergo a second or further metamorphism. The element of time being very important in bringing about metamorphism it follows that the older rocks are the more subject they have been to have undergone this process. The more ancient rocks have necessarily been those most liable to disturbance from these changes which have always been going on in the crust of the earth, so that they have been moved from their original positions and have been tilted, crushed and contorted more than the newer ones, almost in direct proportion to their age. The very fact of strata standing at high angles to the horizon appears to be connected with the metamorphic processes, and rocks which are locally disturbed, as in certain mountain chains, are found to be metamorphosed, while the same strata in continuation are not changed where they are found nearly horizontal. Great outflows of igneous matter have also in many instances had the effect of altering rocks locally.

A crushing and disturbing force due to the constant shrinking of the earth and acting horizontally at the surface has been going on in its crust from the earliest times. The effect of this force may be seen, not only on the large scale, in the tilting, folding up and faulting of the older rocks, but also in their microscopic structure, thin sections of them very often affording the clearest evidence of their having been subjected to intense pressure, forcing asunder solid grains, grinding them against each other or crushing them to small particles. Another effect of the intense lateral pressure referred to has been to produce in rocks a schistose or a slaty cleavage at right angles to the direction of the force. In the crystalline schists this has been effected by the crushing force, aided often by a shearing movement, causing the component particles to move slowly around till their greater diameters assumed positions at right angles to the direction of this force. In the schistose rocks the cleavage planes of such minerals as possess cleavage have been made to correspond with the directions of the mechanical arrangement of the other particles, so that in cross section the whole texture has a parallelism of its grains, giving it a laminated appearance. Dioritic schists have probably been originally massive diorites, and have had their cleavage structure developed in the manner just indicated. Many geologists believe that some kind of gneiss have been formed out of massive granite in the same way.

These processes involve an enormous lapse of time, so that a crystalline and schistose condition is *prima facie* evidence of antiquity. Indeed if we exclude those cases of local metamorphism which have been referred to, it may be said in a general way, the more crystalline and altered rocks have become the more ancient they may be presumed to be.

Notwithstanding the apparent stability of the rocks in this part of the world, far removed as they are from volcanic activity, there exists nevertheless within them a state of perpetual unrest. Unceasing changes are going on in the arrangement of their constituents as illustrated by crystal enlargement, pseudomorphism and decomposition in a petrological sense.

Besides the constant internal changes taking place in the rocks there is restless action or movement on a large scale throughout the whole body of the earth. One of the primary causes of this movement is the constant shifting of the matter on the surface by the action of air and water or ice. The earth is not a rigid solid, but obeys hydrostatic laws. When a certain weight of matter has been transferred from one part to another its effect is to sink down the part to which it has been transported, while there will be a tendency to rise to a corresponding degree at the point which has been relieved of this burden. These oscillations were probably more frequent and rapid in the earlier geological ages than they are now, but they will continue to go on to a greater or less extent as long as air and water exist to transport matter and disturb the equilibrium of the earth.

### Divisions of the System.

The lower division of the Laurentian system is characterized by monotonous uniformity in the nature of its rocks, which consist of gray and red gneiss, usually much bent or disturbed, and having generally only a rudely foliated structure and a solid or massive character. Its felspar is almost entirely orthoclase, whereas the other species are abundant in the upper division. There is a general absence of economic minerals, and the number of mineral species is small as compared with the latter. The upper division is of a more complex or differentiated character, or comprises a greater variety of rocks and minerals. It possesses more regularity in its stratification and includes great banded masses of crystalline limestones, vitreous quartzites, mica and hornblende schists, massive pyroxene, and both massive and foliated labradorite rocks. Considerable areas of granite and syenite occur in the formation. These, as well as the pyroxene rocks, and perhaps also the hornblendic bands, are evidence of igneous action. The dykes of greenstone and porphyry which cut the upper Laurentian may belong to a later geological period.

Upwards of sixty different mineral species have been found among the upper Laurentian rocks in Canada. They also contain a variety of economic minerals, among which may be mentioned graphite, apatite, mica, serpentine and limestone marbles, limestones suitable for calcining, felspar for porcelain, porphyries and other ornamental stones, pyrite, sulphates of barium and strontium, asbestos, crysotile, building stones, and ores of iron and other metals.

It is not impossible that gneiss may have been formed in more than one way. While some varieties, from their microscopical characters and other circumstances, appear to be of clastic origin, it seems to be equally certain that others owe their foliation to pressure and internal changes which may have taken place in rocks of igneous origin. Dr. Sterry Hunt is of the opinion that we have not yet discovered any rocks which can be regarded as having formed part of the original crust of the earth, that is, if we suppose the crust to have been first formed by the mere superficial cooling of a molten mass, since the earliest rocks of which we have any knowledge all contain water and free silica.

The lower Laurentian gneisses are the oldest rocks with which we are acquainted. Their thickness is entirely unknown, and it may ever be found impossible to arrive at even an approximation to their volume. It must however be enormous. The upper Laurentian, of which some kind of measurement is possible, may be roughly estimated in the Ottawa valley, where it has been more studied than elsewhere, at from 50,000 to 100,000 feet, or nearly 20 miles in thickness, and even much more.

Although the older Laurentian rocks may afford no mechanical proof of the permanent existence of a sea upon the earth, unless their foliated or stratiform character be taken as such evidence, water appears to have been present, perhaps as only temporary precipitations upon the surface, at every stage of their formation. But in the upper Laurentian the great deposits of nearly pure carbonate of lime and of tolerably pure silica in distinct bands afford strong support to the aqueous theory of their deposition, while it negatives that of their igneous origin. An important feature in the general character of the Laurentian system is that its rocks, as a whole, are of an acid nature, or contain a preponderance of silica in their ultimate chemical composition. We shall see further on that in this respect they contrast with a considerable proportion of those of the Huronian system, which are largely of a basic character.

Whether we regard the bulk of the Laurentian rocks as having had a clastic or an igneous origin, the general condition of the surface of the earth does not appear to have undergone any great change while they were being formed, or while the cooling process was going on to the extent of their thickness. Even in the upper Laurentian we have found no proof of the pre-existence of solid rock or dry land such as might be afforded by conglomerates.

### A Period of Change.

But with the beginning of the Huronian period came a new order of things. Great volcanic activity took place, and at the same time we have distinct evidence of the permanent abode of water on the surface of the earth and of the wear and tear of the sea on the solid rocks. Immense quantities of volcanic ashes, cinders or tufa, broken rock and other ejectamenta were thrown out, in some cases with explosive violence. Molten matter was poured forth in great quantities from vents and rents in the crust, forming thick sheets and large masses that became incorporated among the marine sediments which were probably accumulating rapidly. The surface of the earth would be almost entirely covered by the sea, which would likely be shallow, hot and full of dissolved mineral matters, the greater part of which have since been eliminated. It would be unfit to support animal or plant life, and it is therefore improbable that we shall ever find any organic remains in this system. Some of the erupted rocks remain massive and unchanged to the present day, except by the internal or molecular action among the constituents themselves, but the bulk of them had become broken up under the strong weathering influences of the period, or by contact with water, and spread out on the bottom of the sea to form the various stratified rocks of the system. The general character of the Huronian rocks may therefore be said to be pyroclastic, this term signifying that although fragmental they have nevertheless had an igneous origin. The Huronian rocks of lake Superior, and the country north and west of it, consist largely of greenish schists whi... are, chemically speaking, basic as distinguished from the gneiss of the Laurentian, which, as already stated, is of an acid or silicious character. A considerable proportion of the great Huronian belt is made up of greenstones and allied rocks that are also basic.

### Rocks south of the Huronian Belt.

In the country represented upon the map, the rocks lying between the great Huronian belt and the shore of Georgian bay appear to belong to the upper Laurentian formation. In the French river region the gneisses are generally characterized by much regularity in their dips and strikes, which often maintain the same course and about the same angle of inclination for long distances. The dips vary from a horizontal to a vertical attitude, but in the majority of cases they are about intermediate between these.

This region is noted for its peculiarly straight and almost parallel rocky channels, many miles in length, having a general course nearly east and west, which are intersected at large angles by other channels almost equally straight, the whole forming a sort of network quite unique in its character. Some of these channels belonging to both sets run with the strike of the gneiss, which when mapped has a sort of zig-zag arrangement on a large scale, while the others follow the lines of the principal set of joints. It sometimes happens that between two leading joint-planes other and parallel joints occur, unusually close together, breaking the rock up into blocks which have been removed by glacial denudation, thus producing these channels. The angles of dip being only moderately steep, those channels which follow the strike occupy ditch-like notches formed along the outcrops of particular sets of beds which have been more easily excavated by eroding agencies than those on either side of them.

It will be observed that the French river flows in two principal east-and-west channels between lake Nipissing and its rocky delta, and that about half way down they both jog to the southward at right angles. This interruption in their course is perhaps originally due as much to some north-and-south break or disturbance in the rocks as to changes in the strike. The long east-and-west channels, whether parallel with or transverse to the stratification, are also probably situated upon lines of crushing, and possibly of some dislocation, along which the strata have been broken up so as to permit of the deeper penetration of the surface waters and the consequent decay of the rock prior to the glacial period, during which these channels have been excavated below the general level of the country. They are really only long and very narrow lakes, with slight falls or rapids between them, and they persist in their courses uninfluenced by the changes in the strike of the rocks they pass through. Besides the channels shown upon the older maps, there are many others in the French river country, all of which belong to the reticulating system of waters which forms so remarkable a feature in this whole district.

The curious rocky delta of the French river has a breadth across its mouths of fifteen miles. The channels, which are very numerous as we leave the coast, form three groups, the east, middle and west, each of which unites by cross channels into one at a short distance up. They are all nearly parallel and have a general northeast and north-northeast course as we enter from Georgian bay. The gneiss in the whole interval covered by these channels runs parallel with them and has a uniform dip to the south-east and east-southeast, with an average inclination of from 40° to 60°. This general strike extends for twenty miles inland from Georgian bay, when it becomes disturbed, and a little fur ther on is cut off by a northwesterly strike in similar gneisses which prevail on the upper part of the French river and the country to the northward of it.

In the central part of the course of the river the strike in different intervals runs about north and south, east and west, northwest and northeast, while between these groups of tolerably straight bands it is often more or less bent or distorted. In some parts of the French river region, even where the strikes are regular, Mr. Murray considered the structure to indicate a series of anticlinal and synclinal folds, in which some of the strata are repeated, and that the thickness of the gneiss is in consequence made to appear much greater than it really is. But after making allowance for this partial repetition, the actual thickness must be very great.

Southeastward of the mouths of French river, along the shore of Georgian bay, the rocks are everywhere well exposed, and the structure of the gneiss and associated strata or their local configuration is well brought out by the erosion to which they have been subjected. This fact is graphically illustrated by the recent charts of Captain Boulton.

Locally the run of the stratification is often indicated by the form or direction of the points and bays, the larger islands and the chains of smaller ones. The curving outlines of the islands, channels and inlets opposite to Penetanguishene, the twisted appearance of Parry island and of the channel on its southeast side, as well as the singular straightness of Partridge bay, the Long inlet, the points on the west side of Parry island and about Shibaishkong island, all correspond with the local strike of the rocks and are due to the effects of denudation, which has formed channels along the courses of the more yielding strata, and left ridges or higher ground where the rocks resisted decay and erosion. Along this shore there is however a class of channels and inlets due to another cause, namely, the existence of dykes of trap and breccia and of granite veins, and also of parallel joints or cracks along which the rocks have been rendered more decomposable; or these latter may have acted merely as starting points or guiding lines for the action of glaciers or other denuding agencies which constantly enlarged and deepened the depressions, once they had been commenced. The channels and inlets of this class usually run nearly east and west and have steep sides, while those which follow the stratification have usually some other course and are not so abrupt.*

These lines of rock-crushing and subsequent erosion have doubtless had a great effect in producing the river and lake features in most of the regions occupied by our upper Laurentian rocks, as well as in some other metamorphic districts of Canada. Dykes of greenstone and breccia have also played an important part in this connection, generally giving rise to river-channels and long lake-basins, but occasionally, where hard or resisting, having the opposite effect, producing ridges, or causing falls and rapids where they happen to cross streams.

Near the head of Byng inlet, a short distance southeast of the mouths of French river, a brecciated rock is exposed near the edge of the water which apparently forms part of an east-and-west dyke, along the course of which the channel of the inlet and of Maganetawan river have been excavated. Parallel to this dyke are joints stained red by oxide of iron, giving a dry and crumbling character to the gneiss along their course, which is east and west, while the gneiss they cut runs in various directions transverse to the joints.

On the lower or western north channel of French river Mr. Murray noticed a friable brick-red quartz-syenite at the Grand Recollet falls and for some miles below it. This probably belongs to an eruptive dyke-like mass, following a line of weakness in the course of the channel.

In the French river country the gneisses are most commonly of dark reddish-grey shades, and they comprise both the mica and the hornblende varieties. Their texture is usually from medium to coarse grained. As a rule the latter are gray and darkly colored, while the finer grained varieties are generally reddish. Silicious belts, in some cases amounting to vitreous quartzites, bands of mica schist with garnets and of hornblende schist occur among the gneisses, and in some localities they are largely developed.

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* Dr. Robert Bell in the Report of the Geological Survey for 1876, page 195.

Veins of coarse reddish and nearly white granite running in different directions cut the hornblende and mica schists and schistose gneisses about the mouths of French river, and similar veins are also met with occasionally in the interior. A few greenstone dykes were noticed along the river, but they do not appear to be very common in this region.

Quartz veins running in various directions are of frequent occurrence in the French river region, but they are all of a "hungry" character, and none of them have been observed to carry economic minerals in promising quantities.

The dividing line between the Huronian and Laurentian systems runs northeastward from the head of Shibaonaning or Killarney bay. Between this locality and the middle of Philip Edward island, including the township of Rutherford and most of Carlyle, the rock is a massive red quartz-syenite or hornblende-granite, which occasionally shows patches of an indistinctly foliated character · but this rock does not appear to extend far inland, although it occupies about twelve miles along the coast. Mr. Murray mentions the occurrence of a similar rock, which seems to have a breadth of about two miles and a length of about four miles, in a northeasterly direction between the western and middle groups of mouths of the French river.

In the region covered by the map certain differences may easily be observed in the general characters of the Laurentian rocks on the southeast side of the great Huronian belt as compared with the rocks on its northwest side, which we have for the present classified for convenience with the same series, because we have not yet found it practicable to separate them by a definite line from the undoubted Laurentian still further northwest, with which they are continuous. Between the shore of Georgian bay and the Huronian belt, and about as far north as the line of the Canadian Pacific Railway, the gneisses are of the typical Laurentian varieties, all evenly stratified and regularly arranged in anticlinal and synclinal forms, according to the structural laws governing stratified rocks. The angles of dip are on an average not far from 45°, although in some cases they are nearly horizontal and in others almost vertical. Except in a few localities the bedding is not contorted, but runs straight and evenly for considerable distances, and these gneisses have every appearance of being altered sedimentary rocks. Red and grey varieties are represented in about equal proportions, and they alternate with each other in both thick and thin sheets. They are mostly mica-gneisses, although the mica is present in rather small proportions, but in some cases hornblende replaces the mica in whole or in part.

No beds of crystalline limestone have been found among these rocks west of the longtitude of Iron island in lake Nipissing, where this rock has been noted by Mr. Alexander Murray. These limestones are also associated with them on some of the islands in the eastern part of this lake and at lake Talon on the Mattawa. Further east, in the Parry Sound district, the writer in 1876 traced five distinct brands of Laurentian limestones running for considerable distances in a northerly direction from the shore of Georgian bay.

The Laurentian rocks between Georgian bay and the great Huronian belt, from the characters which have just been described, would therefore be classified along with those of the counties of Ottawa and Argenteuil, which belong to the upper portion of the system.

### Rocks northwest of the Huronian Belt.

On the northwest side of the great belt the conditions are different. At some distance to the northward of this belt the heavy contorted gneisses of the lower Laurentian cover an immense area, but there is an intermediate region in which red hornblende granites prevail, but they are mingled in some parts with gneiss. The granites are largely developed along the northwest border of the Huronian belt all the way from the west side of lake Wahnapitae southwestward to the Sable river, and probably still further. From this geological boundary they extend northwestward out into the midst of the lower Laurentian gneisses to a variable distance, their greatest extension being unknown. Along the main line of the Canadian Pacific Railway they are found all the way from the junction of the Huronian at Onaping station to Spanish Forks and westward from the railway to the Spanish river, but beyond these limits the country has not been carefully explored.

Similar red hornblende granite, occasionally showing gneissoid texture, forms an elongated area in the middle of the Huronian belt in the Sudbury district, extending from near the South bay of lake Wahnapitae southwestward to the township of Drury. The southern boundary of the main granitic area crosses the Spanish river midway between the northern and southern lines of township 111, whence passing westward it sweeps round to the south and forms a promontory in the townships of Gough and May. From the northern part of the latter township the boundary between the granite on the north and the Huronian quartzites, greywackes and schists on the south runs westward parallel to the shore of lake Huron, as far as the township of Proctor, were it turns northwestward and the Huronian rocks occupy a large area lying to the northward of Algoma Mills.

Although the granites which have just been described are provisionally classed with the Laurentian, it is uncertain that they are all really of this age. In some localities they are so intimately associated with gneisses of the ordinary Laurentian types that it would be impossible to draw a line between them. In such cases they may have been formed out of portions of the gneiss softened by heat and re-crystallized after having lost their stratiform character. In other places it is quite possible they may be due to the alteration of arkose or greywacke similar to that which is so common in the adjacent Huronian series. Or it may be that these granites are mainly eruptive in their origin. The writer has pointed out in various reports on the Archaean rocks of northern Canada that the commonest situation of the granitic areas among these rocks is at and near the junction of the Laurentian and Huronian series, and there is perhaps no good reason yet known why they should be assigned to the one more than the other.

In the region at present under consideration, along the line of contact between these granites and the Huronian quartzites, schists, etc., the rocks are often much broken up and intermingled with one another, both in great masses and smaller fragments. This effect has probably been produced when the granite was in a soft condition and subject to intense pressure, coupled with more or less movement. Referring to the last mentioned consideration, it is not improbable that faults of considerable extent have taken place along the lines of junction between these two classes of rocks, not only in this region but in other localities where the Laurentian and Huronian rocks come into contact. This is only what we might expect to occur along the lines dividing rocks having unequal powers of resisting the great strains to which the crust of the earth must have been subject in all ages. These faults may be looked for more especially at those parts of the junction of the two sets of rocks which have been most exposed to lateral pressure, and along those portions of the lines of contact which are tolerably straight for considerable distances. The bed-planes of the Huronian and Laurentian rocks on the opposite sides of a contact thus faulted might show some want of parallelism, and from this accident a general unconformity of the two series might be erroneously inferred. The few instances of apparent local want of conformity which have been observed seem to be capable of explanation in this way. One of these instances may be seen at the Wahnapitae river where it is crossed by the Canadian Pacific Railway.

Within the area represented on the map, besides the gneissic and granitic rocks flanking the great Huronian belt, there remain to be noticed a few inliers of these rocks. One of them, consisting of gneiss, lies between the north and northeast arms of Temagami lake. Another, also of gneiss, which has been described by the writer in the report of the Geological Survey for 1875, surrounds Paul's lake on the upper part of Sturgeon river, and appears to extend for some distance to the south of it. A short distance east of the angle formed by the junction of Proudfoot's east-and-west and north-and-south lines an area of red hornblende granite was discovered, which may extend to the northward, but its limits have not been traced out. Two belts of gneiss projecting from the northward cross Montreal river, one at Elk lake and the other at the sharp turn in the river about midway between this lake and the junction of the east branch. Both of these belts appear to terminate at no great distance to the south of Montreal river.

THE GREAT HURONIAN BELT.

Sir William Logan and his assistant, Mr. Alexander Murray, after examining the crystalline rocks of lakes Superior and Huron, gave the name Huronian (at the suggestion of Dr. Sterry Hunt) to all those of both regions which lie above the granitic series which they called Laurentian. These terms were not restricted to any particular area, but were meant to designate the two great divisions of the Archæan rocks and to be of general application in Canadian geology. Both sets of rocks extend into the United States and the Canadian names, having priority, were adopted there. But of late years efforts have been made to abolish the convenient and well established designation Huronian, except for one small area of these rocks lying on the north side of lake Huron and forming only a part of the great belt which is continuous from lake Superior to lake Mistassini, a distance of 700 miles following its axis, on the asserted ground that the selected part alone forms what some geologists call the "typical Huronian." I cannot however understand why one particular portion of one belt of rocks of the Huronian system should now be selected for this distinction to the exclusion of the remainder of the belt which is continuous with it, and also of other areas of rocks which are most naturally placed with them and which were expressly included by Logan when he classified them and gave them this name.

The rocks of the Huronian system as defined by Logan consist of crystalline schists in great variety, quartzites, conglomerates and agglomerates, clay slates, greenstones, dolomites, etc. At the time referred to, more than forty years ago, the science of petrology was in a crude state compared with its present position, and the microscope was but little used in determining the nature of rocks. Hence Logan did not recognize the volcanic or rather pyroclastic character of a large proportion of the Huronian rocks. Some of the rocks of the system, such as the quartzites and clay-slates, although they do not themselves show a direct igneous origin, may have been derived from the products of volcanic activity through the intervention of water.

Owing to the pyroclastic origin of the majority of these rocks the various members in any region are not usually persistent for any great distance, but diminish in volume and are replaced by other beds which increase in thickness as the first diminish. As these rocks are usually tilted to high angles, the sections afforded by the surface of the earth are generally nearly at right angles to the bedding, and when mapped often show the interlocking character of the different bands as they terminate in both directions. This want of persistence is exhibited on both a small and large scale, so that the general characters of wide belts of Huronian rocks differ much in different regions.

In other parts of the world, such as Scandinavia and Scotland, where Archæan rocks are largely developed, series corresponding with our Laurentian and Huronian are met with. Nowhere have rocks of a different character been found to intervene between them. We might therefore infer that in a general way the two systems are conformable to one another. This inference is borne out by our observations over the enormous area of Archæan rocks which we have in the Dominion. It might be expected that in some parts of this great area a local want of conformity might be detected at the same time that the two systems were conformable on the grand scale. But in the few instances where there appears to be a want of parallelism in the stratification on the opposite sides of the contact, this is more probably due to faulting.

On the other hand, we have observed numerous instances where there is a gradual and conformable transition from the lower into the upper series. The beds of passage as a general rule consist of hornblende and mica schists alternating with fine-grained gneisses, and these are followed by other crystalline schists. In the Huronian areas of lake Superior crystalline schists predominate, although representatives of all the other varieties of the rocks of the system are not wanting, while in the lake Huron region and to the northeastward of it greywackes and quartzites with clay slates are the most conspicuous rocks, but the various crystalline schists similar to those of the lake Superior region are likewise to be found.

An impression has got abroad in some quarters that one of the distinguishing features of the Huronian rocks on the north side of lake Huron is that they usually dip at very moderate angles. Even if this were true, it would be a matter of no consequence in chronological geology. It is however only an incorrect assumption, and on the contrary as a rule the rocks of that region are highly inclined, as shown in a section by Mr. Murray in the report of the Geological Survey for 1856, and in my own section across the Sudbury district published in 1891. They do however dip at low angles in certain limited areas, such as the tract lying northward from St. Joseph's island and in that situated to the east of lake Wahnapitae, and again between lake Temagami and the Montreal river. But instances of equally low dips are to be seen among the upper Laurentian gneisses, as for example in a large region to the northward of Montreal.

Although in the lake Superior region and thence westward to Lake of the Woods the Huronian rocks consist so largely of crystalline schists, still there are silicious rocks among them, which may be the equivalents in diminished volume of the quartzites of lake Huron; also conglomerates, clay-slates, serpentines, dolomites, etc., and on the other hand there is an abundance of crystalline schists among the Huronian rocks of the lake Huron region. Conglomerates occur at various horizons among these rocks in both regions, but any single conglomerate bed is probably only of local occurrence and cannot be held to be the equivalent of any particular conglomerate in another region. As these conglomerates cannot be connected with one another in different Huronian areas it can scarcely be said that they represent a general break in the chronological continuity of one part of the system with another, much less a time break between this system and any other.

From what has been said of the nature of the Huronian system we should not expect even contemporaneous parts of it to be everywhere represented by the same kind of rocks. On the contrary, great local differences might be looked for at the same horizon. In a given region one variety may be largely developed, and yet in another this may be entirely replaced by a different rock without there being any difference in the age of the two. Rocks like those of the Lake of the Woods may be the equivalents in time of those of the north side of lake Huron, or of some other part of the system where the lithological difference is equally great. Still we have always admitted that perhaps the prevailing schistose series of the lake Superior region may belong to an older part of the system than the quartzite, clay slate and greywacke series of lake Huron, which apparently forms the newest portion of the great belt. Thus the area characterized by the great development of quartzites in the region extending from lake Huron to lake Abittibi may be somewhat newer as a whole than those portions of the series where the quartzites are in small amount or entirely absent. At the same time it is not to be forgotten that the quartzites of the region mentioned are associated with a variety of crystalline schists, such as may be seen on Spanish river, around Temagami lake, on Montreal river and in the region to the northward of it. The stratigraphical sequence of the various kinds of rocks found in the Huronian belt within our region has not yet been ascertained with sufficient certainty. The following descriptions of these rocks are therefore not given in the supposed order of their superposition.

### Quartzites.

It is an interesting fact in connection with the origin of these rocks that the quartzites and clay slates are so often found together. The decomposition of the arkose or greywacke and the separation of the silicious grains and the clayey portion would give rise to these two kinds of rock. Or they might result from the decomposition of the binary granite, from which the greywacke itself is probably derived, by the separation of the quartz grains from the argillaceous matter that would be produced from the felspar. Nearly all the quartzites contain more or less felspar, and sometimes it is present in large proportions, giving the rock the general outward appearance of granite. In some instances observed by the writer this mixture had become so far metamorphosed back into granite that it required to be examined in thin slices under the microscope before it could be decided that it had ever been a clastic rock at all.

These highly felspathic quartzites are abundant along the North river canoe-route from lake Mattagamashing (just east of lake Wahnapitae) to the upper part of Sturgeon river, and again west of Lady Evelyn lake, which lies north of Temagami lake. In other regions however the proportion of felspar in these rocks is generally small, and the texture of the nearly pure quartzites varies from compact with conchoidal fracture and composed of microscopic grains up to coarsely granular, made up of small pebbles closely crowded together. Some beds in almost every large outcrop of these rocks are of a distinct conglomerate character, the pebbles being well rounded and almost all of white quartz.

In the country just north of Bruce Mines, and again on the north side of Goulais bay, lake Superior, some beds and groups of beds of these conglomerates contain pebbles of red and dark jasper and light-colored chalcedony, thickly scattered among others of white quartz, all in a matrix of white quartzite. This beautiful rock has long been known as jasper conglomerate, and forms a fine ornamental stone, but owing to its hardness it is expensive to cut and polish. A few scattered pebbles of jasper are found here and there in the quartzites all the way from the above localities to Montreal river.

Light grey and nearly white quartzites form the north shore of lake Huron from the mouth of Spanish river eastward to Killarney bay. They constitute the LaCloche mountains, which run as two and sometimes three parallel ridges close to the shore, and nearly due east and west with the strike. The height of the front ridge varies from 400 to 755 feet above lake Huron, but the altitude increases in the continuation of these hills to the eastward, and it rises at one point to an elevation of 1,180 feet. The dip is everywhere nearly vertical. Similar quartzites, also standing nearly on edge, form the long and high points jutting out into lake Huron in a southwesterly direction between McGregor and Killarney bays. The strata forming these points are probably repetitions of those of the La-Cloche mountains, on the opposite side of a synclinal of nearly vertical strata, one extremity of which would be in the vicinity of the east end of lake Panache. The quartzite of the points and islands south of Frazer bay continues southwestward, and appears on Heywood island, and further on upon Grand Manitoulin island, at the head of Sheguiandah bay, and thence past the northern sides of Bass and Pike lakes. Quartzites, mostly of light colors, constitute the prevailing rock around lake Panache and the great bend of Spanish river, and northeastward to the township of Broder, but beyond this, for some distance on the general strike, they diminish in volume, and a considerable proportion of what remain merge into greywackes in passing through the contracted part of the belt in the Sudbury district. Still further on in the northeastward strike, or in the country to the eastward of lake Wahnapitae, the greywackes have passed into or have been replaced by clay-slates and argillites, dipping at much lower angles.

Northward of lake Wahnapitae the quartzites are again met with in great abundance. Along the upper Wahnapitae river they strike north-northwestward parallel to the Laurentian boundary in that direction, and dip at high angles. On the North river chain of lakes the general strike is east of north, turning more easterly in approaching Sturgeon river, beyond which the quartzites run northeasterly towards Lady Evelyn lake and Maple mountain to the west of it. These rocks are exposed in numerous places along the main Montreal river, and both its branches south of the great bend. Still further north they are largely developed in the country along the height of land westward from its intersection with the north and south inter-provincial boundary line.

In the region northeast of the St. Mary river the quartzites show considerable differences of color, and on this ground Mr. Alexander Murray separated them into different bands. In the southern part of the district shown on our map they are nearly all of light shades, but near its northern border there are red, pink and purple varieties. These are however of local occurrence. Greenish and yellowish tinges are common in all parts of the distribution of the lighter varieties.

### Clay-slates and Argillites.

The term slate should be given only to rocks formed principally from clay, in which arallel cleavage planes have been developed independent of the bedding. It is not properly pplied to those crystalline schists in which the cleavage is more or less imperfect and the

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planes are not parallel to one another. Argillites are claystones in which the slaty cleavage has not been developed.

Confining our remarks always to the area represented on the map, rocks of these two kinds are met with most largely in the country between lake Wahnapitae and Sturgeon river, along that stream between the Maskinongé and Round lake branches, about the north end of Temagami lake, and thence by Lady Evelyn lake to Montreal river, and on the latter; likewise along the Matabechawan river, which discharges into the foot of lake Temiscaming. These slates are mostly of olive or bluish green, purplish, drab and gray colors, and are often barred across the cleavage with narrow parallel bands of different shades. At the northern outlet of Temagami lake a greenish compact variety is marked by thin interrupted black bars. This rock, when cut, takes a smooth surface, and was much prized by the ancient Indians for ornaments and ceremonial stones.

These principal accumulations of slates and argillites appear to be in a general way about contemporaneous with the quartzites, that is to say, they were being deposited in the above localities at the same time that the quartzites were forming in others. Where they occur in smaller volumes they are sometimes found in proximity or interstratified with one another. As already stated, they may both be derived from the greywackes, which form so large a proportion of the rocks of the great Huronian belt in this region; and the greywackes in their turn are evidently made up of the *debris* of a quartz-felspar rock or binary granite. Or they may have been formed directly from the decomposition of this rock and its rearrangement by water, the silica and the undecomposed felspar, when any of the latter remained, going to make the quartzites, while the fine mud resulting from the decay of the felspar was carried elsewhere, and now constitutes the slates and argillites. As far as our present knowledge goes, the quartzites therefore cannot be said to be either older or newer than the slates of this part of the Huronian series.

The roofing slates found among the metamorphic rocks of the Eastern Townships in the province of Quebec are probably of somewhat newer geological age than those just described, which in some places may be found suitable for roofing purposes. Among the localities where the argillites or non-cleavable varieties occur may be mentioned the southern part of Mattagamashing lake, Koo-ka-gaming and Lady Evelyn lakes. Good cleavable slates occur on the Canadian Pacific Railway a short distance east of Algoma Mills. Felsites are sometimes found associated with the slates and quartzites, but they are more abundant among the greywackes.

Dark gray or drab and almost black clay slates are found along the Spanish river, in the northern part of Baldwin, and at the falls on lot 1, fifth concession of Nairn. Similar slates are met with on the Canadian Pacific Railway in the southwestern part of Graham, and again just south of Geneva lake. They are also said to occur in the township of Drury and a short distance east of Bannerman lake.

### Greywacke or Arkose.

In some parts of our region a rock which may be described under either of the above names is met with in great abundance. It has some resemblance to sandstone, but does not usually occur in distinct beds with parallel faces, and is generally either massive or divided by joints or a rough sort of cleavage. Under the hammer it breaks readily, and may be easily bruised or scratched, thus showing the presence of a considerable proportion of ingredients softer than quartz. It has an ashy appearance, and its color is usually some shade of ash-gray. On closer examination it is found to consist of comminuted granitic *debris*, and generally holds quantities of pebbles and angular fragments of all sizes of the granite itself. The latter are mostly of the same character in all parts of the district, and consist of a binary granite or quartz-felspar rock of either a red or gray color. Fragments of gneiss and other crystalline rocks are occasionally mingled in small proportions with those just described. Under the microscope the matrix or finer portion of this rock is seen to consist of somewhat rounded grains of quartz, and more angular ones of felspar, with a filling of fine serecite or of some dark amorphous mineral.

Rocks of this kind occur here and there in almost all parts of the Huronian belt within our region, but they are particularly abundant in the narrowed portion in the

Sudbury district and around Temagami lake and Rabbit lake to the east of it. They are also common in the Onaping and Straight lake outliers and all along the Spanish river, below the granite area, and thence westward as far as Mississaga river.

Sometimes, as on the Montreal river, the included fragments of granite attain the size of boulders, and these, as well as the smaller inclusions, may occasionally be found so closely packed together that only the interstices are filled by the finer material. The fragments are most common in the greywackes where the latter occur in large volume, and in these cases there is little evidence of stratification. The more uniformly-grained varieties, without angular fragments, are often found interstratifying quartzites, as in the Sudbury and Whitefish lake regions, and they may be seen containing every proportion of quartz grains till they themselves become quartzites.

There was no doubt great volcanic activity on the earth at the time these greywackes and their associated rocks were being formed. The thick unstratified and brecciated masses of greywackes may represent volcanic ashes or mud with stones thrown out upon the land or in shallow water, while the stratified varieties may have been similar ejectamenta thrown into deeper water and modified by the currents or waves of the sea. Some of these rocks, whether stratified or otherwise, may represent volcanic products which were originally poured into the sea in a molten condition and became broken up and disintegrated. The glass breccia already referred to as forming such a thick belt in the Sudbury district is direct proof of volcanic activity with explosive violence on a scale probably grander than any such action in modern times. Even without this and many other proofs which might be cited from the earliest records of the rocks themselves, it would only be in accordance with the general geological history of the globe to believe that volcanic or igneous action was going on upon the surface more generally and on a greater scale in the earlier than in the later geological times.

From a study of the greywackes and the rocks associated with them there would appear to be little doubt that the former constituted the crude material from which the quartzites and clay-slates were derived by the modifying action of water. Again by the action of time, pressure, heat, electricity, and perhaps other metamorphosing agents upon different varieties of greywacke, some of our granites, syenites, gneisses, felsites and possibly other rocks were formed. Many instances were noted in the Sudbury district where the more massive greywackes exhibited a proneness to revert to granite again, while some of the stratified varieties showed different stages of their passage into gneiss, and again certain of the finer-grained and more homogeneous kinds had been altered into felsites.

### Slate-Conglomerate.

Some of the argillaceous varieties of the greywacke containing pebbles of granite, and occasionally some of quartz, jasper, etc.,and having more or less slaty cleavage, were called slate-conglomerates by Mr. Alexander Murray, and he even extended this term so as to include massive brecciated forms of greywacke, which show no cleavage at all. This name was also given to certain Huronian schists containing rounded pebbles and boulders, and likewise to dioritic schists full of lens-shaped inclusions parallel to the cleavage or bedding, and which in cross-section look like elongated pebbles but which may be of a concretionary character in the majority of cases. They are often inconspicuous or difficult to distinguish on dry surfaces of the rock, but when wet are quite distinct, having a lighter color than the matrix. But they do not appear to differ much in composition from the rest of the rock. These rocks, which have sometimes been called dioritic schist-conglomerates, are very common in the lake Superior region, but they appear to be scarce in our present district.

### Imperfect Gneisses.

Imperfect gneisses are met with in most of the Huronian areas in both the lake Superior and lake Huron regions, but they always occur in limited quantities. They differ from the Laurentian gneisses in being usually finer grained and less perfectly crystalline. Under the microscope they sometimes show traces of clastic origin. In all of the numerous cases tried by the writer it was found that they invariably contained carbonate of lime, whereas the Laurentian gneisses are seldom calcareous. Where their crystallization has been coarse enough to observe their felspars easily these have sometimes proved to be of triclinic species, while the felspars of the Laurentian gneisses are chiefly orthoclase.

### GREENSTONES.

Within that portion of the great Huronian belt which traverses our district are numerous areas of greenstone, varying in dimensions from masses too small to define on the map up to others many miles in length. The word greenstone is used in this paper to include a variety of trappean rocks which cannot always be distinguished from one another in the field. These crystalline masses have often undergone metamorphism as well as the sedimentary rocks, and it sometimes happens that even a microscopic and chemical study of them in the laboratory fails to prove what their original condition has been. The term greenstone, which includes them all, is therefore a very convenient field-name In the Sudbury district they consist of diabases, diorites and gabbros. The last named constitute some of the dykes, while the others shade into each other, and as a class may be divided geologically into three groups.

The first of these consists of masses of highly crystalline dark green diorite (sometimes passing into diabase) of medium texture and holding disseminated specks and spots of pyrite, pyrrhotite and chalcopyrite. These masses occur principally among the greywackes, quartzites and clay-slates, and with few exceptions their greatest lengths are in the direction of the general strike of the surrounding rocks. They may have been originally laid down as molten sheets in nearly horizontal positions with the enclosing strata, and subsequently tilted to the present high angles of inclination. In a few cases the lower surface of a greenstone mass may be seen filling inequalities which seemed to have been worn in the underlying rock prior to the advent of the greenstone. As these masses appear to have become incorporated with the strata before the latter had assumed their present positions it becomes uncertain that they are all intrusive, although some of them probably are so, but their original positions with regard to the horizon have been changed owing to the subsequent folding which has taken place in the crust of the earth. Greenstone masses of this kind are found in the Huronian belt all the way from the shore of lake Huron northward to the border of our sheet, and thence for a great distance towards James bay. They are numerous and often large in the Sudbury district, where upwards of fifty occur, and also around lake Tamagami and in the valley of the Montreal river, but towards lake Huron they become smaller and do not form so prominent a feature in the geology of the region as they do further north.

Our second variety of these rocks has a grayer color and more coarsely crystalline texture, while the disseminated specks of metallic sulphides are not by any means so abundant as in the first. Its composition appears to be always that of a diabase. This rock forms three distinct belts among the granites and gneisses of the Sudbury district, and they appear to cut through them as intrusive masses. They all run northeast and southwest.

Windy lake on the main line of the Canadian Pacific Railway lies upon the central portion of the most northwesterly belt, which has there a breadth of about one mile, but narrows to a point in the northeastern part of Levack on the one hand and in Trill on the other, the total length being about eighteen miles. The second belt runs northeastward through Morgan towards Sagi-tchi-wai-aga-mog lake, while the third runs from the township of Creighton to the vicinity of Whitson lake.

The third variety differs from the first mainly in being schistose in some parts, and in frequently containing rounded and angular pebbles and masses of all sizes and of various kinds of rocks, but especially of quartzites, other varieties of greenstones, granites and greywackes, thus constituting agglomerates and breccias. These portions appear to run in ill-defined bands about parallel with the longest diameters of the masses. The greenstone belt which extends from Garson to Graham belongs to this class, as do also the areas of this rock in the fourth and fifth concessions of Denison. All these lie against the southeast side of a long granitic area, and it may be that they have suffered more from lateral pressure coming from the southeastward than the dioritic masses described under the first division, which may have been protected by the more yielding rocks with which they are surrounded. Examples of the greenstone agglomerates and breccias referred to may be seen near the Blezard, Stobie, Copper-cliff, Crean and Vermilion mines, and also where the main line of the Canadian Pacific Railway crosses lot 8 in the fourth range of McKim, and again where it crosses lot 5 in the fifth concession of Moncrieff.

### Diabase Dykes.

Dykes form an interesting feature among the rocks of our district, and they may also prove to have some bearing upon its economic geology. They consist of gabbro and olivine diabase, and are of rather frequent occurrence in some sections. As far as direction is concerned they may be said to belong to two sets, the course of one varying from west-northwest to northwest, and of the other from north to north-northeast. Most of them decompose more rapidly than the containing rocks, and their positions may be recognized by the depressions they form on the land and the channels in the lakes. On the shore of lake Huron some of those belonging to the northwesterly set may be seen in the vicinity of Shibaonaning or Killarney, and around Frazer bay. Many dykes of both sets are shown on the geological map of Sudbury district by the writer. Around Ministic lake in Ermatinger and Cascaden, where a number of them cut the gneiss, their general course is northwest. Almost in continuation of these, a large dyke at the junction of Agnes river with the Spanish in township 108 cuts the granite there in the same direction.

Dykes belonging to the northwesterly set may be seen here and there along the main line of the Canadian Pacific Railway between Sudbury Junction and Straight lake. Between Sudbury and the Murray mine and again between Windy lake and Cartier station they have facilitated the building of the line by the depressions which now mark their courses through the rocky hills whose general course lies across that of the railway. In the granitic region between the Onaping and upper Vermilion river dykes belonging to both sets are met with. A large dyke running north-northeast crosses the Vermilion river near the middle of the east line of township 66.

The basin of Onaping lake appears to be excavated along the course of parallel dykes cutting the granite and gneiss in a northerly direction. The lake is about twenty-six miles long, and except towards the south end is very narrow. In some parts the shores are formed by the dyke walls, to which patches of greenstone are still adhering. A large dyke running a little west of south is traceable along the east side of the southern part of the lake. A dyke which may be a continuation of this occurs also on lot 4 in the third concession of Moncrieff.

A short distance north of the head of Onaping lake we pass over the height-of-land and come to the head-waters of the Mattagami river, which flows northward in nearly the same longitude and falls into the western side of the lake of the same name. Mattagami lake has about the same length as Onaping, and is also narrow. Its outlet flows northward in the continuation of the valley, and at about seven miles falls into the head of Kinogamissé lake, another long narrow sheet of water, also running north and south and having a length of twenty-two miles.

On the course of the river connecting Mattagami with Kinogamissé lake a great north-and-south dyke makes its appearance, and below the latter lake large dykes, cutting the Huronian and Laurentian rocks and all having a northerly course, are met with at intervals along the Mattagami river until it enters upon the Silurian and Devonian basin extending to James bay. Several of these occurrences may be only different sections of one great dyke. Some of them are 300 to 400 feet wide. They are more compact near the walls than along the centre, which has been more easily eroded and in some parts forms the channel of the river.

The head waters of Moose river, from the Missinaibi to the Abittibi, covering a breadth of 120 miles in the lattitude of Abittibi lake, comprise upwards of a dozen nearly parallel north-flowing branches which afterwards converge to form the main river. The Montreal river is remarkable for drawing its waters from several nearly parallel streams, also flowing north, but they fall into a valley in which they are immediately turned round to the eastward through more than a right angle and pursue almost a straight line southeast to the Ottawa. The north and south valleys of these streams belong, as far as their origin is concerned, to the same set as the extraordinary parallel valleys of the basin of Moose river. Dykes and elongated masses of greenstone with a general north-and-south course were found along both the east and west branches of the Montreal river, and it may be assumed that they also exist along the other parallel tributary streams and lakes of this system.

As far as our present knowledge goes, this parallelism of the water-courses in both the hydrographic basins which have just been named is due to the guiding influence on eroding agents of the large greenstone dykes with which the whole region is seamed. There is no doubt that dykes like these have played an important part in determining the present topographical features of this part of the country. Previous to the glacial period the dykes probably decomposed to a greater depth than the enclosing rocks, and when the ice passed over the land the trenches which would soon be excavated along them under this powerful denuding agent would act as guiding lines for further erosion, and the depressions along them would become deepened and enlarged until they had formed the various lake basins and river valleys that lie upon their courses. In the upper parts of the Moose and the Montreal river basins the general direction of the glaciation was sufficiently near that of the great dykes which have been mentioned for it to adjust itself locally to them.*

These dykes, whether of diabase or gabbro, when undergoing decomposition at the surface weather into rounded boulder-like masses, the result of the disintegration and crumbling away of their angles and edges along the joints which had originally divided them into blocks. After they have been reduced to the rounded form they scale off in concentric layers, and this gives them a concretionary appearance. This is a common characteristic of such dykes everywhere, and often causes their outcrops to resemble rows or ridges of boulders. When fresh, both of the above-named dyke-rocks are very tough or difficult to break. The gabbros are as a rule of a lighter color, and resemble granites more than the diabases do; but they are generally deeply penetrated by the effects of the weather, which gives them a brownish discoloration, and it is only when deep-seated or completely unexposed portions are broken that the true color is seen. One of the principal differences between the two rocks is that in the gabbros the augite or pyroxene takes the form of diallage.

### Microscopic Characteristics.

Samples from both these varieties of the dykes of the region have lately been examined microscopically for the writer by Professor George H. Williams, lithologist of Johns Hopkins University, and in order to convey a correct idea of their structure, composition, etc., we cannot do better than quote a description of each by this distinguished authority.

On the Spanish river, opposite the foot of the 5th portage, or just below the junction of the Agnes river, in township 108, there is to be seen a dyke of medium-grained gray olivine diabase 240 feet in width, running north 40° west, from which a specimen was submitted to Prof. Williams. He says:

The microscope shows this specimen to be a fresh aggregate of olivine, reddish augite, plagioclase and ilmenite, with accessory apatite and biotite. Its diabase or ophitic structure is very typical. The olivine in this rock is remarkably fresh. It is in small pale yellow grains, which rarely show external crystal boundaries. It has a very high refractive index, no pleochroism and contains glass inclusions. The augite is of the reddish and slightly pleochroic variety common in diabase. It not uncommonly shows zones of growth, having different shades of color. In form the augite is allotrimorphic, filling the interstices between the laths of plagioclase. The felspar (probably labrodorite) is idiomorphic, and forms an interlacing net-work of lath-shaped crystals. It is

* The agency of dykes in forming a river valley is sufficiently clear in the case of the Mattagami river, one of the parallel branches of the Moose, and which has been already described.

the only constituent that shows any alteration, and this is comparatively slight. The opaque iron oxide is probably ilmenite. It is without distinctive form or alteration, and is sometimes surrounded by a narrow rim of biotite. Apatite is abundant.

At the Dominion Mineral Company's mine on lot 4, second range of Blezard, there is a dyke from 30 to 50 feet wide, running north 35° east, a specimen from which is described by Prof. Williams as a quartz hypersthene gabbro with accessory biotite. He says:

The microscope shows this to be an eruptive rock of quite exceptional character and interest. It belongs to the general type of gabbros, but has traces of a diabase-like structure in its long idiomorphic felspars; is related to the norites by the abundance of its hypersthene, and contains what is exceptional for all of these rock-types—an abundance of original quartz. The rock is quite fresh, but shows the effect of dynamic action in the bending of felspar crystals and the uralitization of the pyroxene. The felspar is in stout lath-shaped crystals of good size which produce a coarse ophitic or diabase structure, as in many of the well known Scandinavian gabbros. They present a brownish color in the thin section from an abundance of ultra-microscopic dust-like inclusions. They exhibit, in a beautiful manner the effect of strain, in the bending of the crystals and the production of secondary twinning lamellæ. The pyroxene is both monoclinic (diallage) and orthorhombic (hypersthene) in about equal amounts. Both are undergoing alteration into compact green hornblende. The mica is an intensely pleochroic biotite. It is abundantly present in large flakes of irregular size and has all the properties of an original constituent. Quartz is also quite abundant in large clear grains of irregular shape, and was apparently the last mineral to crystallize. Apatite, zircon and magnetite are also present in considerable amount. This rock, although a typical gabbro, is unusually acid and approaches in its quartz and zircon to the augite granites.

### Lines of Crushing.

In the region we are considering the effects of cleavage and bedding, fissures and joints, rock-crushing, intrusive dykes, etc., on the topography are so well marked that it is worth directing attention to some points in connection with the subject. The joints, fissures and dislocations of the rocks in any given district generally run in two sets, those of each one being nearly parallel to one another. One set is usually more strongly marked than the other and exercises an important influence in the decay and disintegration of the rocks, and this in its turn affects the contours and other topographical features of the district.

Greenstone dykes, even when thin, are often remarkable for persistence in length. They are also often parallel, or nearly so, and transverse to the strike or cleavage, and in these respects are allied to both joints and dislocations. This is only what might have been expected, for the igneous matter could not have come up from below to form them unless the rocks had first been rent. The forcing asunder of the walls of the original fissure or joint may have been due to the hydrostatic pressure of the molten matter itself, which must have been very great on such extended surfaces. In the various processes of decay, denudation and erosion of dykes, joints—fissures and dislocations have co-operated to produce parallelism in the natural features of many parts of our district, as well as in other regions underlaid by crystalline rocks.

Among Archæan rocks evidence of intense pressure is almost universal, which is not the case with regard to the newer and undisturbed strata. When thin slices of these rocks are made, so that their elementary structure may be examined under the microscope, it is found that in some parts they are crushed, while in others there is evidence that they have been slowly stretched, proving that they have been subjected to great and long continued strain. In this process the patches and grains of rock had time to constantly adjust themselves, and they have been kept firmly cemented together by the contiguous mineral matter, so that the strength and outward firmness of the rock have not been affected by this internal rearrangement of its component particles, and therefore when lithologists speak of a rock as "crushed" they do not mean that its present strength is weakened. But this latter state has been produced along certain lines of more recent movements affecting only the present outward condition. This phenomenon will be more fully described further on.

Although the textural crushing just described may be detected so generally among the ancient crystalline rocks, it is particularly manifest at points unusually exposed to the action of the forces which produced it. One of these occurs on the west side of lake Wahnapitae, where a promontory of the granitic rocks projects into the Huronian belt at its narrowest point.

The spaces which have been left by the inequalities along lines of fracture after dislocation in certain Archæan rocks have sometimes been filled by the debris ground off the walls, and which now forms dykes of breccia. An example of these may be seen at the first rapid in the Maganetawan river, eastward of the head of Byng inlet. The breccia dyke runs eastward with the course of the stream. Its matrix is amorphous and very brittle. Some of the fragments consist of a dark reddish-brown opaque cherty rock, and others of a dark variety of syenite. The mass holds a little calcspar and specks of iron pyrites.

But these long lines of fracture are not often marked by any consolidated filling. The conditions near the surface may not have been favorable to the formation of such a filling, and many of these fractures are perhaps too recent to have allowed of sufficient time for this process to have taken place. Close to these lines the rock all along is broken into small pieces, which however have been only slightly moved from their original sites; but as we recede from the lines of crushing the angular pieces become larger and larger till the whole rock has resumed its normal solidity.

This broken condition has permitted the percolation of the surface waters to great depths, which has been followed by the decay of the fractured rocks more or less rapidly in proportion to the fineness of the pieces into which they have been crushed. The joints for some distance on either side of these lines are stained with the oxide of iron, resulting from the general decomposition.

The disintegration of the rock on such lines, as well as that of the greenstone dykes, has caused valleys to be formed along them as the result of glacial and other eroding agencies. In the district under consideration the writer in referring to this subject in 1876 said:

"Between the mouth of the Maganetawan river and the first fall, especially along the north side, the gneiss, which runs in various directions, is of a dry, crumbling character along a set of joints which run parallel to the stream and are lined with oxide of iron. The course of Byng inlet and of the Maganetawan river (in continuation of it) is remarkable for being comparatively straight and crossing the general course of the gneiss and mica and hornblende schists, as well as that of the lakes and the numerous smaller streams of the district. This would appear to indicate that the formation of this channel has had something to do with the existence of the brecciated dykes or the joints above described."*

Lines of crushing in the Laurentian rocks were seen by the writer in some of the precipices in Hudson strait, where they were observed traversing walls of gneiss, and were well marked by the crumbled gneiss, still quite fresh.

Transverse depressions or gaps in crystalline rocks have also been formed in the following manner: The parallel joints which so frequently traverse granite, gneiss, quartzite, etc., are apt at intervals to occur in groups closer together than usual, or two or three may run side by side, which are stronger and more persistent than the single ones and comparatively distant from the nearest of them. The narrow walls of rock between such joints have suffered decay or injury from the surface influences in pre-glacial times, and, yielding to erosion more easily than the rest, have formed the starting lines of depressions and valleys. This phenomenon was referred to in connection with the erosion of water-channels in the French river region, and it may also be observed in various rocks in other parts of our district.

Two sets of nearly vertical joints often traverse crystalline rocks at angles approaching 80° or 90° to each other. When such rocks are cut by a third set almost horizontally they are then divided into rhombohedral blocks, and are much more easily removed by abrading and disintegrating forces. It not unfrequently happens, as in the case of some granites, that there may be four sets of joints, thickly penetrating the rock and dividing it into comparatively small triangular pieces. This imparts a shattered

*Report of the Geological Survey for 1876-7, p. 202.

character to the whole mass, and renders it useless for building or monumental purposes. Some masses of granite have been saved from the forces which produced these numerous joints or cracks, apparently by the protection afforded by yielding belts of schist. At all events the more solid and serviceable granites are often thus sheltered.

### Crystalline Schists.

The Huronian system comprises a great variety of crystalline schists in both the lake Huron and lake Superior regions. In the latter the older portions of the series are to a great extent formed of mica, hornblende, diorite and chlorite schists, while these and other varieties of schists are interstratified with different rocks higher up in the scale. In the Sudbury district the northwestern border of the Huronian belt in the townships of Waters, McKim and Blezard is largely made up of crystalline schists, of which dioritic, hornblendic, silicious and felsitic are the most abundant. Further to the northeast similar schists are abundant on lake Temagami. Silicious and felsitic schists are largely developed between lake Wahnapitae and the line of the Canadian Pacific Railway. Coarsely crystalline hornblende rock, such as is found among the Huronian strata of lake Superior, has been met with just east of the Stobie mine in Blezard, in the fifth concession of McKim, and near the McConnell mine in the fourth concession of Snider; also at the southwest bend of Spanish river and at Lamorandiere bay in the northwest corner of Rutherford. Green schists, schistose greywacke and gneissoid schist, the latter enclosing boulders, occur among the rocks of the Straight lake Huronian outlier.

In illustration of the mode of occurrence of crystalline schists among the Huronian rocks of the lake Huron region, the following examples on the Spanish river are selected from the descriptions in the report of the writer for 1888-90.

Half a mile up the west branch of this river a rock was met with which consisted of a mixture of green schist and fragments of granite. At the bend of this branch, four miles from the main stream, there was found what Professor Williams describes as a "pinkish to brownish crypto-crystalline banded rock, which might be macroscopically described as a banded jasper or felsite. The microscope shows that it is a clastic rock, consisting mostly of quartz which has been wholly re-crystallized under the influence of intense pressure, and that it has thus had the parallel structure developed in it by an elongation of its grains in one direction that is commonly known as stretched."

On lot 1, sixth concession of Baldwin, just below a large island in Spanish river, the rocks in the bed of the stream consist of fine-grained pink quartzite in thin layers, interstratified with rough-surfaced black slate, dipping southward at a high angle, while at a greater elevation there is exposed a heavy band of dark green mica-schist formimg the top of a long ridge.

At the narrows of the river, on the east side of lot 12, first concession of Hyman, there is a coarse gray glistening schist and a small quantity of a dark greenstone. Below the narrows, on the next lot (11 in the same concession) a glossy dark bluish grey schist and a slaty greywacke strike northeast along the flank of a mass of diabase which has a length of more than a mile in a northeasterly direction. A fine-grained hornblende rock also occurs at this locality. In the same vicinity, where the line between lots 10 and 11 intersects the north bank of the river, quartzite occurs dipping south at an angle of 55°.

In the northwest corner of lot 8, first concession of Hyman, there is a chute in the Spanish river with a fall of 15 feet. At this locality there is an extensive exposure of rather fine-grained silver-gray mica-schist with crystals of staurolite, thickly scattered over the cleavage surfaces.

In the middle of lot 5, second concession of Hyman, the river passes through a cañon or narrows, with gray schist on the northern side, and the northern flank of a ridge of fine-grained splintery greenstone running north 70° east on the southern. At a rapid in the north half of lot 3 in the same concession, a bluish gray satiny schist strikes due north and south, the dip being east at an angle of 45°. This sudden change in the strike is accompanied by an equally sudden turn in the course of the river.

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The rocks at Kettle falls, on lot 2, second concession of Hyman, are gray and satiny schists with a three feet band of nearly black hornblende schist, all striking north 76° east, with a southerly dip of 75°. On the line between lots 2 and 1, first concession of the same township, and opposite the west end of an island in the river, the rock is a glossy gray, finely-arenaceous schist nearly on edge and striking north 85° west. A gray glistening schist, standing vertically and striking north 75° east, occurs at the falls on the south side of the island.

A soft bluish-gray schist striking eastward with the course of the river is found on lot 11, first concession; and on the northeast corner of lot 9 there is a glossy green schist, but without strong cleavage.

A gray hydro-mica schist running southwest occurs where the Canadian Pacific Railway crosses the Spanish river, in the centre of lot 11, second concession of Nairn.

## Serpentine, Steatite and Dolomite.

These three kinds of rocks may be mentioned among those which occur in minor volume in the Huronian system. Serpentine has not yet been found at all within our present region, but some exposures of it were met with at Pigeon lake on the west branch of Montreal river, a short distance to the northward. The serpentine occurs by itself, or associated with calcspar, or passing into limestone, on some small islands in this lake.

On the shores in the vicinity are fine-grained and massive reddish-gray quartzite, greenish-gray clay-slate, fine-grained reddish-gray syenite, light greenish-gray finely crystalline diorite, with disseminated grains of iron pyrites and gray porphyry very thickly speckled with opaque-white crystals of felspar and a few of shining black hornblende. The serpentine on fresh fracture shows different shades of green, and is somewhat mottled. Under the weather the natural surface becomes rough and of a rusty color. It contains oxide of chromium, both in the form of small grains and in chemical combination with the rest of the rock, and thus resembles the serpentines of the Eastern Townships in the province of Quebec. The writer has been shown specimens of serpentine said to have been collected among the Huronian rocks some miles north of Pigeon lake. On the point about the middle of the west shore of Abittibi lake the late Mr. Walter McOuat of the Geological Survey met with dark green serpentine, weathering dull white, strongly magnetic and containing grains of chromic iron. Mr. E. B. Borron informed the writer that he had heard of serpentine having been found in the country lying north of the west end of Abittibi lake.

On the Mattagami river, thirty chains below the junction of the Muskoota branch, there is an exposure of massive gray semi-crystalline steatitic rock, holding grains of specular iron and cut by small veins of whitish bitter-spar. Although this locality, as well as those for serpentine which have been mentioned, are outside of the limits of our sheet, both of the rocks referred to above may be looked for wherever similar rock associations exist within this area. The greenstone of the Evans mine, near Sudbury, has changed in some parts into a variety of steatite or soapstone.

Dolomites or magnesian limestones, having certain characters in common, occur sparingly in the Huronian system in the most widely separated areas of these rocks. They are usually fine grained to compact, silicious and marked by strings and fine threads of quartz and sometimes of calcspar, which have commonly a reticulating arrangement. Most of them are ferruginous, and the weathered surface is generally yellow, brown or red, but sometimes gray or black. The iron is often present in large enough proportion to form a spongy crust of the oxide. Occasionally these dolomites become rather finely crystalline, like saccharoidal marble, and nearly white. In our present region they have never been traced far on the strike, although they attain from 100 to 300 feet in thickness.

Midway up the northeast side of Pigeon lake, already mentioned, on the west branch of Montreal river, there is a bluff thirty feet high of semi-crystalline, yellowish-gray limestone, mottled with green and reddish-brown patches and full of reticulating strings of white calcspar. The weathered surface has a ferruginous crust, from one-half to one inch thick, showing the rock to contain a large proportion of iron. A thickness of upwards of one hundred feet of the limestone is exposed at this place, and it continues northward along the shore for a quarter of a mile or more. The other rocks in the vicinity of this dolomite consist of syenite, diorite, serpentine, porphyry and different varieties of quartzite.

On the eastern side of South bay, lake Wahnapitae, and thence round the promontory towards Outlet bay, Mr. Alexander Murray described a calcareous breccia associated with quartzites and greenstones.*

In Geneva lake, about a mile and a-half northeast of the outlet, there is an islet entirely composed of thinly bedded light gray, dove-colored and nearly white dolomite, striking north 35° east, and dipping to the westward side at an angle of 80°. It is compact and has a conchoidal fracture, but is traversed by fine threads of quartz, which prevent it from taking a good polish, otherwise it might be suitable for marble. The same rock is exposed on the east side of the lake on the point just southward of the above islet, but the band could not be found on the northern side of the lake, towards which it strikes in the opposite direction. On the railway track three-quarters of a mile south of the outlet of Geneva lake there is a fifteen-feet bed of gray to dove-colored fine-grained dolomite, weathering dark brown. It strikes north 45° east, and the bedding is about vertical. This dolomite band is separated from hornblende granite to the southeast by about three hundred feet of ash-gray greywacke. The granite towards its contact with the latter becomes mixed with coarse breccia and conglomerate. On the other side, or to the northwestward, the dolomite is followed by coarse felspathic sandstone and silicious greywacke-conglomerate or breccia. At the outlet of Geneva lake the rock is a greywacke passing into granite, and it includes some black slate and a patch thirty feet thick of impure dolomite.

A band of magnesian limestone occurs at Island Portage on Wahnapitae river, about four miles below the outlet of the lake of the same name. It has a width of at least 300 feet across its general strike, but owing to the undulation of the strata the true thickness of the band could not be determined. On fresh fracture it is mostly light greenish-gray in color, fine grained, soft, somewhat impure, and weathers to a brown color. The weathered surface in some parts is marked by small corrugated ridges, like that of the Huronian limestone of Echo lake, which result from the weathering out of minute silicious streaks following the bedding. An exposure of the limestone at the head of Island Portage shows a more massive variety with a brownish gray color on fresh fracture.†

Referring to the magnesian limestones of lake Panache Mr. Alexander Murray says:

On the north shore of lake Panache, about midway between the inlet from lake Lavase and its western extremity, a band of limestone occurs which when first observed appears to be both underlaid and overlaid by syenitic slate-conglomerate. The mass of this limestone, which measures about sixty yards across and may be about 150 feet thick, is of a pale gray color on fracture, weathering to a bluish gray, with thin layers which have the appearance of chert, but are in reality only harder portions of the limestone, weathering quite black. About the base of the calcareous strata some of the beds are blue, holding more silicious matter than the gray beds, while others are of a brecciated character. The beds are all more or less intersected by small veins of fine greenish jaspery-looking trap which weathers brown or yellowish.

To the eastward of this exposure the only indications observed of the presence of limestone were on the east side of the large island at the entrance of the south bay, and in the peninsula on the north side at the entrance of the eastern arm; in both of these localities small exposures of a black-weathering brecciated rock, which proved to be calcareous, came up in one or two parts just over the surface of the water. On the island the calcareous rock is overlaid by a black-weathering slate which, though without pebbles, resembles the matrix of portions of the slate-conglomerate. On the peninsula at the eastern arm the brecciated rock comes directly in contact with greenstone.

At the head of the lower south expansion of lake Panache the limestones are again seen on both sides, and also on the two islands near the middle, striking about east by

* Report of the Geological Survey for 1856, p. 177.
†Report of the Geological Survey for 1875, p. 296.

north and west by south, and showing a southerly dip on the north side of the exposures; but the slate conglomerate with which it seemed to be associated at other parts onl; appears on the south side of the large island lying at the entrance to the northern army and between this island and the exposure of limestone on the west side of the bay there is a point to the northeast of the limestone displaying fine-grained green slate which, though very much disturbed and intersected by quartz veins, appears to show a general dip to the northwest.*

Mr. Murray thinks that some of the above strata might yield good stone for burning into lime. A specimen from the section on the north side of lake Panache was analysed by Dr. T. Sterry Hunt, and gave in 100 parts 55.10 carbonate of lime, 6.50 carbonate of magnesia, 38.40 insoluble sand and a trace of iron. A specimen of the limestone at the lower end of lake Panache, analysed by the same chemist, gave 41.97 per cent. carbonate of lime, 2.40 carbonate of magnesia and 55.63 insoluble residue; and a specimen from the lower lake near the outlet, lying between the two ridges of the mountain range, gave 36.50 per cent. carbonate of lime with a little magnesia.†

Along the northern arm of the larger La Cloche lake calcareous rocks or impure limestones occur at several places passing below a considerable thickness of slate conglomerate, and they are again met with on the smaller lake to the northwest. High ridges of quartzite, standing nearly on edge and forming part of the La Cloche mountains, rise on either side of the southern arm of the larger lake, while greenstone and quartzite are found on the northern side of the smaller one. It would therefore appear that in this part of the great Huronian belt the magnesian limestones occur among the quartzites, and are sometimes more immediately associated with slate-conglomerate.

A band of finely crystalline limestone occurs among the Huronian rocks in the northern part of the township of Rutherford. The locality is near the boundary line between red granite to the southward and a great thickness of quartzites to the northward. The junction of the granite to the southeast with the Huronian quartzite and hornblende schists to the northwest occurs at the south side of a rather elevated rocky island in a cove about one mile north of the western entrance to "the passage" or channel, on the north side of which Killarney village is built. The geology of this locality and the relations of the limestone referred to can best be given by quoting the description in the Geological Survey report by the writer for 1876, page 209:

On the west side of the township of Rutherford, from the northern limit of the granite (at the elevated rocky island above mentioned) quartzites and hornblende schists hold the shore as far as Lamorandiere bay, in the northwest corner of the township. A blackish green massive and rather coarsely crystalline hornblende-rock, having an exceedingly rough or irregularly pitted surface, is exposed on either side of the narrow entrance to this bay. Upon the slope of the hill, about 100 yards in from the north shore of the bay, at a point about half-a-mile from the above-named narrows, a band of finely-crystalline limestone occurs among the Huronian rocks. It has a vertical attitude and runs about north 70° west at the part examined. Its total thickness is about 75 feet, of which the 25 feet along the northern side consist of a single solid band of nearly white finely-crystalline limestone, clouded with light greenish and grayish patches. The remaining 50 feet are mixed with shaly patches of hornblende, together with a little shining granular magnetic iron ore. Adjoining the limestone on the north side is a band, only a few feet in thickness, of dark smoke-colored chert-rock, ribboned with streaks of a dull red color. It breaks easily with a fine conchoidal fracture, and appears to be identical with a rock which was used by the mound-builders for making some of their arrow-heads. This is followed to the northward by a dark-colored dioritic conglomerate, in which the pebbles are mostly small and generally widely scattered, and farther on by a very dark gray, soft massive-looking micaceous schist, most of which is full of small pebbles. Measured from the limestone band, a thickness of between 100 and 200 feet of these rocks is exposed.

On the north shore of Lamorandiere bay, a few hundred yards eastward from the outcrop of limestone above described, are two exposures of very tough massive hornblende rock, and between the two arms of the bay is a more fissile variety, interstratified with a reddish gray quartzite, which also overlies the mixed rocks. The dip is here northwestward at an angle of 60° to 70°, and the series is underlain by granitoid gneiss.

*Report Geological Survey for 1856, pp. 181-183. †*Ib.* p. 190.

### Intrusive Granites.

The red granite of George island and the township of Rutherford may be of intrusive origin, notwithstanding that it shows an approach to lamination towards the edges of the mass. "Its position is along the junction of the Laurentian with the Huronian series, and it appears to belong to the latter rather than the former. It has a medium texture, and is composed of reddish felspar and bluish-white quartz with a little hornblende, which however is often wanting. Excepting at the sides it has a massive homogeneous structure, but in a few instances a single reddish or yellowish-green shaly streak, an inch or two in thickness, was observed running in a northeasterly direction with a dip to the southeastward of about 50°. Towards each side the grain of the rock begins to assume a sort of parallelism or a gnessoid structure."*

Reference has already been made to an area of red granite measuring about four miles in length by two in breadth between the western and middle outlets of French river, and also to a brick-red granite or syenite along the upper part of the lower north channel of that river just below Grand Recollet falls.

Red granitic rocks border the newer ones which lie to the south of them all the way from the township of Cascaden to lake Wahnapitae. Although the macroscopic appearance of these rocks is that of a red granite, yet in some parts, as on the east side of Windy lake, the textural arrangement of the component minerals is more like that of a quartz-diorite, and they are certainly of eruptive origin. Professor George H. Williams examined under the microscope a thin slice of a fine grained variety of these rocks from Kin-ni-wabik lake in the township of Levack. He pronounced it micropegmatite, and stated that it was an undoubted eruptive. Towards lake Wahnapitae similar rocks continue to be fine grained, but in that direction they become dark grayish-red in color. Around Washai-gamog or Fairbank lake the rocks have a similar color and texture to the last, and their appearance is the same except that they are distinctly stratified and occur in very even beds. The granitoid rocks above described merge into gneiss at varying but not great distances to the northward.

About a mile east of the angle formed by the intersection of Proudfoot's east-and-west with his north-and-south line red hornblende granite was found. Its extent has not been ascertained, but it may continue a considerable distance northward.

A Laurentian inlier has been mentioned as occurring around Paul's lake on the upper part of Sturgeon river. Where first entered upon in ascending the river at four miles below the lake the rock of this inlier consists of a rather coarse dull red quartz-syenite, or hornblende granite, but this passes into gneiss before the lake is reached. An area of coarse red granite crosses lake Temiscaming about the middle.

### General Nature of the Huronian Rocks.

While the greater portion of the Huronian rocks show the agency of water in their formation, there is also abundant evidence of widespread contemporaneous volcanic action. These detrital or clastic sediments were largely derived from igneous matter which had been more or less recently erupted, and hence they may be called pyroclastic, as indicating both phases of their nature. Besides rocks of this character, we have seen that the Huronian system contains large igneous or crystalline masses. The whole series having been considerably metamorphosed, the true origin of some portions may not be at first apparent. But our study of them on a large scale in the field as well as the microscopic examination of hand specimens go to show that the above is the general nature of the Huronian rocks in all the areas which have been explored. The pebbles and boulders of the conglomerates of the Huronian system consist of binary-granite, schists, quartzite, white quartz and red jaspar, greenstone, gneiss and other rocks derived from older parts of the same series or from the underlying Laurentian.

The presence of these conglomerates and the ripple-marks which are sometimes plainly seen on the surfaces of beds of quartzite prove the existence in those days of either dry land or of seas which were very shallow in some places. The limestones or dolomites are

*Dr. Bell in Report of Geological Survey for 1876, p.

only of local extent. They are sometimes nearly pure, or, as we have seen, they may be largely mixed with insoluble matter, or they may be brecciated with silicious fragments. The lime and magnesia may have been derived from the decomposition of the pyroxene and hornblende of the greenstones. Some of the masses may be of a segregated or a concretionary character, while others were precipitated from water.

### NEWEST ROCKS OF THE SUDBURY DISTRICT.

The newest rocks of the Sudbury district form a distinct basin extending from near the west side of lake Wahnapitae southwest to about the centre of the township of Trill, a distance of thirty-six miles, with a breadth of eight miles in the centre. This basin constitutes a prominent feature in the geology of the district, and it may prove to be of lower Cambrian age. Along its northern side it is bounded by the granitoid rocks already described, and on its southern by a belt of Huronian schists and greywacke. The rocks of the basin consist of two principal divisions,—(1) the lowest being a band, probably three or four thousand feet thick, of dark colored or almost black silicious volcanic breccia or vitrophyre tuff, most strongly developed along the northern side and passing into black slate and black slate-conglomerate along the southern; and (2) drab and dark gray argillaceous and nearly black gritty sandstones with shaly bands which vary in color from greenish drab to black. At the base of the volcanic breccia a conglomerate consisting of a grey silicious matrix with rounded white quartz pebbles is seen in some places, but this may belong to the underlying series.

The area of this geological basin corresponds in a striking manner with certain well marked physical and geographical features. The volcanic breccia forms a range of hills more conspicuous and rugged than any others in the district, while the sandstones and shales constitute a low and nearly level tract from which lakes, elsewhere so common, are absent. The Vermilion river flows southwestward with the strike all along the northern side of this division, and Whitson creek flows in the same direction along the southern side.

The silicified glass-breccia or vitrophyre tuff maintains the same character and apparently about the same thickness all the way from the vicinity of lake Wahnapitae to the township of Trill. It occurs in massive form and falls from cliffs or ridges in large blocks. It breaks with a conchoidal fracture, and when fresh is seen to be made up of angular fragments, mostly small and closely crowded together and flecked with irregular white spots. The fragments are not so dark as the matrix, and present various shades. When examined with a lens many of the fragments show a distinct vesicular structure. Prof. George H. Williams has examined this breccia carefully both in hand specimens and under the microscope, and says that it is "composed of sharply angular fragments of volcanic glass and pumice, which, in spite of almost complete silicification, still preserve every detail of their original form and microlithic flow-structure with a distinctness not to be exceeded by the most recent productions of this kind . . The fragments even down to those of the smallest dimensions have the angular form characteristic of glass shreds produced by explosive eruptions. The flow-structure is as perfectly marked by sinuous lines of globulites and microlites, which terminate abruptly against the broken edges of the glass particles as in the most recent vitrophyre. Minute spots of opaque pyrrhotite are scattered through the section. The groundmass is of a dark color, owing to the massing in it of minute black globulites, to whose nature the highest magnifying power gives no clue . . . After a careful study of this rock I find it possible only to interpret it as a remarkable instance of a very ancient volcanic glass-breccia, preserved through the lucky accident of silicification. Nor did this process go on as is usual through devitrification and loss of structure, but rather like the gradual replacement of many silicified woods, whose every minute detail of structure is preserved. The rarity of such rocks in the earth's oldest formations is readily intelligible; but, for this very reason, the exceptional preservation of a rock like this is all the more welcome proof that explosive volcanic activity took place at the surface then as now, and on a scale if possible even greater than that with which we are familiar."*

*Bulletins of the Geological Society of America, 1890, pp. 138-40.

A fresh section of this rock is exposed in a cutting on the Canadian Pacific Railway at the high falls of Onaping river, twenty miles northwest of Sudbury Junction. An analysis of an average specimen from this place was made by Mr. Hoffmann of the Geological Survey, and it was found to contain 60.23 per cent. of silica. A smoothed surface of this dark rock has a handsome appearance, but it is incapable of a high polish.

The dark argillaceous sandstones and drab and dark shales of the higher division of the rocks of this newer basin may be seen at all the southward bends of the Vermilion river from Onwatin lake nearly to Vermilion lake. The strike corresponds with the general course of the river, and the dip is southeastward at rather high angles. The sandstones are characterized by disseminated grains of transparent quartz, and they often hold rounded or ovate spots from an inch or two up to three feet in diameter, of a lighter color than the rest of the rock. On exposed surfaces these spots weather into depressions. Several parallel ridges of this sandstone with a northeasterly course cross the Canadian Pacific Railway line diagonally between Larchwood and Chelmsford. It appears to be well suited for building purposes. This sandstone, both as regards the spots just described and its dark color and massive character, bears a strong resemblence to the silicious rocks which, in the form of boulders and smaller pieces, are scattered so abundantly around the shores of James bay and over the country for a great distance to the southwest of it. A similar rock is found in place on Long island on the east coast, and at Churchill on the west coast of Hudson bay, and there are reasons for believing that it is very extensively developed on the floor of that sea.

## LOWER SILURIAN OR ORDIVICIAN SYSTEM.

The islands of the La Cloche group and the peninsula of the same name in the southwestern corner of our sheet consist of flat-lying fossiliferous rocks of the Lower Silurian or Ordivician system, with some ridges and knobs of Huronian quartzite protruding through them. The middle portion, which constitutes the bulk of this group, is made up principally of rather thinly-bedded, lumpy and uneven surfaced gray limestones, with many thin, shaly beds and partings interstratifying them. But underlying these measures are from 50 to 100 feet, or perhaps more, of reddish and chocolate colored calcareous marls with greenish layers and mottlings, together with some beds of fine grained white and reddish sandstones, while overlying them and interstratifying the upper portion are beds of hard, compact, dark gray magnesian limestone, which weathers to various yellowish and reddish shades.

The lower or marly and arenaceous portion of the series has yielded no fossils by which its age can be identified, but it is believed to represent some formation older than the Trenton group, and it was thought by Logan that it might be the equivalent of the Sault Ste. Marie sandstones, which he considered to be Chazy, but which are referred to the Potsdam formation by the United States geologists.

The upper beds of the Trenton group are seen at the north end of Strawberry island, and in the north-facing bank at Little Current at the northern extremity of Manitoulin island. At these localities they are overlaid by the black bituminous shales of the Utica formation. The breadth across the strike from the north side of La Cloche island to the commencement of the Utica shales on Strawberry island is eight miles. The average dip to the south is assumed to be 40 feet in the mile, so that the total thickness of the Trenton group would be about 320 feet. The fossils which have been collected among these rocks from the summit of the marly and arenaceous portion up to the highest beds on La Cloche island, and also from the islands just west of the latter, belong to the Birdseye and Black River divisions of this group, so that the Trenton formation proper in this region is confined to a strip bordering the shore for six miles in the neighborhood of Little Current and thence round into West bay, the northern part of Strawberry island and the peninsula between Manitowaning and Smith bays. On Heywood or Rat island, along with a little Utica shale there is some limestone which appears to belong to the Trenton formation. Patches and margins of fossiliferous gray limestones resting on the quartzite and dipping into the lake are found here and there along the high point which runs from Killarney bay towards Heywood island and on the islands just south of it. These rocks appear to be identical with those forming the central part of La Cloche island, and they would therefore belong to the Birdseye or Black River formation.

As already stated, the black shales of the Utica formation rest upon the top of the Trenton limestones in the village of Little Current and cover the greater part of Strawberry island. They are found near the quartzite ridge at Sheguiandah village, also at the base of the Hudson River formation between Manitowaning and Smith bays, and in a similar position at cape Smith.

## ECONOMIC MINERALS.

Only a small part of the district represented on the accompanying map has yet been explored for useful minerals, but the discoveries already made are sufficiently numerous and important to lead to the belief that a promising future is in store for this part of Canada as a mining region. The metallic ores appear to be confined to the Huronian rocks, which are here so extensively developed. The Sudbury district has become well known for its extensive nickeliferous deposits, and prospecting has been as yet confined chiefly to that region. Ores of several other metals have also been found in the district, and the indications are in favor of meeting with some of them in paying quantities. What has been accomplished in the Sudbury district may be repeated in various parts of the great unexplored Huronian belt to the northeastward.

But the useful minerals of our present region do not consist entirely of metallic ores. The non-metallic mineral products, such as building and ornamental stones, rock for lime and glass-making, etc., are also important. Some of these occur among the Laurentian and others among the Huronian rocks. As the district is only beginning to be inhabited, and the need of such materials has scarcely been felt, little or no effort to find them has yet been made; but as soon as there is any demand they will no doubt be found in many new localities. The possibility of discovering workable deposits of phosphate of lime among the Laurentian rocks of the district, and of asbestos along with the Huronian serpentines, as well as of other substances usually found among these rocks, should be borne in mind.

### IRON.

Among the quartzites of the La Cloche region small isolated deposits of magnetite and one or two of hematite have been found, but none of those yet discovered appear to be sufficiently extensive to justify mining operations. From analyses reported to have been made of the ores from two or three of these deposits they would appear to be sufficiently free from titanium, phosphorus and sulphur to constitute first-class ores. It is to be hoped that further explorations among these rocks may bring to light larger masses of iron ore.

Thin veins of good magnetite, accompanied by quartz, occur in the red hornblende-granite two miles north-northwest of Cartier station, and again in the same rock on the Spanish river a short distance below The Elbow. But the granitic districts do not appear to be promising for the ores of iron.

The existence of iron ore on Iron island in lake Nipissing is only known to most of those interested in the minerals of the district by vague report. It may therefore be worth while to quote the description of it given by the late Alexander Murray of the Geological Survey.

> Small masses of specular iron ore are common to most of the rock in the island, and in the crystalline limestone there is a very great display of it. For a breadth of about forty yards along the cliff on the east side the rock holds masses of the ore of various sizes, sometimes running in strings of an inch thick or upwards and at other times accumulating in huge lumps, some of which probably weigh over half a ton. The beach near the outcrop is strewn with masses of all sizes, from great boulders weighing several hundred pounds to small rounded pebbles not bigger than marbles. The limestone with which the

ore is associated is frequently cavernous, and the crevices and small fissures are thickly lined with crystals of blue fluor-spar and red sulphate of baryta or cockscomb-spar.

Crystalline limestone crops out on the opposite or west side of the island and, judging by the strike on the north side, it must correspond with that holding the iron ore on the east. The same minerals were found disseminated through the rock and strewn upon the beach. At the extreme southwest point of the island the rock is again crystalline limestone, and a long beach running out from it to the westward is perfectly covered with boulders of specular iron ore. Iron ore occurs also at the southeast point of the island, although not in such great abundance and only in detached masses strewn upon the beach.*

In the Huronian iron-bearing region of lake Superior the ores have two different sets of associations or modes of occurrence. In the one case they are associated with hornblendic or chloritic schists which appear to belong near the base of the system, and in the other they occur with fine grained silicious and jaspery rocks. The magnetite of the Atik-okan region is an example of the first, and that of Hunter's island and Kaministiquia river of the second.

## NICKEL.

The comparatively recent discovery of workable deposits of mixed copper pyrites and nickeliferous pyrrhotite over a large area in the Sudbury district is one of the most important events in the history of mining in Canada. Although masses of pyrrhotite are known to exist in other parts of the Dominion, there is no other region where they are so numerous and in such proximity to one another, and with the exception of one near St. Stephen in New Brunswick they do not appear to be nickeliferous to an economic degree, whereas in Sudbury district all the deposits so far tested are comparatively rich in nickel. The pyrrhotite of this region is found in the midst of rocks of different characters and belonging to different horizons, but it is always more immediately accompanied by greenstone. Indeed this rock may be regarded as the parent of the ore. These facts would seem to indicate that in the Sudbury region the greenstone had a common and deep seated origin. The area over which the ore has been discovered is of an eliptical form, and measures about 70 miles from southwest to northeast and 50 miles from southeast to northwest.

The first discovery of nickel in this region was made about 1846, at the Wallace mine in Bay of Islands on the north shore of lake Huron, about a mile west of the mouth of Whitefish river. This mine was opened in 1847 and was visited in 1848 by the late Alexander Murray of the Geological Survey, but at that time mining operations had been temporarily suspended. The ore consists of chalcopyrite with magnetic and arsenical pyrites rich in nickel, occurring in chloritic and quartzose schists close to a mass of greenstone. The extent of the deposit cannot at present be seen on account of the debris on the surface and the shaft being full of water. Mr. Murray in his report says:

The temporary condition of the mine at the period of our visit rendered it impossible to obtain such specimens as might be considered an average sample of the material excavated from the shaft; but with a view of ascertaining the quality of the nickeliferous portion of the ore a specimen of it, as free as possible from the copper pyrites, was submitted to analysis by Mr. Hunt, who found it to contain 8.26 per cent. of nickel with a trace of cobalt; but as nearly two-fifths of the specimen consisted of earthy materials which might readily be separated by dressing, the quantity of nickel in the pure ore which this would represent would equal nearly 14 per cent.†

The existence of nickel and copper in the greenstones of what is now the Sudbury district was first made known by Dr. T. S. Hunt and Mr. Alexander Murray of the Geological Survey in 1856. In that year Mr. Murray explored Salter's base line, running northward from Whitefish lake, and in what is now the township of Waters he found a mass of magnetic trap which proved to contain disseminated nickel and copper. He says:

Specimens of this trap have been given to Mr. Hunt for analysis and the result of his investigation shows that it contains magnetic iron ore and magnetic iron pyrites generally disseminated through the rock, the former in very small grains; titaniferous iron was found associated with the magnetic ore and a small quantity of nickel and copper with the pyrites.‡

*Report of Progress for 1854, page 123.
†Geological Survey Report for 1848, p. 44.
‡Report of the Geological Survey for 1856, p. 180.

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Again referring to this subject Mr. Murray says:

The magnetic trap discovered on Mr. Salter's meridian line north of Whitefish lake was observed to hold yellow sulphuret of copper occasionally; and Mr. Hunt's analysis of a hand-specimen of the rock, weighing ten ounces, gave twenty grains of metalliferous material, of which eleven were magnetic and consisted of magnetic iron ore, with a little titaniferous iron ore, and magnetic iron pyrites containing traces of nickel. The nine grains of non-magnetic mineral consisted of iron pyrites, containing from two to three per cent. of copper and about one per cent. of nickel. Many large quartz veins occur on the lower lakes of the Whitefish river, but iron pyrites was the only metalliferous substance which they were observed to contain.*

In constructing the Canadian Pacific Railway line in 1882 the mass of ore which is now being developed as the Murray mine, three miles and a half northwest of Sudbury Junction, was cut through at the surface. This discovery was followed in 1883 by the finding of ore at what are now the Stobie, Copper-cliff, McConnell and other mines in the neighborhood. These occurrences were at first regarded as of value only for the copper which they might contain, and, notwithstanding that the existence of nickel among the associated rocks of the region had been pointed out by Murray and Hunt so long before, it was not till three or four years after the above discoveries had been made and a thousand tons of dressed ore had been sent to England from the Copper-cliff mine that the value of the ores for nickel was recognized.

The ore is very much the same at all the occurrences in the Sudbury district. It consists of a mixture of nickeliferous pyrrhotite or magnetic pyrites, with more or less chalcopyrite or copper pyrites. The larger ore-masses generally approach lenticular forms, with their longer diameters parallel to the strike or to the line of junction of the enclosing rocks. Their attitude is usually nearly perpendicular, the dip or underlie being sometimes apparently at higher angles than those of the adjacent rocks.

Each of the larger ore-bodies is made up of a brecciated or a conglomerate-like mixture of the above-mentioned sulphides and the country rocks next to it, the fragments of the latter varying in dimensions from mere grains and very small pieces up to immense boulders, but the average size is a few inches in diameter. In some cases the stony fragments constitute so large a proportion of the mass that they come almost into contact with each other, the interspaces being filled with the sulphides, while in others there are considerable bodies of nearly pure ore with only occasional rocky fragments scattered through them. In a few instances a granitoid filling between the fragments takes the place of the sulphides. A good example of this may be seen at an opening in one of these ore-masses on lot 3, fifth concession in the township of Levack.

The usual site of these ore bodies is at the junction of greenstone with some other rock, especially granite, gneiss or felsite. Another circumstance which appears to have influenced the localization of the ore is the intersection of the ore-bearing planes by one of the dykes which have been described, or by a throw, or a number of minor dislocations. The existence of one or other of these conditions has been noticed at or near most of the larger ore-bodies of the district.

These deposits have not yet been worked to a sufficient extent to prove much in regard to their persistence or otherwise, in depth. The Copper-cliff mine however has been already wrought to a depth considerably greater than the horizontal length of the ore-mass, either on the surface or in any of the levels. Ore deposits of a similar character in other parts of the world have sometimes proved on working to possess a much greater depth than horizontal measurement. In the absence of any indications to the contrary, it may therefore be expected that the nickeliferous deposits of the Sudbury region will prove equal in depth to their horizontal extensions.

As to the genesis of the ore bodies, the evidence points to their origin from a state of fusion. The fact that the ores always accompany the greenstone (itself of igneous origin) is a strong proof of this supposition. These sulphides fuse at about the same temperature as the greenstone, and in the cooling of the latter they would naturally tend to coalesce in small and large masses. The dissemination of both the chalcopyrite and the

* Report of the Geological Survey for 1886, p. 189.

pyrrhotite so generally throughout the whole mass of the commoner varieties of the greenstones, and the rich impregnation of these rocks with the same sulphides in the vicinity of the ore bodies, are additional evidence in the same direction. In the isolated kernels of ore, often scattered so thickly through the greenstone in the vicinity of the workable deposits, we find groups consisting of either of the sulphides, separately or intermingled, and often the individual kernels will be made up of the two kinds mixed together. These kernels, together with larger patches of the ores, constitute every proportion of the rock, from a small percentage up to half the total weight or more, when the mass has become sufficiently rich to put upon the roast heaps. In the mixed sulphides of these ore bodies the pyrrhotite generally contains a certain proportion of disseminated grains of quartz and other stony matter, while the chalcopyrite is usually tolerably pure. This may be owing to the manner in which the latter separated itself from the former, whether in a state of fusion or by some subsequent process. Although most of these ores appear to have separated themselves from a cooling magma, we find occasionally evidence of subsequent modifying processes. Still there can be little doubt that the larger ore bodies of this district were not originally deposited from aqueous solution like the gangue and ore of ordinary metalliferous veins.

The above ores do not contain a very high percentage of nickel or copper, their value depending more on their abundance and the facility with which they can be mined than on their richness. The Canadian Copper Company, after having smelted thousands of tons of the ores from the Copper-cliff, Evans and Stobie mines, found the average yield of nickel for the year 1890, to have been 3.52 per cent. and of copper 4.32 per cent. The ore smelted at the Blezard mine up to March, 1891, averaged 4 per cent. of nickel and 2 per cent. of copper; that smelted at the Murray mine up to the same period averaged 1.5 per cent. of nickel and 0.75 per cent. of copper. Mr. F. L. Sperry, late chemist to the Canadian Copper Company, found the average of nine assays of ores from the mines of his company to be 2.38 per cent. of nickel and 6.44 of copper. Assays of eleven samples of the ores of the district made under the supervision of Mr. Hoffmann, chemist to the Geological Survey, gave an average of 1.69 per cent. of nickel. The average of all the above smeltings and assays gives us 2.62 per cent. of nickel, which may be taken as the general average of the ores of the Sudbury district. Exceptionally rich ores however have been found in smaller quantities, especially at the Worthington mine in Drury and the Vermilion mine in Denison.

### Cobalt.

Cobalt amounting to little more than a trace has been detected in many of the Sudbury ores. In connection with the Wallace mine it has been mentioned that in 1848 Dr. Hunt ascertained the presence of cobalt in the ore which Mr. Murray had brought from this locality.

### Copper.

Reference has already been made to the copper always contained in the ores of the Sudbury district. The result of smelting several thousand tons of the ores from the three mines worked by the Canadian Copper Company was a yield of 4.32 per cent. of copper from these ores as placed on the roast heaps. It has been mentioned that the roasting ores smelted at the Blezard mine yielded 2 per cent., and at the Murray mine 0.75 per cent. of copper. In the ores of all the mines the chalcopyrite or copper pyrites is generally so intimately mixed with the pyrrhotite as to make it almost impossible to separate it by any mechanical process. But at the Stobie mine masses of several tons of almost pure copper pyrites are occasionally encountered, and the Copper-cliff mine when first opened showed a large body of the same ore near the surface.

At the Vermilion mine on lot 6 in the fourth concession of Denison copper has been found in paying quantities. The ore consists of chalcopyrite, which however is remarkable for having a deep purplish-blue tarnish, causing it to resemble bornite or purple copper ore. It occurs as a streak about four feet wide in greenstone, but it has no distinct walls like a vein, nor any gangue except a mixture of the country rock. A shaft had been sunk on this deposit to a depth of twenty feet when it was visited by the writer in 1888.

The upper ten feet was decomposed to a loose gossan, mixed with fragments of rock, which had probably been held in the ore streak before its decomposition. The recently discovered mineral sperrylite, which is an arsenide of platinum with a little tin, and which occurs in fine crystalline grains, was found by washing this gossan. Copper pyrites has been found on almost every lot in the fifth concession of Denison, along the southern border of a belt of greenstone that runs nearly east and west through this concession.

A short distance north of the region under description the writer in 1875 met with a group of copper-bearing quartz veins running north 70° west, and south 70° east, crossing the east branch of the Montreal river ten miles and a half before it falls into the main stream. This group of veins is about a quarter of a mile wide. They vary in thickness from mere strings to thirty or forty feet, and contain a good deal of specular iron, and in some places promising indications of copper in the form of pyrites. Mr. Hoffmann found a sample of the specular iron to contain 39.41 per cent. of the metal. The country rock here consists of massive beds of quartzite and greenstone, both holding large bunches or "clouds" of fragments of syenite, quartzite and Huronian schists, and all interstratified with sandstone and clay-slate.

On the north shore of Narrow bay or Baie Fine, and two miles east of its entrance, a small vein cutting the quartzite contains gray copper ore. This bay lies between Frazer and McGregor bays, and the above-mentioned occurrence of copper ore has been described by Mr. James T. B. Ives in the Transactions of the American Institute of Mining Engineers for 1889-90.

The most productive copper mines ever worked in Canada were those of the West Canada Mining Company, which included the Bruce on the east, the Wellington in the centre and the Huron Copper Bay mines on the west. These mines are situated at the western extremity of the north shore of lake Huron, and although they are outside of our present sheet they deserve a brief notice as affording the best examples of the occurrence of copper in the Huronian greenstones. These mines were opened in 1846 and worked till 1875, a period of thirty years. The actual workings extended for a distance of over two miles east and west. The ore occurs principally as the yellow sulphide in veins of white quartz, cutting a dark grayish-green diabase. But when the veins on the Bruce location were first opened a good deal of the purple sulphide was found near the surface. On this location several nearly parallel veins running about east and west were worked, the thicker ones being about four feet wide. But on the other two locations work was carried on chiefly on two master veins called the Main lode, which varied from three to fifteen feet in thickness, and the New or Fire-lode, a branch of the latter, and about equal to it in breadth. On the Bruce location the veins were worked to a depth of only about thirty fathoms, but on the other two locations the average depth was from forty to sixty fathoms. Between the latter levels an almost barren floor was generally encountered, although in some place profitable mining extended to seventy fathoms in depth.

The vein-matter as mined contained an average of five per cent. of copper, but it was concentrated by crushing and jigging to about twenty per cent. before shipping to England, which was the chief market. At different times in the history of these mines both smelting and cementation had been tried upon the ground, and abandoned. From information supplied by Captain Benjamin Plummer and other reliable authorities the writer ascertained that copper ore, precipitates, ingots and slags amounting to 40,515 tons, and realizing about $3,300,000, had been shipped from these mines in the thirty years during which they had been worked.

### Lead and Zinc.

Small quantities of galena and zincblende have been found in veins in the belt of black volcanic breccia and slate, which has been described as occurring in the Sudbury district, and they are worth mentioning as possible indications that these ores may be discovered in greater abundance in these rocks. One of the localities is on Pawatik river, about a mile and a quarter northward of the Vermilion, in township 65 ; a second is just below Onaping falls, and a third on the south side of Vermilion lake, near the outlet. Vein-like masses of blende mixed with pyrite occur at Stobie falls on lot 10, sixth con cession of Creighton. Galena has been detected with the pyrrhotite in the Copper-cliff mine, and on lot 6, third concession of Graham. It is also associated with this mineral on Moore's location on lots 2 and 3 in the fifth concession of Craig. It occurs in small quartz veins in dioritic schist on lot 5, fourth concession of Denison.

### Gold.

In 1887 a rich auriferous bunch was found in a vein of light gray finely granular quartz about two feet thick on lot 6, fourth concession of Denison. The opening made on this vein came known as shaft No. 2 of the Vermilion mine. The gold was mostly in the form of small nuggets scattered rather plentifully through the quartz. It is said that several thousand dollars worth were mined, but the gold did not appear to hold out in depth. The country rock on this part of the lot resembles a fine grained greenish gray greywacke, but on critical examination it is found to be an altered greenstone full of very small grains of iron pyrites. Prof. George H. Williams, who examined thin slices from two specimens of this rock under the microscope, describes it as an extremely changed basic eruptive, probably originally a gabbro or a diabase—most likely the former. Its present composition is a confused aggregate of chlorite, biotite, epidote, sericite, quartz, yrite, opaque iron oxide, leucoxene, calcite and apatite needles.

Among the quartzites and greenstones on the south side of lake Wahnapitae a discovery of gold in visible specks was made in 1888. It occurs associated with mispickel in some thin veins of quartz following a belt of quartzite, boulder conglomerate and reddish felspathic quartzite having somewhat the appearance of granite. A sample of the quartz from one of these small veins, which also contained mispickel and pyrite, was assayed by Mr. Hoffmann of the Geological Survey and found to contain 5.425 ounces of gold and 0.233 of an ounce of silver to the ton of 2,000 pounds, but the quartz from another of these small veins contained neither gold nor silver. A band of fine grained dark colored greenstone runs parallel to and at no great distance from either side of this gold-bearing belt of quartzite. It is not unlikely that gold may be found among the rocks of the western part of lake Wahnapitae, which, as already mentioned, have been subject to much crushing in past ages. Gold is reported to have been found by Prof. Heys and others in quartz from veins in the northwestern part of Creighton and the eastern part of Fairbank. Out of a considerable number of samples of quartz from the Sudbury district assayed for the precious metals by Mr. Hoffmann of the Geological Survey, the following results were obtained: From vein No. 1 on mining location W. R. 3, township 40 (southeast of lake Wahnapitae), the property of Mr. Donald McLaren, 0.117 oz. of gold per 2,000 pounds; from location M. 3, at the south extremity of lake Mattagamashing, a short distance east of lake Wahnapitae, owned by Donald McLaren, 1.167 oz. of gold and 0.233 oz. of silver per 2,000 pounds; from Simpson's mine, lot 11, second concession of Graham, near Whitefish station on the Canadian Pacific Railway, 0.350 oz. of gold per 2,000 pounds.

Some distance to the west of our district, or in the western part of the township of Galbraith and about fifteen miles north of Bruce Mines, a large vein of auriferous quartz occurs in a country rock of greenstone. The vein runs about west-northwest, is of a mottled gray color, contains a considerable sprinkling of various sulphides, and is tolerably rich in gold. Of three assays made by Mr. Hoffmann, the highest result was .583 oz of gold per 2,000 pounds.

### Platinum.

Sperrylite, already referred to as occurring at shaft No. 1 of the Vermilion mine in Denison, was first determined to be a distinct mineral species, containing 52.57 per cent. of platinum, by Prof. H. L. Wells of Yale College early in 1889. Some months previously however Mr. Robert Hedley had ascertained the presence of platinum in the ore of this shaft, the proportion in one assay amounting to about five ounces to the ton. It is unlikely that the occurrence of platinum at the Vermilion mine will prove to be the only one in the district; it is more probable that intelligent research will show the existence of this valuable metal in other places among the Huronian rocks. It is reported to have been detected in small quantities at one of the mines on Lake of the Woods.

### Building and Ornamental Stones.

The red granite of George island and vicinity would make an excellent stone for massive structures and monuments, as well as for ordinary buildings. Many of the evenly and somewhat thinly bedded gneisses of the French river region and of the shore of Georgian bay from French river to Parry Sound would serve as very substantial and tolerably easily wrought building stones.

The nearly horizontal beds of limestone of the Trenton group on the islands in the North channel, at Little Current and on Strawberry island are well adapted for ordinary building purposes and are very conveniently situated for transportation by water. They are mostly fine grained or compact, and of dark bluish and grayish colors.

The dolomites of the Niagara formation further south on the Grand Manitoulin island are more heavily bedded, softer or more porous and much lighter in color.

The light gray and cream-colored dolomites of the Guelph formation are found on the southeastern extremity of Grand Manitoulin island and the south end of Fitzwilliam island, but in these localities they are coarsely spongy or full of small cavities.

On the shores of the high points and islands to the north and west of Killarney the light gray and whitish quartzites in many places would make very serviceable building stones. The bed-planes are generally very even and parallel, and layers can be found of almost any thickness desired.

Some varieties of the greywackes, so common among the Huronian rocks, split readily in any direction, and as they are tolerably easily dressed they may be found suitable for purposes of heavy construction. The argillaceous sandstones of the supposed Cambrian basin of the Sudbury district also afford good building stones and they have been quarried to a small extent on the line of the Canadian Pacific Railway between Larchwood and Chelmsford.

In regard to ornamental stones, the dolomites of the Huronian system when cut often show good colors for marbles, but as already stated they generally contain silica in scattered grains and as strings and threads running in all directions through the mass, which prevents them from taking a good even polish. Exceptions to this general rule may however be found in such cases, for example, as the finely crystalline and nearly white variety found on the north side of Lamorandiere bay in the township of Rutherford, which has not yet been tested as marble.

The olive and greenish argillites barred with black, such as occur at the northern outlet of Temagami lake, and which were so highly prized for ornamental stones by the ancient Indians, may be found serviceable for the manufacture of a variety of artistic objects.

The brecciated green chalcedony, which occurs in abundance at the outlet of White Beaver lake, at the head of the east branch of Montreal river, would form a handsome stone for fine ornamental purposes.

### Roofing Slate.

It sometimes happens that clay-slates show a good cleavage in natural exposures resulting from the long continued action of surface influences, while the same rock, when freshly quarried deeper down, will not split readily under artificial treatment. It is therefore difficult to pronounce upon the value of such slates without practical experiment. In our district slates showing fair natural cleavage have been observed in various localities, among which may be mentioned the banks of the Matabechawan river which discharges Rabbit lake into lake Temiscaming, Maskinongéwagaming lake and the lower part of Mattagamashing lake, and Spanish river both above and below the Great Bend. It has been already mentioned that a good cleavable slate occurs on the line of the Canadian Pacific Railway within a mile or two east of Algoma Mills. While these slates may not be as good as those of Melbourne and Shipton in the province of Quebec, they are better than the slates used for roofing purposes in many parts of Great Britain, and it is considered worth while to call attention to them among the mineral products of economic value occuring in this region.

### Lime.

The limestones and dolomites which make up the bulk of the rocks of the various Silurian formations of the islands of the La Cloche group and of Grand Manitoulin island are well adapted for burning into lime, the calcined dolomite passing under this name. Stone suitable for burning into lime and also for metallurgical purposes may be found among the Huronian magnesian limestones already described at Lamorandiere bay, lake Panache, on Wahnapitae river, near Cartier station and on Geneva lake.

### Stone for Glass-making.

Suitable material for glass-making may be found almost anywhere among the Huronian quartzites near lake Huron, where they are nearly all of light colors. In addition to their occurrence in the La Cloche mountains and on the high points and islands towards Killarney, these quartzites are met with on the north side of La Cloche island, at the southern extremity of La Cloche peninsula and in a ridge which runs into Manitoulin island from the head of Sheguiandah bay.

### Apatite or Phosphate of Lime.

This mineral has not yet been found in economic quantities within our district. It exists however as a constituent of all the greenstones of the region which have been examined under the microscope, and large crystals of it have been met with among the ores of the Copper-cliff and some of the other mines in the district. Numerous crystals of apatite were found in a vein near Nasbonsing station on the Canadian Pacific Railway, east of lake Nipissing. As this mineral may be looked for among the Upper Laurentian rocks generally, it would not be surprising if it should be discovered in commercial quantities in the Nipissing or Parry Sound districts. It occurs in various localities in other parts of the province among the Upper Laurentian crystalline limestones, but elsewhere it is found in larger masses in association with pyroxene rock among gneisses and quartzites, as in the county of Ottawa. Five bands of crystalline limestones among the Upper Laurentian rocks were traced through the Parry Sound district by the writer in 1876, but the region northward of Georgian bay has not yet been sufficiently examined to determine whether pyroxene rocks exist there or not. Should they be met with in sufficient abundance the finding of apatite in economic quantities would be pretty sure to follow.

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