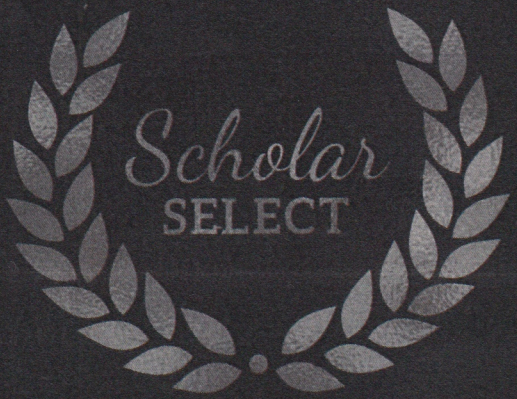
The Nickel and Copper Deposits of Sudbury District, Canada



ROBERT BELL

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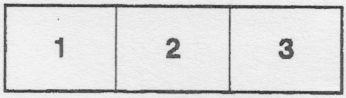

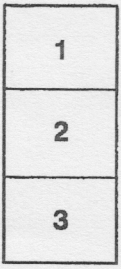

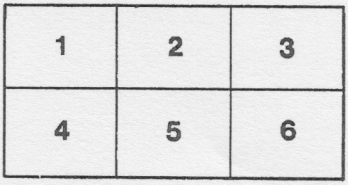

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL 2, PP 125-140

THE NICKEL AND COPPER DEPOSITS OF SUDBURY DISTRICT, CANADA

BY

ROBERT BELL, B A SC, M D, LL D
ASSISTANT DIRECTOR OF THE GEOLOGICAL SURVEY OF CANADA

With an Appendix on

THE SILICIFIED GLASS-BRECCIA OF VERMILION RIVER, SUDBURY DISTRICT

BY

GEORGE H WILLIAMS

ROCHESTER
PUBLISHED BY THE SOCIETY
FEBRUARY, 1891

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(*Read before the Society December 31, 1890.*)

CONTENTS.

INTRODUCTION.

The town of Sudbury, a creation of the Canadian Pacific railway, is situated in the backwoods of Ontario, thirty-six miles north of the mouth of French river, on Lake Huron. Parts of the surrounding country are tolerably level, but in a general way this region may be said to be hilly. Some sections are very broken and rugged, while in others rocky ridges alternate with swamps or alluvial intervals. Occasional tracts of land are fit for cultivation, but, as a rule, where the surface does not consist of rock or swamp it is much encumbered with bowlders. At one time the district supported large quantities of white-pine timber, but forest fires at different periods have destroyed the greater part of it and inferior kinds of wood are now growing

up in its place Rock maple, red oak, black birch and other hard woods form considerable groves in some sections The general elevation of this tract is probably between 800 and 1,000 feet above the sea

The construction of the Canadian Pacific railway in 1882 led to the discovery of nickel and copper, besides various other metals, in this part of the province, and now the Sudbury district promises to become of great importance as a mining region. It may be remarked in passing that Sudbury is not the name of a political division but is merely a convenient designation, in connection with mining, for the territory lying partly in the district of Nipissing and partly in that of Algoma

The Geology of the District.

As a preliminary to the proper understanding of any account of the nickel and copper deposits of the Sudbury district, some remarks on the geology of the region will be necessary The district is situated in the course of the best known and perhaps the longest Huronian belt in Canada Beginning in the west, the general northerly boundary of this great belt commences at the promontory of Nanuinse* on the east side of Lake Superior and runs approximately parallel to the shore of that lake, the St Mary's river and the north shore of Lake Huron as far as Spanish river, leaving a border of Huronian rocks of varying width between the water and the Laurentian nucleus to the north Near Spanish river the dividing line between the two systems turns inland and runs northeasterly nearly to Lake Wahnapitae, whence it trends northward and northwestward till it gains a point lying northeast of Michipicoten on Lake Superior, thus almost surrounding a large elliptical area of Laurentian rocks.

The boundary between the Huronian trough and the Laurentian system along its southeastern side leaves the shore of Lake Huron at Shibaonuning ("Killarney") and runs in a tolerably direct line to the foot of Lake Temiscaming at the great bend of Montreal river, and thence it continues in a somewhat zigzaging course nearly to the southern end of Lake Mistassini, 335 miles due north of Montreal, or a total distance of 600 miles from the commencement of the belt on Lake Superior in a general course of 700 miles, following the axis of the trough Lake Wahnapitae lies at the upper extremity of the contracted portion of the Huronian belt after it has turned northeastward from Lake Huron, but beyond it these rocks spread out widely to the northward

Within the general limits of the Huronian region just sketched, we find a good many inliers of gneiss and red quartz-syenite, some of which correspond with Laurentian types of these rocks, and it is uncertain whether they are

* Meaning, little sturgeon, often improperly spelled Mamainse

from which the mammoth, Indian elephant, and *E. armeniacus* have been derived. The stump is wonderfully like some of the mammoth's in my collection, but it is narrower.

"(Signed) W. Boyd Dawkins."

"Philadelphia, *Dec. 19th, 1882.*

"I have never seen a tooth which presents all the peculiarities of this one, but each of its characters can be found separate in different teeth of the mammoth. It is probably a last deciduous molar of a variety between the typical *E. primigenius* and the smooth-plated *E. columbi*.

"(Signed) E. D. Cope."

Elephas columbi of Dr Hugh Falconer, to which this molar belongs, according to Professors W. Boyd Dawkins and E. D. Cope, has been found on the Pacific coast of Alaska.* Falconer only knew of its remains in

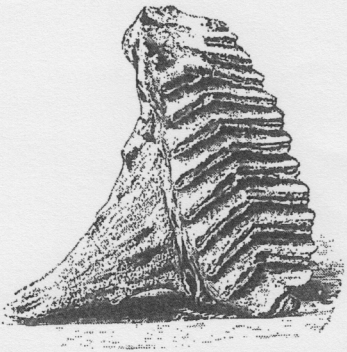

Figure 1.—*Molar of Elephas columbi from Long Island, Hudson Bay.* (½ natural size.)

the more southern of the United States and Mexico; but the present discovery, and that of a similar molar, near Edmonton, N. W. T., taken in connection with its occurrence in Alaska, shows that its range in North America was even more extensive than that of *E. primigenius*. Considering how very rare the discovery of elephantine remains of any kind has hitherto been over all that great portion of the continent between Bering strait and the vicinity of lake Erie, we may reasonably expect that among

* Bulletin of the U. S. Geol. Survey, no. 81, 1882.

In the district under consideration the main line of the Canadian Pacific railway crosses, almost at right angles, the narrowest part of the Huronian belt proper, which has here a width of only about twenty-four miles. The strike is therefore northeast and southwest, and in this pinched portion of the trough the rocks on the opposite sides dip at high angles toward the center. Sudbury Junction is situated southeast of the center of the trough, and from it the Sault Ste. Marie branch of the railway runs upon the general strike of the Huronian rocks throughout almost its entire length. At thirty-three miles northwest of Sudbury Junction, or near Geneva lake, the main line enters upon an outlying basin of stratified Huronian rocks measuring eight miles in width on the railway by seventeen in length from northeast to southwest, and having a long point running westward into the township of Craig. This, for convenience, may be called the Geneva lake outlier. At the southern extremity of Onaping lake, a few miles to the north of this outlier, there is a smaller one, measuring only three miles in width by four in length.

The various members of the Huronian system in the Sudbury district are of much interest in connection with questions relating to metamorphism and the origin of crystalline rocks, and also as illustrations of the general character of the system in this part of Canada. They consist principally of graywackes and quartzites, various forms of diorites, quartz-diorites and hornblende schists, mica schists, diabases, argillaceous sandstones, black and drab clay slates, together with volcanic breccias, in addition to the gneiss and quartz-syenite already referred to.

The rocks which occur in greatest quantity in the stratified Huronian belt between lakes Huron and Wahnapitæ, and which constitute the lowest members of the series, are quartzose graywackes and quartzites, with occasionally a little felsite. Thick bands of quartzites, mostly very light in color and standing at high angles, form the conspicuous range of La Cloche mountains overlooking Lake Huron and the long narrow points projecting into that lake between Spanish river and Killarney. The fact that this great local development of quartzites happens to occur at the most accessible part of our principal Huronian belt has given rise to the erroneous notion that the Huronian rocks of Canada in general consist mostly of these rocks. The quartzites of the region about La Cloche appear to belong to three or four belts which double around in a synclinal form, and are thus repeated within comparatively narrow limits. Quartzite constitutes the principal rock all around Lake Panache and along the lower parts of Vermilion and Spanish rivers, but further to the northeastward, or in the contracted part of the belt of the Sudbury district, the corresponding rocks, with a greatly diminished volume, are much mixed with felspathic and argillaceous matter, constituting massive graywackes; while still further on, or in the country

east of Lake Wahnapitæ, they have passed almost entirely into pure argillites, which are there very extensively developed. To the north of Lake Wahnapitæ the quartzites reäppear in great force. On the opposite or northwestern side of the Sudbury trough this series is represented by a thick band of gray quartzite, which appears to be always characterized by scattered pebbles of white quartz, but it is insignificant in volume compared with the quartzites and graywackes along the southeastern side of the trough.

In the graywacke and quartzite area of the region under consideration the crystalline diorites occur as numerous intruded masses, varying from half a mile to ten miles in length. They are of various forms, but their greatest diameters are approximately parallel with the strike. The rock is generally of a dark or sea-green color and moderately finely crystalline. Three or four of these masses occur around Lake Panache and nine or ten to the northeast, between this lake and the Canadian Pacific railway line, and seven more beyond that part of the railway between Sudbury and Wahnapitæ river. About a dozen small diorite areas have been found in the quartzite and argillite region around Lake Wahnapitæ. Besides these massive diorite , bands of obscurely stratified varieties of the same rocks, of quartz-diorite and of dioritic and hornblendic schists are sometimes associated with the quartzites and graywackes in the townships of McKim and Denison, in the Geneva lake outlier, along Spanish river and around Lake Wahnapitæ. A beautiful and very coarsely crystalline hornblende rock occurs near the Dominion, the Stobie, and the McConnell mines and in a few other localities.

Bands of compact brown-weathering dolomite, generally whitish and dove-colored, occur locally in the graywacke and quartzite series. They are found in considerable volume on different parts of Lake Panache, and they occur also near Lake Huron in the township of Rutherford, on La Cloche lake, on Wahnapitæ river, on Geneva lake, and near Cartier station. Similar dolomite is occasionally found as patches in the finer-grained syenite or altered graywacke.

Two long and remarkable intrusions of diorite of a gray color and having a coarser texture than those already described are found cutting the gneiss and quartz-syenite areas of this region. They are each about a mile wide in the middle. Both run northeast and southwest, or parallel to the general strike of the stratified portions of the Huronian rocks nearest to them, and diminish to narrow points at the extremities. The first of these commences at Whitson lake, in the township of Blezard, and runs southwestward into Denison, a distance of twenty-four miles, while the second has been traced from the northeastern part of Levack for about eighteen miles southwestward. Most of the heavier deposits of nickeliferous ore, so far discovered, are associated with these two diorite belts, and they will be again referred to in this connection. A smaller dioritic intrusion, apparently of the same class as

those two and running parallel with them, is found in the northeastern part of the township of Morgan.

The next member of the series, in ascending order, is the most remarkable of all. It consists of a thick belt of nearly black volcanic breccia, which has been traced from Vermilion lake northeastward in the valley of Vermilion river to beyond the latitude of Wahnapitte lake. It is a compact silicious rock, with conchoidal fracture and consists of angular fragments, mostly small, closely crowded together and flecked with irregular angular white spots. These Dr. G. H. Williams finds to consist of fragments of pumice, which, while retaining their structure, are completely replaced by silica. This band appears to be several thousand feet thick and, as it has resisted denudation well, forms an elevated, rough and broken country along its whole extent.

The highest rocks of the series in this district, or those which occupy the center of the trough, are made up of evenly bedded drab and gray argillaceous sandstones or graywackes, interstratified with shaly or slaty belts, and overlain at the summit by black slates. As these rocks dip at comparatively low angles, they occupy a greater geographical width than the other members in proportion to their thickness, which, however, must be very considerable.

Along the lower part of Spanish river, above and below the great bend, the Huronian belt has a wider spread than near Sudbury Junction and here we find a considerable development of rocks associated with the quartzites which are not met with to the northeastward in the district under consideration. Among these are, soft bluish-gray satiny sericitic schist, sometimes ligniform, accompanied by nearly black hornblendic schist; coarse and fine-grained glossy green and greenish-gray schist; silver-gray fine-grained mica-schist, studded with crystals of staurolite; hard green schist; dark-gray clay-slate; fine-grained greenish-gray silicious felsite; and slaty graywacke, passing into gneiss.

The stratified Huronian rocks and also the gneiss and quartz-syenite of Sudbury district are traversed by dikes of gray, coarsely crystalline diabase, which are often large and can be traced for considerable distances. Their commonest course is about west-northwest. They all have the same physical characters and appear to be of identical composition. The sound, fresh rock is extremely tough, but the exposed surfaces disintegrate easily under the weather into brown crumbling débris, especially along the joint-planes and at their angles. The outer portions of the masses thus separated scale off concentrically, so that they become rounded and bowlder-like. These dikes, as we shall show further on, apparently play an important part in the economic geology of the district.

Referring now to the nickel and copper ores for which this district is becoming famous, it may be remarked, in the first place, that there is much uniformity both as to the characters of the ores themselves and the conditions under which they occur. Yet these deposits are not confined to the undoubted Huronian rocks, but are equally abundant within the gneiss and quartz-syenite areas. They may be said to be connected with a certain geographical area rather than with a single geological horizon. In other words, it would seem as if, within certain limits, the ores might have had their origin beneath all the rocks found at the surface. The ore consists in all cases of a mixture of chalcopyrite and nickeliferous pyrrhotite. The area over which this ore has been found up to the present time extends from the Wallace mine, on Lake Huron, in the vicinity of La Cloche, northeastward to the north side of Lake Wahnapitae, a distance of about seventy miles, and from the southeastern boundary of the Huronian belt, in the Sudbury district, northwestward to the limits of the Geneva lake outlier, a distance of about fifty miles.

It is rather singular, first, that pyrrhotite should exist so commonly within this region as compared with any other in the country, and, secondly, that no matter in what kind of rock we find it to occur, it should generally be nickeliferous to an economic extent. Although, as a rule, pyrrhotite, wherever found, contains traces of nickel, it has only been detected in commercial quantities in a few places in other parts of the world.* The investigations of the writer in the Sudbury district have shown that the combined nickel and copper ore is found on or near certain lines of contact between diorite, on the one hand, and gneiss or quartz-syenite most frequently on the other, but only at certain points on these lines. As no circumstance is without a cause, we may look for some reason which determines the concentration of the ore at one place more than another, and the writer believes he has found the reason in this case to consist in the intersection of the ore-bearing belts near these occurrences either by one of the diabase dikes above described or else from the pinching in or perhaps from a transverse disturbance of the belt.

The ore seems to have been derived in all cases from the diorite, but for some reason the proximity of the gneiss or quartz-syenite appears to be also favorable for the production of the large deposits. If the diorite flowed out originally upon the nearly horizontal surface of the other rock, the constituents of the ore which it contained may have sought the

* Assays have recently been made of samples of pyrrhotite from near Shreiber and Jackfish bay, Lake Superior, and from the counties of Peterboro', Hastings, and Lanark, in Ontario, none of which yielded more than traces of nickel.

lower portion of the mass; or if it were injected between the preexisting rocks, these materials may have been impelled to the sides.

In some cases the belts of diorite are much broken up and disturbed longitudinally, and along these horizons they are mixed with large and small fragments of other rocks showing lines of volcanic movement during their formation. Examples of coarsely brecciated diorite of this kind may be seen near the Dominion mine, the Stobie mine, and thence southwestward to beyond the Canadian Pacific railway, at the Copper Cliff, the Crean or McConnell and the Vermilion mines, in Denison, at Ross' location north of Morgan township, in the northeastern part of Levack and near the western end of Bannerman lake. This condition of the diorite seems favorable for the production of the ore, probably on account of the physical disturbance which it indicates. The lines of northeast and southwest disturbance, along which successive occurrences of the ore are found, cannot always be traced continuously on the ground, but as the evidences of such disturbances make their appearance from place to place upon these lines, and as geological breaks are apt to be very persistent, we may infer that they are continuous.

The first of the two long, narrow intrusions of gray crystalline diorite which have been referred to, in its course from Whitson lake to the township of Denison, cuts off a narrow slice all along the southeastern border of the tongue of gneiss and quartz-syenite which lies in the middle of that part of the Huronian belt. The ore deposits of the Waddell, Dominion, Russell, Little Stobie, Murray, McConnell (in Snider), Lockerby and McIntyre properties, of lot 10, range I, of Snider, of the Crean or McConnell mine, and of the "mineral range" of Denison appear to be all situated along the southeastern side of this diorite intrusion, or in its course, when it becomes narrow, while those of the Stobie and Frood mines and the other occurrences for two miles southwest of the former, of the Copper Cliff and others in the vicinity, of the Evans, of lot 12, range III, of Graham, and of the Vermilion mine lie along the southeastern side of the separated slice of the gneiss and quartz syenite range just referred to, and mostly within the diorite belt which skirts it on that side.

The north wall of the Copper Cliff mine is formed of felsite, quartzite, and a coarse red mixture of feldspar and quartz, besides diorite like that of the south wall, but the ore itself is invariably associated here as elsewhere, with the diorite. The Evans mine is situated further from the contact of the gneiss than any of the others. The top of the ridge on which it occurs consists mostly of greywacke, but the ore is accompanied by diorite which in parts passes into a kind of soapstone or serpentine. A break in the continuity of the gneiss and quartz syenite ridge runs northwestward across it from the Copper Cliff to the McConnell mine, and all along this break there are evidences of the existence of the ore, accompanied by crystalline and

schistose diorites and a brecciated condition of the gneiss and quartz-syenite. The Evans mine appears to be connected with a continuation of this break.

A number of more or less promising occurrences of the mixed ore have been found in the two southern ranges of Denison, in Louise, Lorne, Nairn, Baldwin, Drury and Hyman, and further north in Neelon and McKim. All

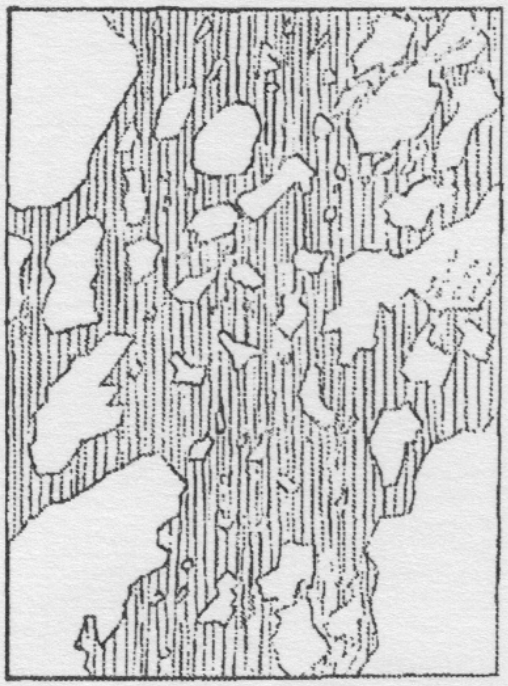

FIGURE 1—*Section of brecciated Ore from Murray Mine.*

these are associated with diorite. In some instances they have been found to be connected with lines of fracture, and this may prove to be so in all cases. The discoveries of the ore which have been made to the west of Lake Wahnapitae are also in diorite in the vicinity of quartz-syenite.

MODE OF OCCURRENCE OF THE ORES.

The various occurrences of the mixed nickeliferous pyrrhotite and chalcopyrite, as far as they have yet been opened up, all resemble each other so closely that a description of one will apply to all. They are associated primarily with the diorite masses which conform more or less nearly with the general strike of the other rocks of the country. The older lines of fracture or disturbance are also approximately parallel with the strike, but their planes may incline at different angles from the local dip. The ore-bodies take the form of stock-works, following the direction of these ancient faults. The bodies are made up of a mixture of the country rock and the sulphides in the shape of a confused mass of coarse and fine fragments of the former, while the ore itself constitutes the matrix or filling between them. The frag-

ments are of every size, from mere grains to that of nuts and small and large bowlders and even great horses. Sometimes the smaller pieces are packed so closely together as to admit of the addition of little ore, while at other

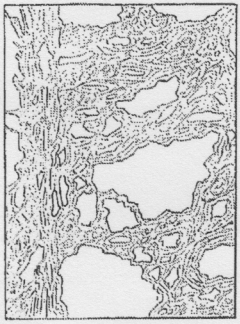

FIGURE 2—*Section of decomposed Ore from Murray Mine.*

times the interspaces are wide and allow the introduction of large quantities of solid ore. The chalcopyrite generally occurs in the midst of the pyrrhotite as distinct masses of irregular form (sometimes quite large), or as streaks,

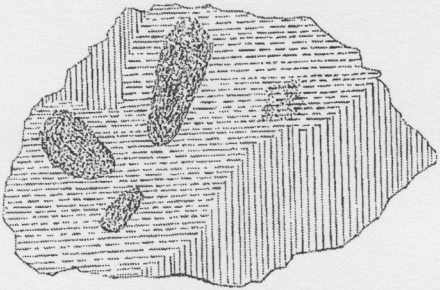

FIGURE 3—*Hand Specimen of Ore from Stobie Mine.*

patches and spots; but occasionally the two sulphides are more intimately mingled. In a part where the pyrrhotite prevails, an included fragment of

the country rock may be coated with chalcopyrite, or the latter may lie as a bunch between the rocky fragments, and *vice versa* as to the other sulphide. There is no uniformity in their mode of occurrence with regard to one another, and they appear to have been introduced among the fragments of broken country rock simultaneously and under the same conditions. The dioritic wall-rocks on either side and also the included bowlders and even the smaller fragments are often thickly impregnated with disseminated grains, spots and patches of all sizes, both of pyrrhotite and chalcopyrite. These spots of ore have usually rounded outlines in cross-section and approach spherical and ovate forms. The two sulphides may occur side by side in the same isolated kernels or amygdules; but just as frequently the latter consist of one or the other alone, although in such cases the same rock-section may contain as many of the one kind as the other and all indiscriminately mingled together.

Figure 1 represents a fresh section of the brecciated ore, two feet high and a foot and a half wide, as exposed at the northeastern end of the drift from No. 4 shaft, Murray mine, in October, 1890, the shaded part being mostly chalcopyrite (with some pyrrhotite) and the rest fragments of diorite. The shaded spots in one of the latter on the right side are included patches of the ore. Figure 2 represents a section four feet high and three feet wide of the decomposed ore on the southwestern side of the railway cutting through the mass at the Murray mine. The shaded portion is the gossan with some undecayed pyrrhotite and chalcopyrite, the rest being fragments of diorite. Figure 3 represents a hand specimen of the ore from the Stobie mine. It was traced directly from nature and reduced to one-half the linear dimensions. The portion shaded horizontally shows pyrrhotite, the vertical shading chalcopyrite and the dotted areas rounded fragments of the siliceous country rock.

Numerous analyses of the ores have shown that the nickel is confined to the pyrrhotite, in which it is present in the proportion of about 1 to 5 per cent.; but it has not been determined whether it replaces a corresponding proportion of iron uniformly throughout the mass or exists in the form of disseminated grains of polydymite. This mineral occurs as crystals, plainly visible in some of the ores from the Worthington mine, in the township of Drury.

The Genesis of the Ores.

The ore bodies of the Sudbury district do not appear to have been accumulated like ordinary metalliferous veins from mineral matter in aqueous solution, but to have resulted from igneous fusion. The fact that they are always associated with diorite, which has been left in its present positions in a molten state, points in this direction. As the diorite and the sulphides fuse at about

the same temperature, they would naturally accompany each other when in the fluid condition. The bodies of molten diorite, being large, would remain fluid for a sufficient time to allow the diffused sulphuretted metals to gather themselves together at certain centers by their mutual attractions and by concretionary action. In the case of great irrupted masses of diorite, the bodies of ore which had formed near enough to the solid walls cooled and lodged with a mixture of the broken wall-rocks where we now find them, while larger quantities, remaining fluid, probably sank slowly back through the liquid diorite to unknown depths. The causes which, at a subsequent time, favored the production of transverse dikes probably aided in determining the deposition of the ore near certain lines rather than elsewhere.

If we suppose that the molten sulphides abstracted themselves, by the laws of mutual attraction, from the general mass of the fluid rock and got together in considerable quantities in an intimately mingled form, the two kinds would tend by the same laws to separate themselves from one another, like going to like, just as salts of different kinds will separate into their respective crystals from an aqueous solution, because there is analogous action between mixtures liquefied by heat and by solution in a supersaturated menstruum. A study of the relations of the pyrrhotite and chalcopyrite to each other in these mixed ores and of the ores of the parent rock shows that this view is in accordance with the facts, and that it is probably a satisfactory explanation of the phenomena. No theory of aqueous deposition appears to account for the facts in connection with these ore bodies; still we do occasionally observe limited local modifications of the ore which may have been due to the solvent action of water with subsequent precipitation of mineral matters long after the consolidation of the mass. This is more particularly the case with regard to the chalcopyrite. Crystals of quartz and of the felspars and rarely of apatite are found embedded in the ore.

Extent and Associations of the Ores.

Other metals, including gold, platinum, tin, lead, silver, zinc and iron, have been found in the Sudbury district, and probably some of them may prove to exist there in paying quantities. The presence of a considerable proportion of nickel in the ore of the Wallace mine, on the shore of Lake Huron and in the strike of the Sudbury deposits, was ascertained by Dr. Hunt more than forty years ago; yet the presence of this metal in the latter does not seem to have been suspected for a considerable time after they had been worked for copper alone. The Huronian is notably a copper-bearing system. West of Sudbury, in the great belt we have already traced, this metal occurs around Batchawana bay, north of Sault Ste. Marie, at Little Lake George and Echo lake, at Huron Copper bay, in Wellington and Bruce mines,

on Thessalon and Mississagui rivers, and elsewhere. To the northeastward it has been found on both sides of Lake Wahnapitae, on Temagami and Lady Evelyn lakes, along Montreal and Blanche rivers, on the watershed east of the canoe route between lakes Temiscaming and Abbittibi, and finally near the southern extremity of Lake Mistassini. The search for this metal along the Huronian belt, which has been described above as running for more than 600 miles, is only in its infancy, and the copper-mining industry may some day be very extensively carried on in various parts of this, as yet, almost unknown section of Canada.

THE SILICIFIED GLASS-BRECCIA OF VERMILION RIVER, SUDBURY DISTRICT.

BY GEORGE H. WILLIAMS.

(*Read before the Society December* 31, 1890, *as an Appendix to the communication on the Nickel and Copper Ores of Sudbury District, Canada, by Dr. Robert Bell.*)

Among a considerable series of rocks from the Sudbury district which I have recently had the pleasure of microscopically examining for Dr. Robert Bell, of the Canadian Geological Survey, there was one of such unusual petrographical character that it well merits a special description. Moreover, this rock is not merely a petrographical anomaly, but it also occupies so large an area as to become geologically of great importance as a member of the Sudbury series.

The specimens of this rock examined by me in Dr. Bell's collection bear the label "Lowest fall of Onaping river, Sudbury," and turn out to be nothing less than a breccia 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 microlitic flow-structure with a distinctness not to be exceeded by the most recent productions of this kind.

Such porous glassy rocks are well known to be more subject than any others to either alteration or complete removal, so that the preservation of this glass-breccia from Huronian times without loss of its original characteristics must be regarded as very exceptional. The production of a mass like this on so large a scale in any geological time is also a matter worthy of notice, for Dr. Bell has traced it as a wide band for over forty miles without then reaching its northern limit.

The following memoranda on the occurrence and distribution of this ancient glass-breccia have been furnished by Dr. Bell and may best be given in his own words:

"This remarkable rock lies along the northwestern side of the Huronian trough, having the red quartz-syenite, which may be Laurentian, on its northwestern flank and being bounded on the southeast by what is here the highest member of the series, which consists of thick-bedded dark bluish-gray argillaceous sandstone, full of clear grains of quartz and interstratified with shaly beds of the same color, all overlain by black slates. Towards its southwestern termination the breccia itself passes into a black shaly mass holding many pebbles, mostly of syenite.

"The belt runs from the township of Trill northeastward along the northwestern side of Vermilion river to a point opposite Wahnapitae lake, where it cuts across the river and continues on northeastward; but its limit in that direction has not been accurately ascertained beyond forty miles from the township of Trill. In this town-

Lightning Source UK Ltd.
Milton Keynes UK
UKHW022020030820
367622UK00005B/1010

Published by Palala Press, an
imprint of Creative Media Partners.
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