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ON THE NICKEL AND COPPER DEPOSITS OF SUDBURY, ONT.

By Alfred E. Barlow, M.A., Geological Survey Department,

(Read before the Logan Club, Ottawa, March 6th, 1891.)

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The presence of large deposits of nickel and copper in the District of Algoma, Ontario, has of late years attracted world-wide attention, in the first place on account of their immense and apparently inexhaustible character, but latterly because of the proposed application of nickel in alloy with steel to improve the quality of the latter. The existence of workable deposits of copper in this region was a fact that had long been known, and as far back as 1770 a company had been formed and attempts made to mine this metal, but the difficulty of procuring and maintaining miners at so great a distance from any centre of civilization, the remoteness of any market for the ore, as well as the absence of facilities for transportation, rendered these first attempts abortive. However, in 1846, owing to the activity in prospecting and locating mineral lands on the southern shore of Lake Superior, and a favourable report by Mr. W. E. Logan, then newly appointed Provincial Geologist, some enterprising Canadians banded themselves together into two associations called "The Montreal Mining Co'y," and the "Upper Canada Mining Co'y." The former company having purchased, amongst others, what was then known as "The Bruce Mines" location, and on account of the richness of the deposit decided to commence active work at this locality, while the Upper Canada Co'y proceeded to develop and work what was known as the "Wallace Mine," at the mouth of the Whitefish River. The Montreal Mining Co'y continued their operations from 1846 to 1865, when, from a variety of causes, the work proving unremunerative, they sold out the whole of their claim to the "West Canada Mining Co'y," who had previously leased and worked the western half of the location under the name of the Wellington Mine. This company continued working till 1876 when, owing to unsatisfactory results, work was suspended and has not been resumed since. The Wallace Mine was chosen on account of its promising character and proximity to civilization, and is chiefly remarkable as having been the first place in Canada in which the presence of nickel had been detected

According to Mr. Alex. Murray, of the Geological Survey of Canada, who made an examination of the location in 1848, "No true vein can be discovered, but the ore occurs at the contact of quartz ose and chloritic slates with diorite, as bunches and strings of pyritous matter, interlaminated irregularly with the slates, and distributed in specks and patches in the diorite. Abundant evidence of disturbance is displayed in irregularities of dip and intrusion of the diorite. The material collected for assay was chosen as free as possible from copper pyrites, but nearly two-fifths of the specimen consisted of earthy materials which might readily be separated by dressing," (See Report Geological Survey of Canada, 1848-49, p. 42—45.) Dr. T. Sterry Hunt, in his report on this ore, says that "the specimen is a steel grey arseniuret, the species not determined, with white iron pyrites and probably some arsenical sulphuret of iron. The mass, weighing 45 oz., was reduced to powder and submitted to analysis, with the following results:—

Iron	24.78
Nickel, with trace of cobalt	8.26
Arsenic	3.57
Sulphur	22.63
Copper	.06
Earthy materials	40.01
	99.31

In the process of washing the ore, the earthy parts being removed by washing, the composition of the ore in 100 parts, as deduced by calculation from the above, would be—

Iron	41.79
Nickel and cobalt	13,93
Arsenic	6.02
Sulphur	38.16
Copper	.10

From the small proportion of arsenic the nickel must, in part at least, be present in a state of sulphuret, a fact which is, indeed, made evident by the spontaneous oxidation of the ore. The nickel from this source contained about three parts in a thousand of cobalt. In conclusion, he remarks that in the same bands of rocks we may detect the presence of nickel and cobalt, a prophecy which has since been amply verified.

A mass of copper pyrites from the same mine weighing 9½ lbs. was also assayed, which yielded 11.6 per cent. of metallic copper. Acting on these and other favourable reports, the company began to sink shafts to test the extent and the quality of the ore, and one of these shafts at least attained a depth of 10 or 15 fathoms. Work was carried on energetically for some years, but the enterprise was finally abandoned, as the quantity of ore did not seem sufficient to justify further expenditure.

In his report for 1856, Mr. Alex. Murray (see Report Geological Survey of Canada, 1853-56, p. 180,) mentions the occurrence of a "dingy green magnetic trap" associated with red syenite in the north-west corner of the Township of Waters on Salter's meridian line. Specimens of this trap were given to Dr. Hunt for analysis, and the result of his investigation showed that it contained magnetic iron ore and magnetic iron pyrites, generally distributed 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. The variation of the magnetic needle near this mass was from ten to fifteen degrees west of the true meridian. It can thus be seen that even at this early period of its history the officers of the Geological Survey were aware of the existence of nickel in this region, and had pointed out the probability that workable deposits would be found. Years passed by and the inaccessible nature of the country deterred prospectors from making very detailed exploration or examination, so that it was not till 1883, when the Canadian Pacific Railway was in course of construction, that the first discoveries of any consequence were made, since which time the whole belt of the Huronian district has been overrun with eager prospectors and miners. A not infrequent accident in newly settled districts led to the first important discovery. Judge McNaughton, stipendiary magistrate at Sudbury, had been lost in the woods to the west of that village, and diligent search was at once instituted for him. A party consisting of Dr. Howey and two others found the judge seated on the small eminence which then marked the site of what is now known as the "Murray Mine." Early in 1884 the Canadian Pacific Railway made a cutting for their main line through this small hill, about 3½ miles northwest of Sudbury, and on July 12th of the same year Dr. Selwyn made a careful examination of the location and pronounced the lode to be one of the most promising he had yet seen in Canada. Other discoveries soon followed, and the McConnell, Lady Macdonald, Stobie, Blezard, Copper Cliff and Evans Mines were all located. At first the wildest notions were entertained as to the extent of these deposits, and the most exaggerated reports circulated as to their value. It was even confidently asserted that these were immensely important discoveries, and would revolutionize the whole copper trade and render other mines then in operation quite unremunerative. Rounded hills of gossan, indicating the presence of the more solid and unaltered ore beneath, occur at intervals for miles in a southwesterly direction, conforming rudely to the strike of the rocks in the vicinity. This circumstance is all that seems to have justified the early discoverers in describing the deposits as veritable mountains of solid ore, many miles in extent and hundreds of feet thick. Closer investigation revealed the fact that these surface gossans everywhere indicate the presence of the ore beneath, and that the ore itself occurs in lenticular masses, entirely separated from one another, whose longer axes correspond with the strike of the enclosing rock. This gossan has resulted, as is usual, from the formation of peroxide and hydrated peroxide of iron, due to the decomposition of the pyrrhotite and chalcopyrite which gives a prevailing red or reddish brown colour to the upper portion of the deposit. This covering of iron oxide is sometimes as much as six feet in depth, although usually it is only two or three feet, gradually merging itself into the unaltered ore beneath. During the last few years prospectors have not been idle, and at the present time about twenty very promising deposits of these ores have been "located" and "taken up." The McAllister Mine, now called the Lady Macdonald Mine, was the first property on which any work was done in the summer of 1885, although later in the fall the Evans Mine was opened up and some preliminary tests made. On January 6th, 1886, the Canadian Copper Company was formed with a subscribed and paid up capital of $2,000,000, which was afterward increased to $2,500,000, to operate the Copper Cliff, Stobie and Evans Mines.

On May 1st, 1886, work was started in earnest at the Copper Cliff mine, and later on in the same year both the Stobie and Evans mines were opened up, and with the exception of a few months last summer, when, on account of some difference with the Canadian Pacific Railway, the Stobie was shut down, these three mines have been in active operation ever since. The chief business of the Canadian Copper Company is done at Copper Cliff, for here they have prepared a well equipped roast yard, two smelting furnaces, laboratory and offices, and other things requisite for carrying on this mining on an extensive scale. The Stobie and Evans mines are provided with excellent rock houses, but all their ore is brought by branch railways to Copper Cliff to be roasted and smelted. In 1889 the Dominion Mineral Company was formed to operate the Blezard mine, and later on they purchased the Worthington mine from the original owners. During the past summer this company have had their smelter in operation, and both their mines are being energetically developed. During the summer of 1889 the Murray mine was prospected under bond by Messrs. Henry H. Vivian & Co., Swansea, England, and in October of the same year they purchased it. About the end of last September, everything being ready, the smelter "was blown in" and set to work on some ore which had been previously roasted. All three companies are now prosecuting the work vigorously, and the output of these mines has already reached very large proportions. The whole district has been prospected, and I think that a very conservative estimate would now place the number of promising deposits at twenty.

The Huronian system in which these ore deposits occur may be regarded as the oldest series of sedimentary strata of which we have at present any certain knowledge. Amongst the more important of these rocks may be mentioned quartzites, greywackés, conglomerates, slates, evenly laminated gneisses, felsites, hydromica, chloritic, epidotic, hornblendic and micaceous schists and narrow bands of cherty limestone. Most of these clastic rocks have been derived from the waste of older felspathic material, and hitherto it has been most generally supposed and stated that the Laurentian gneiss was the source from which the sediments had been derived. The Huronian conglomerates, however, hold no pebbles that are undeniably referable to the Laurentian, and the origin of the syenitic, quartzose and jaspery pebbles is still a matter of doubt. The microscope can throw no certain light on the original character of some of these rocks, for very often metamorphism and recrystallization has gone on to such an extent that the former structure has been either partially or completely obliterated. A close study of these uncertain rocks in the field, aided by the use of the microscope in the laboratory will eventually enable us to assign them their proper place. We have thus numerous sedimentary rocks showing the various stages of this metamorphism, from the typical sandstone or greywacké, composed of well rounded grains of quartz and felspar, to the compact felsite, which contains no trace of its original clastic structure. Associated with these sedimentary strata are certain undoubted eruptive and irruptive rocks, among which may be mentioned many varieties of diabase, diorite and gabbro. Besides these igneous rocks, there are some granites and gneisses concerning whose origin many are in doubt. After a close and careful study of these rocks, which have usually been classified as Laurentian, and their relations with the true Huronian stratified deposits, I have been fully convinced of their irruptive nature. These granites and gneisses probably represent the original crust of the earth which has undergone refusion, and was in a molten or plastic condition at a period subsequent to the hardening of the Huronian sediments. The earth gradually cooling from a state of original incandescence, had reached that stage in the process when it admitted of being surrounded by an ocean nearly, if not quite, universal. Then began that tearing down and building up which has since gone on in forming the sediments which subsequently hardened into rocks. The first formed crust was necessarily thin and weak, and it is therefore not surprising that there were frequent irruptions, accompanied by the fusion of the lower portion at least of the first formed deposits.

It is unnecessary here to go into all the facts of the case, as my views have already been stated at some length in a paper read before this club on February 27th of last year. Suffice it to say that the fuller examinations of last summer have served to further strengthen these views. Both clastic and irruptive rocks have been subjected to intense pressure, as evidenced by the extensive cataclastic structure which has been developed in both series of rocks. Frequently the rocks show a pyroclastic origin, and volcanic tuffs and breccias are very commonly met with. The relations of the diabase or basic irruptive rocks with the surrounding sedimentary strata was closely examined in a large number of instances, and revealed the fact that the diabase is apparently of later age, as it breaks through and alters the bedded Huronian. The occurrence of these masses of diabase with a surrounding breccia or agglomerate in many cases would seem to point to the fact that they are the bases of Huronian volcanoes, which continued in action after the latest sediments had been deposited. Some of these diabasic masses send out dykes which ramify through and alter the surrounding strata, these dykes frequently containing fragments of highly metamorphosed Huronian quartzite. These irruptive masses are usually lenticular, although occasionally rudely circular or oval in outline, and their longer axes correspond in general with the strike of the enclosing rock. They vary in breadth from a few chains to half a mile, or even more, and frequently extend for miles in length. The origin of the nickel and copper is closely connected with this diabase or gabbro, and the formation of the fissures containing these ores was no doubt due to the disruptive forces of the intrusion, and the contraction caused by the subsequent cooling of the igneous rock matter. These fissures were necessarily most frequently formed along the line of contact with the cooler sedimentary strata although in certain cases they were formed in the midst of the igneous mass itself. In nearly every case, therefore, the deposits of nickel and copper occur close to the contact of the diabase with the stratified rocks, although in a few cases they are found in the diabase near its junction with granite or micropegmatite. Another proof of the common genesis of these ores and the enclosing diabase is that the diabase itself commonly contains these sulphides disseminated through its mass, these impregnations occasionally forming such considerable and rich deposits as to be workable.

All geologists who have examined these deposits agree that they are not true fissure veins, and although at times a certain sloping surface is obtained which seems to have a uniform inclination, yet it seems certain that there are no regular walls in the miner's sense of the term, and at both sides of the deposits the enclosing rock is impregnated more or less with the pyritous matter. Though mining is thus rendered somewhat difficult and uncertain on account of the absence of the walls and irregularity in the distribution of the ore, so that there is no means of knowing in what direction to drive the levels, this uncertainty is more than compensated by the extent and massiveness of the deposit when found. The ore bodies like the masses of diabase with which they are so intimately associated are lens or pod-shaped and "pinch out" in both directions. This structure is also characteristic of their downward extension, and the deposits have been very truly likened to a string of sausages, so that when one lenticular body of ore gives out another commences close at hand, which in its turn gives place to another, and though at the Copper Cliff they are down about 600 feet on a slope of 45°, the quantity and quality of the ore shows no diminution. I have occasionally found true veins of quartz holding this pyrrhotite, but such evidences of secondary action are extremely rare and proves nothing in regard to the origin of the more massive deposits. The ores and the associated diabase were therefore in all probability simultaneously introduced in a molten condition, the particles of pyritous matter aggregating themselves together in obedience to the law of mutual attraction. The ore bodies were, therefore, not contemporaneous with the stratified Huronian, although there is nothing to prove that they do not belong to the close of the Huronian period. Mr. Ferrier of the Geological Survey has noticed the occurrence of this nickeliferous pyrrhotite in a specimen of chloritic schist and gneissic granite, which had been taken to show the contact between the two rocks. The pyrrhotite is disseminated through both rocks, and its occurrence here in the Township of Dill at the junction of what has been called Laurentian would seem to be another proof of the irruptive origin of this gneiss.

The ore itself is a mixture of pyrrhotite, a monosulphide of iron ($Fe_7 S_8$) and chalcopyrite, a sulphide of copper and iron ($Cu Fe S_2$). The two minerals are not so intimately commingled as to form a perfect homogeneous mass, but one may be described as occurring in pockets, spots, bunches or threads in the other. The chalcopyrite is not so closely intermixed with the pyrrhotite, but isolates itself rather in spots and patches enclosed by massive pyrrhotite, so that it is not hard to separate considerable masses of chalcopyrite that will assay over 30 per cent. of copper, or pyrrhotite that will only show traces of that metal. In practice, however, careful examination and trial have proved that the two minerals are too intimately associated to make sorting by hand at all practicable, and the pyrrhotite is very often so feebly magnetic as to preclude the possibility of separation by magnetism. Although the chalcopyrite seldom occurs free from the pyrrhotite, large and massive deposits of the latter occur comparatively free from copper. In this connection Dr. Peters mentions a slope which, having furnished about 2,000 tons of pyrrhotite, gave place, just before the end boundaries were reached, to a deposit which afforded nearly 20 tons of almost pure chalcopyrite. In some instances these ore bodies show a brecciated character, large angular or partially rounded boulders or "horses" of almost barren rock being mingled with the ore, which seem to evidence the disruptive force of the intrusive mass, while in others, as at the Worthington mine, the diabase in which the ore occurs has developed a concretionary structure while cooling, and large irregularly rounded concretions, which, on weathering, peel off in concentric layers, are cemented together, so to speak, by a very pure chalcopyrite and highly nickeliferous pyrrhotite. The concretions themselves usually contain more or less pyritous matter disseminated through them, but are usually cast aside as too barren for the roast heap. The pyrrhotite varies in colour from steel-grey to bronze yellow, and the chalcopyrite is the usual brass or deep yellow colour. Both tarnish readily, and very beautiful iridescent specimens can be easily obtained from the ore heap or scattered around the works. These sulphides, therefore, may be said to occur in three distinct ways—

1st. As contact deposits of pyrrhotite and chalcopyrite situated between the clastic rocks, such as felsites, quartzites, etc., and irruptive diabase or gabbro, or between these latter and granite or micropegmatite. Good examples of the former are furnished by the Evans, Stobie and Copper Cliff, while the Murray mine may be cited as illustrating the latter.

2nd. As impregnations of these minerals through the diabase or gabbro, which are sometimes so rich and considerable as to form workable deposits. These sulphides are in no case present as disseminations through the clastic rocks very distant from the diabase or gabbro, which seems clear evidence that they have been brought up by the latter.

3rd. As segregated veins which may have been filled subsequently to the irruption which brought up the more massive deposits. These veins are not very common, although certain portions of the more massive deposits may have been dissolved out and re-deposited along certain faults and fissures.

The composition of the ore varies according to the preponderance of either the pyrrhotite or chalcopyrite in the specimen examined. The pyrrhotite may be said roughly to be composed of 40% sulphur and 60% iron, with a varying proportion of the iron replaced by nickel, while the chalcopyrite contains 35% sulphur, 35% copper and 30% iron. The mines of the Canadian Copper Co'y, as the name of the company indicates, were first opened for their copper contents, and it was not until considerable work had been done that nickel was discovered to be present in the ore. A large shipment of ore had been made to New York, and a chemist there who was making a volumetric determination of the copper contents by the Potassium Cyanide process, was struck by the great variation in his results, which led him to make a more minute examination of the ore, when he found that nickel was present. The ore has now become of more value on account of its nickel than its copper contents, and Dr. Peters himself greatly doubted if the mines would pay to work for copper alone. The percentage of nickel and copper varies greatly, as might be expected, but assays of nine samples from the different mines of the Canadian Copper Co'y, made in November 1888, will show the usual percentage of these metals. These assays were made by Mr. Francis L. Sperry, and show a range in the percentage of nickel from 1.12% to 4.21%, with an average of 2.38%, while the copper varied from 4.03% to 9.98%, with an average of 6.44%. A minute proportion of cobalt also occurs in the pyrrhotite, usually about $\frac{1}{30}$th as much as the nickel present. Mr. G. C. Hoffman assayed four samples from this district which I collected last summer, and these showed the nickel contents to vary from 1.95% to 3.10%, with an average of 2.25%. Three of these samples contained traces of cobalt, which are included in the above percentage of nickel. The nickel is usually spoken of as replacing an equal quantity of iron in the pyrrhotite, but the discovery of undoubted crystals of millerite or sulphide of nickel 150 feet below the surface at Copper Cliff Mine, as well as the more recent recognition of polydymite, a ferriferous sulphide of nickel, at the Vermilion Mine, in the Township of Denison, seems to justify the assumption that in the more highly nickeliferous deposits of the region at least, the nickel is also present as a sulphide, disseminated through the ore mass like the iron and copper.

This view is also borne out by Dr. Hunt's analysis of the ore of the old Wallace mine which seems precisely analogous to some of the richer deposits nearer the Canadian Pacific Railway. Traces of gold and silver, as also platinum are also usually found in these ores, and in this connection it was thought advisable to call your attention to the detection of what Messrs. Clarke & Catlett call a "platiniferous nickel ore from Canada." They say (see article xxxix, page 372, *American Journal of Science*, 1889) During the autumn of 1888 we received, through two different channels, samples of nickel ores taken from the mines of the Canadian Copper Company at Sudbury, Ont. From one source we obtained two masses of sulphides to be examined for nickel and copper, from the other came similar sulphides together with a series of soil and gravel-like material (gossan), 7 samples in all. In the latter case an examination for platinum was requested, and in 5 of the samples above mentioned it was found the gravel yielded 74.85 ozs. of metals of the platinum group to the ton of 2,000 lbs. The sulphide ores submitted to us from Sudbury were all of a similar character. They consisted of mixed masses in which a grey readily tarnishing substance was predominant with some chalcopyrite, possibly some pyrite and a very little quartz. Two samples were examined in mass: one gave 31.41 % nickel with a little copper, and the other gave 35.39 % nickel and 5.2 % copper. The nickel mineral itself proved to be a sulphide of nickel and iron, and as ores of that composition are not common, it was thought advisable to examine the substance further. It is steel-grey, massive and exceedingly alterable in the air with a Sp. Gr. of 4.5. An analysis of carefully selected material gave :—

Nickel	41.96
Iron	15.57
Silica	1.02
Copper	.62
Sulphur	40.80

These figures give approximately the formula Ni_3 Fe S_5. Neither cobalt nor arsenic could be detected. If we deduct silica together with the copper reckoned as admixed chalcopyrite and re-calculate the remainder of the analysis to 100°/₀ we get the following figures:—

Nickel	43.18
Iron	15.47
Sulphur	41.35

In short the mineral has the composition of Ni_4 S_5 with about ¼th of the nickel replaced by iron, which seems to agree with Laspeyres polydymite of which it is doubtless a ferriferous variety. Probably in most cases the niccoliferous constituent of pyrrhotite is millerite, but other sulphides like polydymite may occur too. The polydymite which was selected for the above analysis came from the mass in which the average of 35.39 % nickel and 5.20 % copper had previously been found.

The mass weighed several kilograms and was remarkably free from quartz. The same mass, with two smaller pieces resembling it, were also examined for platinum. The results were as follows, "A" representing the large mass in which the polydymite was determined :—

A....	2.55 oz.	platinum per ton,	or		.0087 %
B....	1.8 oz.	"	"	"	.0060 %
C....	7 oz.	"	"	"	.024 %

Probably the platinum exists in the ore as sperrylite, although this point was not proved. The amount of platinum in the mass most thoroughly examined would require to form sperrylite only about .007 % of arsenic, which is too small a quantity for detection by ordinary analysis. That platinum should exist in appreciable quantities in an ore of such a character is something quite extraordinary, but whether it could be profitably extracted is an open question. Sperrylite was first found at the Vermilion mine in the gossan or loose material, and was named after Mr. Francis L. Sperry of the C. C. C. by Messrs. Horace L. Wells and S. L. Penfield, of the Sheffield Scientific School, who examined and described this new species. It is isometric; simple cubes are common, octahedrons are exceptional, while the majority of the crystals are combinations of the cube and octahedron. H.—Between six and seven, as it scratches felspar but not quartz. The crystals have no distinct cleavage, but are very brittle and break with an irregular, probably conchoidal fracture. The chemical composition, according to the mean of two analyses was as follows:—

Arsenic	40.98
Antimony	.50
Platinum	52.57
Rhodium	.72
Palladium	trace.
Cassiterite or oxide of tin	4.62

The composition is therefore represented by the formula $Pt\ As_2$, a small portion of the platinum being replaced respectively by rhodium and antimony. The color of the mineral was nearly tin white or about the same as metallic platinum. The fine powder is black. Nearly all the grains showed extremely brilliant crystal faces, though most of the crystals were fragmentary in size they were usually $\frac{1}{50}$—$\frac{1}{500}$th of an inch in diameter. Sp. Gr. 10.602.

ROASTING.

The metallurgical treatment of this ore commences at the roast yard whither it is conveyed, and, being piled in convenient heaps on previously laid cordwood, is exposed at high temperatures without fusion, or, at most, incipient fusion, to the action of a current of air. The objects of this roasting are, 1st, an oxidation of the iron, and, incidentally, of the sulphur, as complete as is possible without involving an undue loss of copper in the slags of the following smelting, and 2nd, the expulsion of arsenic if there is any present. If the oxidation be very imperfect the resulting matte will contain so much iron that its bringing forward will be unduly costly, while, if the oxidation be too thorough, an undue loss of metal will occur on smelting the roasted ore.

At Copper Cliff the Canadian Copper Company have spared neither trouble nor expense in the construction and equipment of their roast yard. The natural rough and uneven surface has been cleared and levelled, and the whole given a gentle slope, which, with carefully made drains, serve to remove at once any rain or surface water. These precautions have to be taken to prevent loss of copper as soluble sulphate of copper, which is liable to be washed out by the rain.

At the Murray mine a large shed has been erected to roast ore during the winter months, with openings in the roof to allow of the escape of sulphurous fumes, but during last summer they had no regular roast yard, and the few heaps burnt could only be placed where the surface of the ground would permit. This was also the case at the Blezard and Worthington mines, and the mechanical loss alone from this carelessness must have been of considerable moment. The shaft of the Copper Cliff mine, on an incline of 45°, has reached already a depth of nearly 600 feet. It is provided with a double skip road, the skips dumping automatically at the mouth of the breaker in the top of the rock house. Here the ore is sledged to a proper size for the 15 × 9 in. Blake crusher set to about 1¾ inches, which has a capacity of nearly 20 tons an hour. It is then passed through a revolving screen where it is sized into three classes for the succeeding operation of roasting. The coarse size passes a 4-inch ring, the medium or ragging, a 1¾-inch ring, while the fines pass through one ¾ of an inch in diameter. Each of these sizes falls into a separate bin under which a car runs. Thus the ore is loaded automatically into cars holding 1½ tons, whence it is transported to the upper story of the ore shed. There it falls into a series of bins from which it is loaded by means of inclined steel shutes into the cars and taken up a rather steep grade to a high trestle which extends the whole length of the roast yard. The only wood that can be obtained is dead pine, a good deal of the surrounding district having been burnt over about 20 years ago. This can be procured very cheaply, and although it does not roast the ores as thoroughly as hard wood, it makes very fair and economical fuel, and serves on account of its short fierce heat to ignite the pile, and this once started continues burning on account of its sulphur contents. These piles are built as follows :—The place selected is first covered with about six inches of fine ore distributed as evenly as possible over the clay soil. Sticks of cordwood of nearly uniform size should be placed side by side across both sides and ends of the rectangular area. The whole interior of this can be filled in with old stumps roots, ties or cordwood, but in such a way as to form a level and solid bed for the ore to rest on. Over all this is placed small wood and chips to fill up all interstices, care being taken to provide small canals filled with kindlings at intervals of 8 or 10 feet leading from the outer air to the chimneys along the centre of the heap. These chimneys which assist in rapidly and certainly kindling the whole heap are usually built of four sticks or old boards, so fixed together as to leave an opening and communicating below with the draught passages. Five or six of these chimneys suffice for each pile, and they should project 2 feet above the upper surface of the heap, so that no pieces of ore could fall into the flue opening. The coarsest class of ore is first thrown on, then the ragging or medium, on top of which is scattered a layer of rotten wood or chips, and lastly the whole heap is covered over with fines till it reaches a height of about 6 feet, The whole structure should then form a shapely rectangular pile with sharp corners and as steeply sloping sides as the ore will naturally lie on without rolling (about 45°). Only a portion of the fine ore is put on at first, the rest being shovelled on after the fire is fairly started. The best way to light the pile is to place a quantity of ignited cotton waste saturated with coal oil down each of the chimneys. About 12 hours after firing the whole heap should be pouring forth dense yellow fumes of sulphurous acid. Great attention is at first paid to the pile to prevent undue local heating which frequently causes partial fusion of the ore, and this can at once be prevented by covering the place with more fines. This heap should then burn from 50 to 70 days when the outer covering of raw or partially roasted ore is removed, and the remainder of the heap conveyed a few yards in wheelbarrows to a sunken railroad which runs alongside of the roast-yard. When filled, the cars are pushed up another steep grade along a track running over the bins back of the smelter. The sloping sides and corners of a pile are frequently covered with almost raw ore, this evil being often remedied by placing ignited sticks of cordwood around the whole structure, or by building a new pile in the passageway between two others which have been almost burnt out, the latter plan adding very materially to the capacity of the roast yard. After this operation the ore is invariably so thoroughly roasted that it is necessary to add from 10 to 25% of raw fine ore during the smelting to prevent the matte from being too rich. Each pile usually contains about 600 tons of ore, and requires 30 cords of wood to roast it. The roast yard at Copper Cliff is nearly half a mile long by 100 feet wide, while each pile occupies a space of 40 x 80 feet, room being left to get round them, and for drains. The present capacity is about 60,000 tons, which, with a little extra work, could be increased to 90,000 tons. Working full power each roast bed can be used four times a year, counting the time in making, roasting and clearing the beds. The yearly capacity would therefore be 240,000 tons, and by increasing the space, 360,000 tons. The unroasted ore contains from 35 to 40% sulphur, and assays of a large number of samples of the roast heaps have varied from 2½ to 8% of sulphur. One analysis taken at random which may be taken as a fair sample of all the rest, gave 5.40% copper, 2.43% nickel, 7.92% sulphur and 25% iron, lime, magnesia, etc., and the residue chiefly hornblende. Up to October 1st, 1890, 56,534 tons had been taken to the roast yard.

SMELTING OF THE ORE.

There are two smelting furnaces at Copper Cliff, and the building which contains these is 65 feet long by 40 feet wide. Thirty-five feet of this length is on a level with the ground, while the rest of the floor is 8½ feet higher, and it is on this upper flat that the ore and fuel bins are situated. The daily capacity of each of these furnaces is 125 tons, although one of the furnaces has reduced 187 tons of ore in one day, and the furnace manager says that 135 tons could be reduced without much forcing. The furnace itself is a steel plate water jacket of the Herreshof patent, made in Sherbrooke, P. Q., by the Jenckes Manufacturing Co'y. It is nearly oval in form, the longer diameter at the tuyères being 6 ft. 6 in., while the shorter one is 3 ft. 3 in. There are 11 2½ in. tuyères through which the blast enters from a Baker's rotary blower under a pressure of about 9 oz. per square inch. It is 9 feet high from these tuyères to the charging door, and is an unbroken water jacket from the cast iron bottom up. It is made of rolled steel with only a 2 inch water space, and not a single brick of any description. The well is a circular, cast iron water jacketed vessel, mounted on four strong wheels for convenience of moving it when repairs are necessary, and so made that the hole in one side connects with the outlet hole of the furnace, which is also thoroughly protected by water and it is through this that the matte and slag flow out of the furnace as rapidly as formed. They thus escape the influence of the blast, and prevent what Vivian calls "the sole objection to blast furnaces" the so-called "sows" or "salamanders" as great masses of metallic iron which choke up the furnace and tie up large quantities of copper and other metals. The charging door is situated on the upper floor, as also the bins for roast ore and coke. The coke used is from Connellsville, Pa., and is brought by way of the Great Lakes and the Sault Branch of the C.P.R. The charge for the furnace consists of 1,800 or 2,000 lbs. of ore and coke mixed, one ton of coke usually sufficing for eight tons of ore. The mass as it melts gathers at the bottom of the furnace, and flows through the outlet into the well or reservoir, where the heavier and metallic portions sink to the bottom while the lighter slag remains on the surface, running in a continuous stream over the jacketed spout into pots on wheels, which are removed when filled, an empty one always being ready to take the vacant place. The matte is drawn off at intervals of 15 or 20 minutes through a separated bronze water-cooled tap-hole casting, near the bottom of the well, and which is filled as usual with a clay plug that can readily be removed with a few blows from a steel bar. The smelting of the ores is greatly facilitated by the basic character of the accompanying gangue rock, for instead of quartz and acid silicates there is chiefly hornblende and very fusible felspars. This circumstance, as well as a judicious mixture of the different qualities of ore obviates the necessity of any flux, which is a very fortunate circumstance, as limestone is somewhat distant and suitable iron ore difficult to procure. The slag buggies or pots are made as strongly and lightly as possible, are case-hardened and shaped like inverted hollow cones, and before each tap are thickly washed with clay water to prevent the matte from welding to the iron mould. This matte is sampled and weighed and allowed to cool before being dumped from the pots and the slag also is sampled and assayed once every 24 hours, so that an accurate record can be kept of the composition of both. An average of two analyses of this matte in February and March, 1889, will probably give us the usual composition: Copper, 26.91; nickel, 14.14; iron, 31.335; sulphur, 26.95; cobalt, .935. Mr. F. L. Sperry says that platinum exists in quite appreciable quantities, so that the matte contains some ounces per ton of that rare metal, while gold and silver occur in strong traces. The first blast furnace was started on the 24th December, 1888, and with slight interruptions has been running ever since. The second furnace was built in the summer of 1889, and was started on the 4th of September of the same year. On October 1st, 1890, there was about 6,500 tons of matte, and the ore on the roast beds would produce about 6,000 tons more, containing 922 and 852 tons of nickel respectively, or a total of 1,774 tons of metallic nickel, and 3,362½ tons of metallic copper.

The average daily output of matte for the month of September, 1890, was 25 tons, but the full capacity of both furnaces would be about 60 tons of matte. If the former average was kept up, the yearly production of matte would reach 9,125 tons, but if the furnaces were run at their full capacity they would average nearly 8½ tons of nickel a day, or nearly 3,066 tons of metallic nickel and 5,913 tons of copper a year. At present the matte is piled in heaps outside of the smelters, and, when wanted to be shipped, is broken up in pieces and placed in old oil barrels, the chinks between the larger pieces being filled with smaller fragments, so that the whole is packed tolerably firm and close. It is then sent to the various refiners in Europe or the United States according to their respective bids. So far no refining works have been built at Sudbury, but the vast quantity of material to treat, the tedious and costly process for the further refining of the ore, consisting as it does of alternate roastings and smeltings, in addition to the great expense incurred at present in shipping the matte to such long distances, seem great incentives to the early erection of refining works, so that the ore could be fully treated on the spot. The proposition to build nickel steel works was lately submitted to the Government by the Canadian Copper Company, and it is to be hoped that some satisfactory arrangement will be arrived at to give a further impetus to our present mining activity in this region.

Nickel is a comparatively new metal for it was not recognized as an element till 1751, when Cronstedt, the Swedish mineralogist, in examining the ores of certain veins in the German Copper mines made the discovery of the two new metals, nickel and cobalt, which names he retained as they were in use amongst the miners. Nickel in its pure state is silver white in colour, hard, tough, fusible with difficulty, and is susceptible to magnetism, although not to the same extent as iron. Its use in the industrial arts has rapidly increased since it has been produced in a pure state, as it formerly existed only as an impure alloy, and so could not be so suitable for the pnrposes for which it is now used. The demand has only grown at a moderate rate as compared with the growth and demand for other useful metals, and a decrease in price from $2.60 per pound in 1876 to the present price, which varies from 50 to 60 cents per pound, seems to have had no very important influence in increasing that demand. The supply of late years has been more than sufficient for the demand and new deposits have always been found in advance of any necessity for their product. The first chief demand for this metal was for making nickel or german silver as a substitute for the more precious metal in making spoons and forks and other ware in general for which silver had been previously used, and its whiteness and the facility with which it received and held the silver, after the process of what is known as electro-plating was introduced cause it to be still more widely used. It is also made use of to plate iron, zinc, &c., and also in alloy with copper for the manufacture of small coins, which are used so extensively in the United States, Germany, Belgium, and other countries. The proposition to use rolled nickel plate as an advance over ordinary tin plate, is one which is receiving attention at present. It has also been recommended for making nickel crucibles to replace those of silver used in chemical manipulations as they would cost less and have the great advantage of melting at a higher temperature.

Nickel plated kitchen utensils are coming into general use as in Germany, and as it is well known that acids have a more or less solvent action on nickel, an investigation was undertaken which showed that 7½ grains of nickel could be taken into the stomach and repeated for a long time without any noticeably bad effects. There is thus no ground for uneasiness in the use of such utensils, especially if the same precautions are used as in the case of copper vessels, namely, thoroughly cleaning them and avoiding the storing of food in them. The proposition to use nickel in alloy with steel to increase the strength and quality of the latter, will, if carried out, increase the consumption very materially, and all have been eager to know the result of the recent experiments undertaken at the instigation of the United States Government. A French invention has effected the means of regulating the composition of such an alloy, and subsequent experiments in Glasgow revealed the fact that this alloy could be made in any good open hearth furnace working at a fairly high temperature as well as in the crucible. In obtaining a correct idea of the value or usefulness of alloys of nickel with iron or steel it should be borne in mind that the composition is complicated by manganese, carbon, silicon, sulphur and phosphorus, whose influence must be carefully watched, requiring a long series of experiments. A comparison of steel alloyed with 4.7 % nickel raised the elastic limit from 16 up to 28 tons, and the breaking strain from 30 up to 40 tons, without impairing the elongation or contraction of area to any noticeable extent. A further gradual increase of hardness was noticed until 20 % is reached, when a change takes place, and successive additions of nickel tend to make the steel softer and more ductile. The alloys polish well, and the colour of the steel is lightened as the proportion of nickel increases. They do not corrode as readily as other steel. The 1 % nickel steel welds fairly well, but this property lessens with each addition of nickel. It can, therefore, be seen that considerable advantage may be expected from these alloys, especially where the percentage of nickel is less than five.

The consumption of nickel and nickel alloy in the United States has increased from 294,000 pounds in 1880 to 421,000 pounds in 1888, while the total consumption of the world was estimated not to exceed 700 or 800 tons of the pure metal. The chief supply at present comes from New Caledonia, a penal colony of France (long. 165° E., S. lat. 22°). M. du Peloux states that the cost of production at this place could be so reduced that the company could sell at from 37 to 46 cents per pound, and yet have a good profit. Dr. Peters in his evidence before the Ontario Mining Commission states that the Canadian Copper Company could sell it from 25 to 30 cents per pound with a handsome profit. A commission appointed by the United States Government to examine the probable quantity of nickel in the Sudbury district has given a very glowing report to their government. It is highly probable, however, as can be seen from the above figures that our mines could supply the whole demand, even if the other sources of supply did not produce anything. It has been decided by the United States Government to make use of nickel steel armour plates, and already the contract has been awarded so that there is every prospect of a brilliant future for this mining industry around Sudbury. In view of our immense deposits it will be necessary to increase its consumption in every possible direction.

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BOOK NOTICE.

CATALOGUE OF CANADIAN PLANTS. Part V. Acrogens. By John Macoun, M.A., F.L.S., F.R.S.C. 1890.

The fifth part of Prof. Macoun's great work appeared last autumn and would have been noticed sooner but for promises made previously with regard to other matter printed in THE NATURALIST. As already stated, we consider Prof. Macoun's catalogue the most important work which has appeared on Canadian botany. Nor is this appreciation of our Canadian Linnæus confined to ourselves. J. E. Bagnall, writing in the *Midland Naturalist*, published at Birmingham, England, says in the February number: "This concludes Vol. II of this valuable work, the first 45 pages being devoted to an enumeration of the ferns and fern allies, with a full account of their geographical distribution through the Dominion of Canada; and as in the preceding portions of this work, the treatment throughout is excellent, and characteristic of the scientific acumen and indefatigable zeal of the author. The remaining portion of Part V is devoted to additions and corrections to Part I–IV, which occupy 103 pages, and record 155 species added to the flora of Canada since the publication of Part IV, raising the total number of flowering plants, ferns and fern allies found in Canada to 3,209 species; of these, 2,340 are Exogens, 771 are Endogens, and 98 are Acrogens."

In the serial literature of this continent, the following taken from the March number of the "Bulletin of the Torrey Botanical Club" may be taken as a sample of many similar articles which have appeared:— "We congratulate Prof. Macoun on the very successful progress of his work. He is contributing more at the present time to our knowledge of North American botany than anyone else, and through his endeavours the distribution of Canadian plants is becoming thoroughly worked out."

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SUMMARY

—OF—

Canadian Mining Regulations.

NOTICE.

THE following is a summary of the Regulations with respect to the manner of recording claims for *Mineral Lands*, other than Coal Lands, and the conditions governing the purchase of the same.

Any person may explore vacant Dominion Lands not appropriated or reserved by Government for other purposes, and may search therein, either by surface or subterranean prospecting, for mineral deposits, with a view to obtaining a mining location for the same, but no mining location shall be granted until actual discovery has been made of the vein, lode or deposit of mineral or metal within the limits of the location of claim.

A location for mining, except for *Iron* or *Petroleum*, shall not be more than 1500 feet in length, nor more than 600 feet in breadth. A location for mining *Iron* or *Petroleum* shall not exceed 160 acres in area.

On discovering a mineral deposit any person may obtain a mining location, upon marking out his location on the ground, in accordance with the regulations in that behalf, and filing with the Agent of Dominion Lands for the district, within sixty days from discovery, an affidavit in form prescribed by Mining Regulations, and paying at the same time an offioe fee of five dollars, which will entitle the person so recording his claim to enter into possession of the location applied for.

At any time before the expiration of five years from the date of recording his claim, the claimant may, upon filing proof with the Local Agent that he has expended $500.00 in actual mining operations on the claim, by paying to the Local Agent therefor $5 per acre cash and a further sum of $50 to cover the cost of survey, obtain a patent for said claim as provided in the said Mining Regulations.

Copies of the Regulations may be obtained upon application to the Department of the Interior.

A. M. BURGESS,
Deputy of the Minister of the Interior.

DEPARTMENT OF THE INTERIOR,
Ottawa, Canada, December 19th, 1837.