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CONTRIBUTIONS TO THE HISTORY

OF

THE ACTON COPPER MINE,

WITH

A PLAN OF THE MINE AND SIX SECTIONS.

BY

THOMAS MACFARLANE.

From the Canadian Naturalist for December, 1862.

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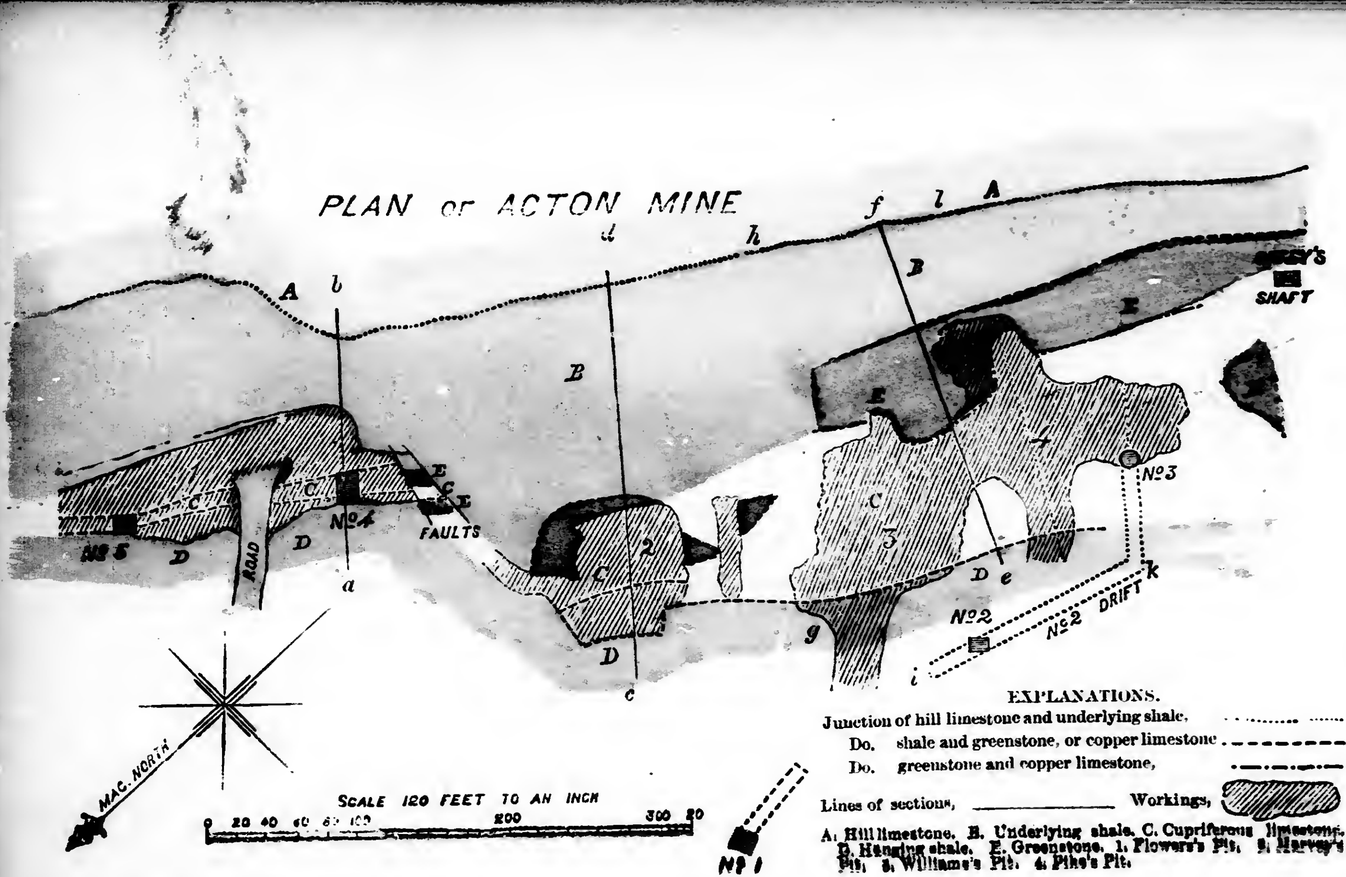

PLAN OF ACTON MINE
SHAFT
FAULTS
ROAD
No 1
No 2
No 2 DRIFT
No 3
No 4
No 5
MAC. NORTH
SCALE 120 FEET TO AN INCH
EXPLANATIONS.
Junction of hill limestone and underlying shale,
Do. shale and greenstone, or copper limestone
Do. greenstone and copper limestone,
Lines of sections,
Workings,
A. Hill limestone. B. Underlying shale. C. Cupriferous limestone. D. Hanging shale. E. Greenstone. 1. Flowers's Pit. 2. Harvey's Pit. 3. Williams's Pit. 4. Pike's Pit.

THE ACTON MINE.

Three years have elapsed since the opening of the Acton Copper Mine, and probably few mines have in such a short time gained a greater or more merited celebrity. It has been my good fortune to be connected with it since September, 1861, in such a capacity as enabled me to gain much experience as to the nature and value of the deposits of copper ore, which are here the objects of mining enterprise. Had it not been for this circumstance I should not have ventured upon another description of the Acton Mine, seeing that so many valuable papers on the subject are already in our possession. As it is, the few observations which I have made, and which I now proceed to record, are only to be regarded as supplementary to former descriptions, especially to those of Sir W. E. Logan, and the Rev. A. F. Kemp; and as embracing a sketch of the progress of the mine from September, 1861, when Messrs. Davies and Dunkin, the proprietors, received the mine back from the lessees who had previously worked it, until the first of October, 1862, when the mine was purchased by the South Eastern Mining Company of Canada.

In the month of September, 1861, mining operations were being carried on in the following workings: Flowers's pit, Williams's pit, Harvey's pit, and No. 2 shaft. It is to be observed with regard to these names, that the word pit is applied to an open working of irregular and very considerable dimensions, while the name of shaft is given only to regular sinkings of the usual and smaller dimensions. The position of the above named workings, and the character of the rocks in which they occur, and by which they are bounded, will be seen from the accompanying map.

The whole of the open workings occur upon a bed of what has been called in former descriptions "copper limestone," the general strike of which is N.E. and S. W., with a dip more or less inclined to the N. W. Immediately underlying this cupriferous limestone, which is dolomitic, there occur from twenty to eighty feet of dark colored shales, in which, especially near the cupriferous limestone, copper pyrites is frequently found disseminated in thin strings and layers. Beneath this occurs another bed of limestone, of very considerable thickness, the outcrop of which forms the hill running along the south-east side of the mine. Between the cupriferous limestone and the underlying shale, there is often intruded a fine-grained greenstone, which sometimes forms very considerable and irregular masses, sometimes intersects the limestone strata, and often presents a peculiar banded structure, resembling more that produced by igneous flow, than that due to deposition from water. This greenstone, although intruded most frequently between the underlying shale and the cupriferous limestone, is sometimes observed occurring between the latter and the hanging shale. This hanging shale, of a black color, which overlies the cupriferous limestone, is also often impregnated with copper pyrites, and has a very considerable thickness. It has not yet been ascertained what rock overlies the hanging shale in the immediate neighborhood of the mine, but from observations elsewhere, it appears to be followed by lighter colored shales, containing small interstratified quartz veins. Upon these shales is superposed a finely and evenly foliated clay-slate, with transversal cleavage. At greater distances from the mine there is found a considerable development of clay-slates and sandstones; some of the latter possessing the characters of the greywacke sandstone of German geologists. The whole of these rocks are apparently destitute of organic remains. According to Sir William E. Logan they constitute a part of the Quebec group of the Lower Silurian formation. Referred to the systems of continental geologists, they would appear to occupy a place between the primitive slate formation and the Silurian, in a formation corresponding to Barrande's Azoic formation in Bohemia, or to the Cambrian formation, as this is understood to be constituted by Cotta; viz., of less crystalline clay-slates and silicious slate, of non-fossiliferous greywacke sandstone and conglomerate.*

Having thus referred to the geological character and age of the rocks in the neighbourhood of the mine, I proceed to describe the various workings above named. Flowers's pit, the most north-easterly of the open workings, has a triangular shape, an average width of forty-five feet, and had in September, 1861, a depth of twenty feet. The bottom of the excavation consisted, on the south-easterly side, of shale, while the outcrop of the cupriferous limestone, having a thickness of four feet, ran along the north-west side. The original thickness of forty-five feet of limestone, had thus, on account of a fold in the underlying shale, decreased to four feet, as shown in the following section at No. 4 shaft.

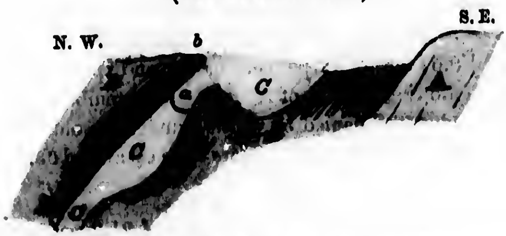
The excavation of the limestone at *a* was continued, (the point

Cotta: Die Flötz Formationen, p. 204.

of shale *b* having been previously taken down) in the south-westerly half of the opening, along a distance of about sixty feet, and to an additional depth of seven feet. The limestone was more or less charged with ore along the whole of this distance; but having in view the disadvantages which attend such large excavations in depth, it was resolved to sink a shaft, in order to examine the

Section on the Line a-b.

(*See General Plan.*)



A, Hill limestone, B, underlying shale, C, cupriferous limestone, D, hanging shale.

ground before hand. Accordingly shaft No. 4 was commenced in the south-west end of the working, and sunk, at intervals, to a depth of seventy-five feet on the inclination of the bed. The first twenty-five feet sunk below the open working was in rock containing very good ore, of which rock eighteen and a half cubic fathoms were excavated, and yielded—

$1\frac{3}{2}\frac{0}{3}\frac{1}{3}\frac{1}{2}$ tons of first quality ore of 24.0 per cent of copper.
$133\frac{2}{2}\frac{1}{4}$ " crush " 2.0 " "

These quantities correspond, after deducting the loss in dressing the crush ore (one-third of the copper contents), to 18.6 tons of 12 per cent ore, or about one ton per cubic fathom. The cost of sinking these twenty-five feet, and bringing the rock to the surface, amounted to $482.94; or to $26.10 per cubic fathom of rock, and $25.96 per ton of 12 per cent ore. Below the twenty-five feet the ground was found to be poor; and in June, 1862, the sinking was discontinued, in order to the stoping of the ore ground on each side of the shaft. Up to the end of July, 45.62 cubic fathoms were stoped out in the north-east side of the shaft, and yielded—

10[illegible]	tons	first	quality	ore of	22.0	per cent.
43[illegible]	"	"	"	"	18.4	"
1[illegible]	"	second	"	"	9.0	"
154	"	crush		"	4.06	"

These quantities, after deducting loss in dressing, correspond to 119[illegible] tons of 12 per cent ore, or 2.62 tons per cubic fathom. The total expenses of excavation and bringing to surface, amounted to $574.10; equal to $12.59 per cubic fathom, and to $4.80 per ton of 12 per cent ore. The average thickness of the bed was here 19½ feet, = 3¼ fathoms. Consequently one square fathom of the bed yielded 8.51 tons of 12 per cent ore, at an expense of $40.92. During the following months of August and September the stoping was continued, accompanied by drifting under the old road leading into Flowers's pit (see map). Here were excavated 63.37 cubic fathoms of ground, which yielded—

40147	lbs.	first	quality	ore of	21.2	per cent.
23850	"	"	"	"	19.8	"
7114	"	second	"	"	13.5	"
17600	"	"	"	"	11.5	"
40320	"	crush		"	5.2	"
134400	"	"		"	4.1	"
22400	"	smalls		"	3.5	"
128427	"	"		"	2.6	"

These quantities, after deducting one-fourth of the copper contents of the crush ore, correspond to 95[illegible] tons of 12 per cent ore, or 1.5 tons per cubic fathom. The total expense of mining and raising this quantity was $873; equal to $13.77 per cubic fathom, or to $9.19 per ton of ore. The average thickness of the bed was at this place 2½ fathoms. Consequently a square fathom of the bed yielded 3.75 tons of 12 per cent ore, at an expense of $34.32.

As regards the north-east extremity of Flowers's pit, a shaft had been sunk in the limestone there previous to September, 1861, to a depth of twenty feet on the incline, below the bottom of the open working, and forty-four feet below the floor, on the present collar of the shaft, now called No. 5. At the bottom, a considerable quantity of copper pyrites was observable, partly in veins permeating the limestone, and partly impregnating the same. In order to the examination of the ground here it was resolved to sink this shaft. The ground gradually improved, and at a depth of fifty-four feet presented an appearance exactly similar to the rich deposits previously excavated on the surface. This appearance has been most suitably and accurately described by Sir W. E. Logan as "a breccia or conglomerate, with a paste composed of variegated and vitreous sulphurets of copper, mingled "with fine grained silicious matter, enclosing fragments of lime-"stone, some angular and some rounded, some of them almost "wholly calcareous and others largely silicious."* The average thickness of the bed in the ten feet thus sunk, was nine feet, the length of the shaft on the strike of the limestone, twelve feet. From the five cubic fathoms thus excavated, there were produced

$1\frac{4\,2\,2}{2\,3\,2\,1}$	tons	first quality	ore of	22.0	per cent.
$83\frac{4}{2\,1}$	"	crush	"	4.5	"

These quantities, after allowing for the loss, correspond to 23.1 tons of 12 per cent ore, or 4.6 tons to the cubic fathom. The costs of mining the above five cubic fathoms, and bringing them to the surface, amounted to $133.33, which is equal to $26.66 per cubic fathom, and to $6.03 per ton of 12 per cent ore. Calculated at the above mentioned thickness of 1½ fathoms, a square fathom of the bed yielded 6.9 tons of 12 per cent ore, and cost $40. The sinking of No. 5 shaft was discontinued during the winter, but resumed during the summer, and at the end of July attained a depth of seventy-six feet on the incline. From it, at a depth of sixty feet, a gallery was carried towards the west, 30¾ feet; at which distance from the shaft the limestone was cut off by the hanging wall, every indication seeming to point out the presence here of a left-hand throw. This fault had a direction of N. 10° W. Some stoping was done both above and below this gallery. Up to the end of July there were excavated in shaft, drift and stopes, 65¼ cubic fathoms of ground. These yielded

$53\frac{2\,3\,1}{2\,3\,3\,1}$	tons	first quality	ore of	19.1	per cent.
$4\frac{2\,1\,5\,7}{2\,3\,3\,2}$	"	second "	"	9.0	"
$316\frac{4\,6\,0}{2\,2\,4\,5}$	"	crush	"	3.95	"

which quantities correspond to $155\frac{2\,1\,7}{2\,3\,3\,1}$ tons of 12 per cent. ore, or 2.38 tons per cubic fathom. The total expense of mining and raising this quantity was $1512.04; or $23.17 per cubic

* Report of Progress for 1858, p. 59.

fathom, and $9.72 per ton of ore. The thickness of the bed at this point was 16½ feet, = 2¾ fathoms. Consequently a square fathom of the bed contained 6.54 tons of 12 per cent ore, and cost $26.73. The limestone in No. 5 shaft generally maintained a dip of from 70° to 80°, and the character of the ore was principally that described by Sir W. E. Logan, as above quoted. The richest specimen assayed from this shaft contained 41.2 per cent copper, and 19.2 per cent of silicious matter. It was not altogether free from limestone. The strike of the bed of limestone from shaft No. 4. to No. 5. is N. 34°. E. Friction grooves have been observed at the junction of both the foot and the hanging shale with the limestone. These generally dip to the west at an angle of about 50°. In August and September, No. 5 shaft was further sunk fifeeen feet, thus reaching a depth of ninety-one feet. The ground between the shaft and the fault above noticed was also stoped out. It was poorer than that previously excavated, but the thickness of the bed increased to twenty-four feet.

Immediately to the west of Flowers's pit, there appears to exist one or more powerful faults, which have thrown the cupriferous limestone 140 feet to the right hand. These are indicated on the map, from which it will be seen that the principal one has a direction of about east and west, and comes in at the east end of Harvey's pit, where the evidences of the existence of this right hand throw are very striking. It is worthy of remark, that a great accumulation of rich ore was excavated from Flowers's pit, at the point where this fault intersected the one described as occurring in the drift to the west of No. 5; traces of this are also be found on the surface. These faults, the existence of which was, I believe, first pointed out by Principal Dawson, will doubtless be found to influence considerably the ore-bearing qualities of the limestone bed.

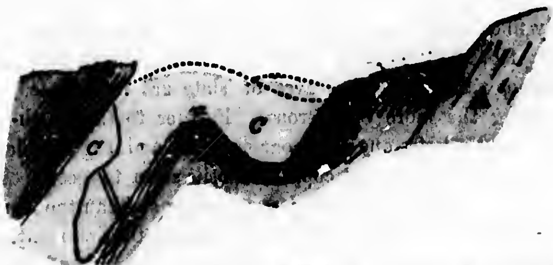
Harvey's pit is the next open working to the west of Flowers's pit. On the surface it has a length of one hundred, and a breath of eighty feet. The following is a section of the working, at right angles to the direction of the strike; from which it will be seen that the same relations exist here as in Flowers's pit, so far as the architecture of the limestone and the underlying shale is concerned:—

The same contraction in the thickness of the limestone is visible here, as at Flowers's pit. This rock, before its excavation, bent over the point *a*, and constituted the arch of limestone mentioned in a former description of the mine, by the Rev. A. F. Kemp.* It was on this arch that the first excavation was made in opening the mine. Harvey's pit was last worked in September, 1861. The previous mining had been done very irregularly, and the cupriferous limestone had not been wholly removed; but a considerable part of it was left against the hanging wall, as shewn in the preceding sketch. This limestone had, moreover, been supported by heavy timbering, which again had been loaded with waste rock. To have taken down the whole of this limestone would have been expensive, and to have cut through it to the hanging wall beneath the timbering would have left the pit in a very unsafe condition. To have sunk a shaft at one end of the pit would probably have been the best plan, had it not been thought preferable to sink or drive from No. 1 shaft, 140 feet northwest of Harvey's pit. These considerations prevented any excavation from being made in this opening; and, since September, 1861, it has been used as a reservoir for water employed in dressing the ore. There is still ore visible in Harvey's pit, nearly in the middle at the deepest point, and on the stope at the west end.

Section on the Line c-d.

(*See General Plan.*)

N. W. S. E.



A, hill limestone; B, underlying shale; C, cupriferous limestone; D, hanging shale; E, greenstone.

The next open working of importance, to the west of Harvey's pit, is Williams's pit. In September, 1861, it was separated from Pike's pit by a piece of ground, since removed, under which a

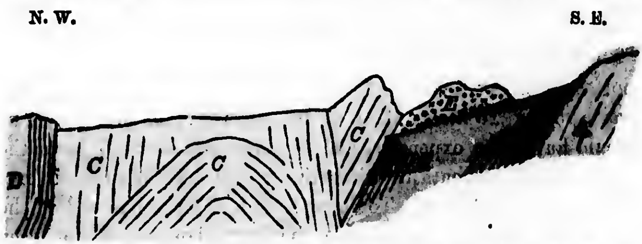
* See Canadian Naturalist, Vol. V. page 360.

very large drift had been excavated. The east side of Williams's pit, was worked in September, 1861, and 161½ cubic fathoms of rock excavated. These yielded:

$16\frac{113}{2332}$ tons, first quality ore of 24.0 per cent.
$211\frac{17}{24}$ " crush " 4.5 "

which, after deducting loss in dressing, correspond to 85 tons of 12 per cent ore. The eastern stope, consequently, contained 0.52 tons of 12 per cent ore per cubic fathom. The total expense of excavation was $1292.00; or $8 per cubic fathom, and $15.17 per ton of 12 per cent.

The distance from the underlying to the hanging wall, on the east slope of Williams's pit, is 135 feet; which extraordinary width is wholly filled up by limestone of slightly different varieties. Next to the foot wall may be observed a fine grained, light grey limestone, with which thin leaves of slate are intercalated, the slate being the more cupriferous. Further to the north-west, there follows a limestone of a coarser grain and slightly darker color, in which the richest copper deposits seem to occur. Portions of this are also slaty, but less regularly so than the variety just mentioned. Still further to the northwest, the first mentioned



A, hill limestone; B, underlying shale; C, cupriferous limestone; D, hanging shale; E, greenstone.

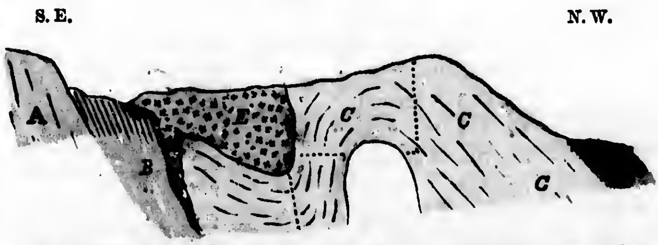
slaty limestone again appears; after which succeeds a cupriferous limestone, characterised by being impregnated with copper pyrites, and by containing here and there patches, consisting of silicious matter and copper pyrites, which project from the surface of the limestone, wherever it has been exposed to the influence of the atmosphere, in the form of moss-like efflorescences. The extraordinary thickness which the limestone attains in Williams's pit, seems to be attributable to foldings in its strata. The stratification of the limestone is very obscure, and is rendered more so by innumerable joints, and veins of calcspar, which ramify through the limestone in all directions. Judging however from the position which a certain narrow band of schistose limestone occupies, it appears as if the limestone of the east slope of Williams's pit was stratified as sketched in the preceding section:

Between Williams's pit and Pike's pit there existed, as already mentioned, previous to January, 1862, an arch of limestone; which was perhaps the most picturesque feature of the mine. During the winter, a large quantity of water having accumulated in Williams's pit, and become frozen over, it was judged advantageous to take down the arch, while the access to it by means of the ice was convenient. The piece of ground on the south side of the arch, abutting against a huge mass of greenstone, together with the rock above the arch, contained 770 cubic yards = 96 cubic fathoms nearly. These produced:

$4\frac{1412}{2352}$	tons	first quality	ore of	23.0	per cent.
$67\frac{9}{24}$	"	crush	"	4.7	"
$154\frac{5}{24}$	"	"	"	2.7	"

which quantities correspond to $69\frac{1}{2}$ tons of 12 per cent ore. Consequently, a cubic fathom of this rock gave 0.72 tons of 12 per cent ore. The cost of mining and hauling was $539, or $5.61 per cubic fathom, and $7.75 per ton of 12 per cent ore. The following is a section of the limestone and the adjoining rocks at this point, as seen from the north-east side previous to the excavation:

Section on the Line e-f.
(*See General Plan.*)



The letters denote the same rocks as in former sketches. The dotted lines show the piece of ground mentioned above. It will be observed that here also there exist evidences of foldings in the limestone strata, and that towards the west end of the mine, the greenstone becomes extensively developed.

After blasting down the arch, Williams's pit was not worked until May, 1862. By that time, however, it was completely filled with water; and the quantity contained in it could not, considering the immense area of the excavation, have been much under a million of gallons. Previous to working the pit, it was emptied to within a few feet of the bottom, by means of a syphon made of a two-inch malleable iron pipe, 350 feet in length, leading into No. 1 shaft; from which the water was raised by the pump attached to the stationary engine there. Blasting was then commenced, and up to the end of July there were excavated 1104 cubic yards = 138 cubic fathoms of limestone, which yielded:

6 $\frac{2066}{2352}$	tons first quality	ore of		20.0	per cent.
56 $\frac{2338}{2352}$	"	"	"	18.4	"
277 $\frac{461}{2240}$	" crush		"	5.2	"

These quantities correspond to 175 $\frac{134}{2352}$ tons of 12 per cent. ore, or 1.27 tons per cubic fathom. The total expense of emptying the pit, excavating the rock, and bringing it to the surface, amounted to $1092.29, or $7.91 per cubic fathom, and to $6.24 per ton of 12 per cent ore. Mining was continued in Williams's pit during the months of August and September, and a considerable part of what constituted the floor of Pike's pit was removed. During these two months there were excavated in all 1468 cubic yards = 183½ cubic fathoms of rock; of which about one-third was in the rich ore-ground on the south-east side of Pike's pit, and the other two-thirds in the much poorer rock situated between the old face of the western stope of Williams's pit and No. 3 shaft. The following lots of ore were produced from the above quantity of rock:

236215	lbs. first	quality	ore of	19.3	per cent.
169200	" "	"	"	19.8	"
28456	" second	"	"	13.5	"
120000	" "	"	"	11.5	"
454720	" crush		"	5.0	"
680960	" "		"	3.5	"
143360	" smalls		"	2.8	"
327040	" "		"	3.5	"

These, after deducting one-fourth of the copper contents of the crush ore, are equal to 507 $\frac{1328}{2352}$ tons of 12 pet cent ore. Consequently, a cubic fathom of this rock yielded 2.76 tons of 12 per cent ore. The total expense of mining and hauling to surface was $1777.12, or $9.68 per cubic fathom, and $3.50 per ton of 12 per cent ore. The width of the limestone horizontally across Williams's pit, at this point, is 150 feet; the width of the stope nine fathoms. If we assume the thickness of the limestone, at right angles to the underlying shale, to be twelve fathoms, which is evidently a moderate estimate, then a square fathom, along the plane of the bed at this point, contains 33.12 tons of 12 per cent ore. In the upper part of Williams's pit, the conglomerate character of the cupriferous limestone, referred to in describing No. 5 shaft, is beautifully developed. Masses of this character have frequently been blasted out, measuring at least eight cubic yards. A large mass of nearly the same dimensions was found loose on the surface of this deposit. On drilling a hole into it, preparatory to blasting it, the borings obtained were carefully collected and examined. They contained:

Silica,	36.98	
Carbonate of lime,	4.64	
Alumina,	0.84	
Iron,	7.01	
Copper,	34.20	by assay.
Sulphur,	16.33	by difference.
	100.00	

The three last ingredients calculated to 100 parts give

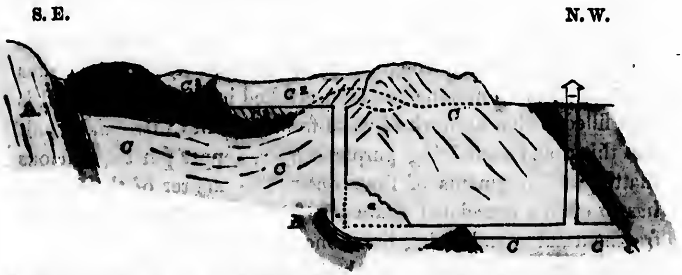
Iron,	12.18
Copper,	59.44
Sulphur,	28.38
	100.00

which figures approximate pretty closely to some analyses of purple copper. In the bottom of Williams's pit, about forty feet below where this mass was found, the ore is more solid, not so much diffused through the limestone, but concentrated in veins, which are pretty distinctly separated from the side rock. In one of these, of considerable thickness, I found the purest purple copper which I have yet observed on the mine. It contained neither lime nor silica, and assayed 61.9 per cent of copper. At no great distance from this vein, the limestone was destitute of copper, and had the following composition :

Silica,....	1.50
Alumina and peroxide of iron,......	2.85
Carbonate of lime,................	7 .10
Carbonate of magnesia,............	24.12
	99.57

Previous to September, 1861, No. 2 shaft had been sunk through shale, and into the limestone to a depth of seventy-eight feet; and a drift carried from it, at this depth, both towards the hanging wall, and towards the foot wall. The direction of this drift was N. 10° E.; consequently not at all at right angles to the direction of the strike, (which in this part of the mine appears to be N. 20° E.); but rather parallel with it. The length of the drift from the shaft to the hanging wall was forty-two feet, to the foot wall sixty feet. This latter, which was partially cut through, was found to be of greenstone, or rather a shaly greenstone, composed of alternate layers of that rock, and of shale with copper pyrites. This constituted at least the lower part of the face of the drift. The upper part was of limestone. In view of these circumstances, and although a gallery had been driven twenty-seven feet along this foot wall to the west, it was deemed proper to continue the main drift. This was done for a distance of sixty feet in the same direction of N. 10° E., always in limestone; the bottom of the drift consisting almost the whole distance of the same shaly greenstone. Some good patches of purple copper were met with, and also some veins of calcspar with purple copper and copper pyrites, dropping down from above; these veins led to the belief that the drift was being carried along underneath the ore. At the distance of 120 feet from the shaft, the direction of the drift was altered to N. 63° W. (in order to meet No. 3 shaft); the drift was then carried sixty-three feet further, always on the foot wall, which gradually rose, until the driving was discontinued; when it was found to have an inclination to the N. W. of 40°. In driving this sixty-three feet, some little copper was discovered, principally in veins of calcspar from one to three inches thick. Shortly after the driving here was discontinued, No. 3 shaft, which was meanwhile being sunk, was carried down to the drift, and made to communicate with it. No. 3 shaft had, previous to September, 1861, a depth under the floor of Pike's pit, of twenty-six and a half feet. In March and April it was further sunk twenty-seven and a half feet, and at the depth of fifty-four feet it broke through into No. 2 drift. The last six feet sunk was in poor rock, but, previous to this, twelve feet had been sunk through cupriferous limestone, permeated by veins of calcspar and quartz, containing purple copper. One of these veins seemed, in the southeast corner of the shaft, to have a dip of about 45° to the N. W., but on the opposite side it became very much flatter

This circumstance seemed to confirm the opinion that No. 2 drift had been carried along underneath the copper, so that it was determined to stope back from No. 3 shaft, overhead in the drift. In a short time the few feet of poor rock constituting the roof of the drift were removed, and a bed of limestone exposed, containing numerous veins consisting of purple copper and silicious matter, and presenting an appearance similar to that described as occurring in the bottom of Williams's pit. The following sketch is a section along a line running from No. 2 shaft to No. 3, and thence across Williams's pit:



A, Hill limestone; B, underlying shale; C, cupriferous limestone; D, hanging shale; E, greenstone; C2, Dark coloured silicious limestone, distinctly stratified, with impregnating copper pyrites.

It will be observed that a jog or bend of the footwall occurs in No. 2 drift, similar to those occurring at the surface in Harvey's pit and Flowers's pit; and that it was in the basin thus formed, and a little from the bottom of the same, that the rich ore at *a* was discovered. The excavation of ore at this point, by widening the drift and stoping overhead, commenced on the 1st. of June. From that date until the 8th of August, 573 cubic yards = 71.6 cubic fathoms were excavated. These produced:

$7\frac{1381}{2352}$	tons	first	quality	ore of	22.0	per cent.
$13\frac{1067}{2352}$	"	"	"	"	18.4	"
$4\frac{1032}{2352}$	"	"	"	"	24.0	"
$2\frac{505}{2352}$	"	second	"	"	9.0	"
269	"	crush		"	4.2	"

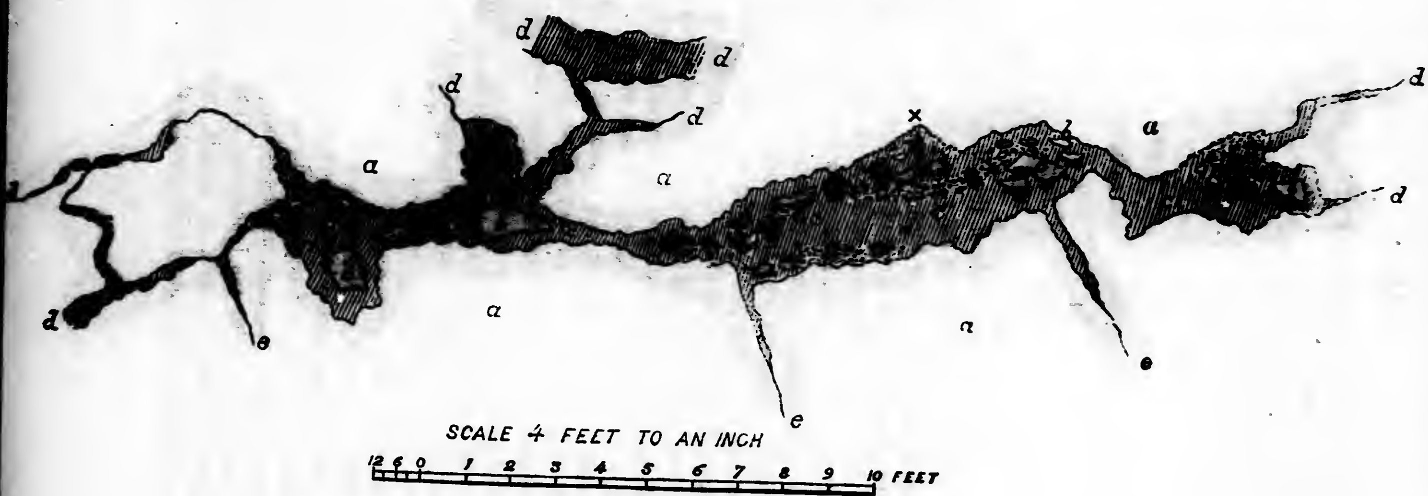
corresponding to $101\frac{808}{2352}$ tons of 12 per cent ore, or 1.41 tons per cubic fathom.

The total expense of mining and bringing to surface was $1288, or $18 per cubic fathom, and $12.71 per ton of 12 per cent. ore. Mining was continued here after the above date, but up to the end of September no further measurement had taken place. Probably nowhere else on the mine are such beautiful and distinct specimens of the copper conglomerate, or rather breccia, observable, as in the excavation above No. 2 drift. In many cases the line of division between the cupreous matrix and calcareous fragments is sharp and distinct; and it not unfrequently happens that there may be found in close proximity to each other, pieces of matrix almost free from lime, and fragments of limestone containing not a trace of copper. To judge from the appearances in No. 2 drift, the cupriferous limestone there does not contain a definite bed of conglomerate running irregularly through, and subordinate to it. It seems rather that the limestone has been cracked in all directions, and is now filled with a network of veins from an inch to two and a half feet thick, and containing purple copper, copper pyrites, silicious matter, and fragments of limestone. The matter of these veins has so often a brecciated character, from the presence of angular fragments of the adjoining limestone, as frequently to entitle it to the old German name of "Gang brockengestein," a term sometimes used for characterising this brecciated structure in veins. The accompanying sketch shews a section of one of these veins cut through in stoping upwards from No. 2 drift :

The following analysis was made of a piece of veinstone, from the same vein which enclosed a well defined angular fragment of limestone :

Silica..........................	38.65	
Carbonate of lime,.............	0.95	
Iron...........................	7.31	
Copper.........................	37.20	
Sulphur,.......................	15.89	by difference.
	100.00	

PLAN OF VEINS IN DRIFT No. 2



EXPLANATIONS.

a. Limestone.
b. Fragments of limestone
c. Purple copper and silicious matter.
d. Leaders connecting with other veins.
e. Offshoots similar to those cut in the drift before the discovery of the copper.
× Points at which specimens were taken for examination.

The angular fragment contained no copper, but gave:

Silicious matter,..............	8.25
Alumina and peroxide of iron...	2.75
Carbonate of lime.............	73.20
Carbonate of magnesia.........	15.50
	99.7

Other specimens of veinstone examined contained as follows:—

	1.	2.	3.
Silica	18.3	30.5	36.9
Copper	47.4	42.6	33.4

From the various analyses made of the purple copper, it does not seem to differ essentially from the variety of this mineral to which the formula $Fe\,Cu^5\,S^4$ has been given.

I have thus described the progress of the mine, and the results obtained in the various productive workings during the thirteen months ending 30th September, 1862. If we take the average of these results, we find that the average produce per cubic fathom has been 1.6 tons of 12 per cent ore; the average cost of mining and bringing to surface, $11.28 per cubic fathom, and $7.03 per ton of 12 per cent ore. These, it will be observed, are the results of mining in the productive part of the cupriferous bed, exclusive altogether of the cost of explorative work, of which latter it was only in No. 2 drift that any considerable amount was done. Probably the cost of prospective work did not exceed $1.50 on each ton of ore produced; so that we may assume that the cost of searching for ore, mining and bringing it to the surface, was $8.50 per ton of 12 per cent.

Before leaving this part of the subject, I may be permitted to make some remarks as to the nature of the deposit and the source of the ore. It will probably be admitted on all hands, that the bed of limestone in which the ore occurs, is of sedimentary origin, and originally possessed a horizontal position. Nor will it probably be denied, that a part at least of the copper; viz., that part which occurs in the form of copper pyrites, finely disseminated through some parts of the rock, was deposited, in some state or other, simultaneously with the limestone. That the limestone and the rocks adjoining it have, by certain powerful agencies, been raised from their horizontal position, and in this process been rent, broken, bent and twisted in the most violent manner, is evident from the various phenomena presented in every part of the mine. Whether this upheaval was caused by the greenstones being thrown up from beneath, seems to be uncertain, but it is probably not unreasonable to suppose that this protrusion of the greenstone occurred simultaneously with the upheaval of the strata; and that both may have been caused by certain more general and wide spread movements of the earth's crust. Whatever may have caused the upheaval, it seems sufficiently evident that this upheaval caused the rending of the limestone, the formation of the fissures and crevices, in which the copper ore was subsequently deposited, and the partial filling up of these by detached fragments of limestone of all possible dimensions. With regard to the filling up of the fissures by the copper ores, we may conceive three different modes in which this may have been effected: 1. The ores may have been injected into these fissures in a fused state. 2. They may have been removed from the impregnated side rock by certain solvents, and re-deposited in the fissures. 3. They may have been brought up from beneath by springs. With regard to the first of these theories, it must be remarked that the general appearance of the veins, coupled with the presence of greenstone in the neighborhood, would seem to be in its favor. But when it is considered that the ore is intimately associated with quartz, or rather with chert, this view of the origin of the ore does not appear admissible. It is difficult to conceive of a fused material so homogeneous as the substance which forms the matrix of the breccia, consisting exclusively of metallic sulphurets and silica. And even although it were possible to imagine a fused mass of this composition, the degree of heat required for its fusion would have been such as to exert an action on the adjoining limestone, similar to that produced by certain igneous rocks, viz., a conversion of the greyish colored limestone into white crystalline marble. With regard to the second theory, the presence of sillica does not present any difficulty, because it is a well-known fact that that substance is deposited in large quantities from hot springs. It is not unreasonable to suppose that the water percolating through the rocks possessed a high temperature, because it is not unlikely that a higher temperature than the present prevailed after the Lower Silurian strata had been deposited. With regard to the manner in which the copper may have been dissolved, and held in solution by the water, it seems evident that it could not have existed in the water in the state of sulphate of copper, from the oxydation of impregnated copper pyrites; because such a solution on coming in contact with limestone would have formed with it sulphate of lime and carbonate of copper. Nor is it possible to ignore the physical properties of copper pyrites, and suppose it to have been, to however slight an extent, soluble in water. The only solvents known for heavy metallic sulphurets, are the alkaline sulphurets. Many heavy metallic sulphurets when fused with sulphuret of potassium or sodium, yield when treated with water, solutions containing considerable quantities of the heavy metals; and I have found that on fusing a regulus containing iron, copper, cobalt and nickel, with sulphate of soda and charcoal, and treating the result with water, a dark green solution was obtained, containing, after careful filtration, all four of these metals. This solution, on exposure to the air, gradually oxydized, became colorless, and deposited the metallic sulphurets as a black powder. I am not quite prepared to assert that the copper in the veins above referred to was deposited in this manner; but I am of opinion that if we are to adopt the theory of secretion from the side rock, this is the only explanation which is admissible. The third theory of the source of the copper is probably the correct one, and it is the one which is most in accordance with generally received opinions. Cotta, for instance, regards it as certain that mineral veins proper have been filled up by infiltration, and that the material thus deposited came from beneath.* If we however attempt to go a step beyond this general explanation, we must enquire as to the nature of the solvent, and in doing so can scarcely arrive at other results than those mentioned in connection with the second theory. We must regard the alkaline sulphurets as the most probable solvents under the circumstances; and when we reflect that the sulphurets of platinum, gold, mercury, tin, tellurium, antimony, arsenic, vanadium, molybdenum, tungsten, nickel and iron, are all soluble in alkaline sulphurets, it will appear that the latter may have played a more important part in the formation of ore veins than has been hitherto supposed. When moreover it is remembered, how numerous and diverse the double sulphur salts are, and how many of these, especially arsenic and antimonious sulphurets

* Cotta: Erzlagerstätten, p. 127.

occur in ore veins, the importance of the agency of the alkaline sulphurets in the filling up of such can scarcely be over-rated.

This sketch of the recent results of mining at Acton would scarcely be complete without a description of the processes employed for concentrating the ore and a reference to certain experiments instituted for the purpose of ascertaining the amount of copper lost in the processes of crushing and jigging.

As soon as the ore has been brought to the surface it undergoes the process of coarse spalling; that is, it is separated from the waste rock, and broken into pieces having a diameter of from four to six inches. These pieces are sorted, according to the quantity of copper they contain, into first quality ore, second quality ore, crush ore and fourths. The first three sorts then undergo the process of fine spalling. The first quality ore is broken into pieces of the size of an egg, and any poor rock which these may contain is picked out. It thus yields marketable first quality ore, containing from eighteen to twenty-four per cent. The second quality pieces, treated in the same way, yield marketable second quality ore, containing from ten to thirteen per cent. The crush ore, after having been spalled down, and separated from the waste rock, assays from three to five per cent. It is further treated by crushing and jigging. The so-called fourths consist of limestone containing copper pyrites in coarse grains, small strings and finely disseminated particles. This quality is not worked up at present. It is piled in separate heaps, in order to be treated by stamping and washing, so soon as the apparatus for that purpose is procured. Besides the coarser rock, there is produced, in the various workings, smalls; which consist of pieces of ore and rock whose diameter does not exceed three or four inches, and which are usually so coated with mud as not to be easily separable from each other. These smalls are first thrown upon a screen, the bars of which are one and a quarter inches apart; the larger pieces which remain upon it are sorted and spalled in the same way as the coarser rock; while the smaller pieces, which pass through, and assay from two to three per cent, are at once subjected to crushing and jigging.

The crush ore, and the finer part of the smalls, are reduced by passing between cast iron rollers, to such a size as to pass through a sieve of twelve holes to a square inch. The crushed product is then brought into a jigging sieve, having sixty-four holes to a square inch. This sieve is wholly immersed in water, where it receives a succession of jerks, each of which causes it to descend, and suspends its contents in the water. These then arrange themselves according to their relative specific gravities; the richest and largest particles at the bottom of the sieve, the poorest and smallest at the top. After the sieve has received a sufficient number of jerks, it is raised out of the water, and the upper layer, or skimmings, scraped off. These contain from one and a-half to two per cent copper, and are thrown aside. That part which collects at the bottom of the sieve, and contains twelve to fourteen per cent of copper, is called ragging, and is a marketable product. There is sometimes produced an intermediate sort called seconds, occupying a position on the sieve between the skimmings and the ragging. This is laid apart, and afterwards re-jigged, the same products being produced as those above mentioned. In this process of jigging a considerable portion, the finest part of the crush work, falls through the sieve into the box below, which contains the water, and is called hutch-work. This, on being washed in a streak from the slime which it contains, assays from eight to eleven per cent. and is then in a marketable state. The costs of these various dressing operations were as follows:—Coarse spalling costs from fifteen to twenty-five cents per cubic yard of rock, according as the same contains less or more ore; fine spalling from fifty to eighty cents per ton of the resulting ore, according to the quality of the rock operated on. The processes of crushing and jigging cost during January, February and March, 1682, $5.60 per ton of products, and $1.15 per ton of crush ore. The total expense of coarse and fine spalling, and crushing and jigging, per ton, of all the products is at present $5.25.

The crushing and jigging processes are almost the same as those adopted in Cornwall for the dressing of crush ore, yet they are attended with the loss of much of the copper contained in the original crush ore. Having for a long time estimated the quantities, and assayed the samples of the crush ore put through the rollers; and ascertained the weight and contents of the resulting products, I have found that the loss of copper is much more than might at first sight be imagined. I subjoin a few of the results obtained: From the 17th of November to the 12th of December, 1861, there were crushed 956,760 lbs. of ore, containing 4.6 per cent, or 44,010 lbs. copper. From this there were produced 283,451 lbs. of products, averaging 10.95 per cent, and containing 31,052 lbs. copper. There were consequently lost 678,300 lbs. of skimmings and slimes of 1.92 per cent, containing 12,958 lbs. copper. Thus 29.5 per cent of the copper contained in the crush ore was lost in the skimmings and slimes. Further, during January, February and March, 1862, there were crushed 2,881,100 lbs. of ore averaging 3.4 per cent, and containing 100,303 lbs. of copper; from which there were produced 615,520 lbs. of products averaging 9.5 per cent, and containing 58,711 lbs. of copper. There were consequently 2,265,580 lbs. of skimmings and slimes of 1.83 per cent, containing 41,592 lbs. of copper. Thus 41.5 per cent. of the copper contained in the crush ore was lost. It is to be remarked, however, with regard to the foregoing results, that much of the copper contained in these skimmings and slimes is with proper appliances recoverable. Subsequent to the first of July, 1862, arrangements were made for dressing the ore by contract, and for working up a part of the slimes as these were being produced. Under this system the following result was obtained:—During the months of July, August and September, 1862, there were crushed 3,348,887 lbs. of crush ore and smalls, of from 2.0 to 5.9 per cent, averaging 4.1, and containing in all 137,969 lbs. of copper. From this there were produced 1,073,644 lbs. of products of from 8.0 to 12.6 per cent; averaging 9.9 per cent, and containing 106,625 lbs. of copper. There were consequently cast aside 2,275,243 lbs. of skimmings and slimes, averaging 1.38 per cent, and containing 31,344 lbs. of copper; which is equal to 22.7 per cent of the copper contained in the original ore.

From the results here narrated, it would appear that at least one-fourth of the copper contained in the crush ore is lost in the process of dressing it. The actual value thus wasted goes far to counterbalance the saving of freight which results from concentrating the ore. It would not certainly be attended with greater advantage to send the crush ore of four or five per cent to market instead of dressing it; but it admits of plain proof, that it would be better at once to sell an ore of seven per cent, and pay freight on it to Boston or New York, rather than to submit it to further concentration by crushing and jigging, and sustain the great loss of copper which occurs in these operations. The following calculations will be found to confirm this statement:

100 tons of 7.0 per cent ore would bring in Boston $4.00 per unit; which for 6.5 per cent, (½ per cent being deducted for the difference between dry and humid assay) is equal to $26.00 per ton,..........		$2600.00
From this deduct freight, barrels, &c., at $9.00 per ton,		$900.00
There remains,..................		$1700.00
On the other hand, 100 tons of 7.0 per cent ore would yield, by crushing and jigging, about 43¾ tons of 12.0 per cent products; which would bring, say at $4.30 per unit, for 11.5 per cent, $49.50 per ton,...		$2163.43
From this deduct:		
Cost of crushing, &c., at $5.50 per ton,.....	$240.70	
Freight and barrels, at $9.00 "	393.75	634.45
There remains,..................		$1528.98

or $1.71 per ton less than when at once sent to market. It is thus evident that an advantageous concentration of a seven per cent ore by means of crushing and jigging, is not possible. The question next arises, as to whether such an ore could not be smelted at the mines, and a large part of the cost for freight and barrels saved :—

100 tons of this ore might, by smelting, be made to yield 16⅔ tons of regulus of 36.0 per cent (even supposing that one-seventh of the copper were lost in the operation). This would be worth, at $4.50 per unit, or $162 per ton,...........................		$2700.00
From which deduct:		
Cost of smelting, at $5.00 per ton,.........	$500.00	
Barrels and freight, $9.00 "	150.00	650.00
There remains,..................		$2050.00
The 100 tons of 7.0 per cent ore sent to market, would have yielded, according to the previous calculation,..		1700.00
Consequent profit by smelting...............		$350.00

or $3.50 per ton of seven per cent ore. It would thus appear that the best mode of treating the crush ore would be to separate from it as much seven per cent ore as possible, and to treat the refuse from this, which might assay two per cent, by stamping and washing. Of this two per cent ore, the fourths (now set aside) would on being worked up, yield a large quantity; and although they might be unable to bear much of the mining expenses, would considerably more than pay the cost of their own concentration.

In order to ascertain the fitness of some of the products for metallurgical treatment the following examinations were made towards the close of last year. A sample of first quality ore from No. 4 shaft gave,

Silica	25.12	
Carbonate of lime	33.10	
Iron	5.81	
Copper	24.75	
Sulphur,	11.22	by difference.
	100.00	

A sample of ragging gave :—

Silicious matter	16.92	
Carbonate of lime	53.07	
Carbonate of magnesia	trace	
Iron	4.06	
Copper	13.07	
Sulphur	11.62	by difference.
	100.00.	

A sample of hutch-work gave :—

Silicious matter	24.32	
Carbonate of lime	53.10	
Carbonate of magnesia	2.10	
Iron	3.36	
Copper	9.95	
Sulphur	7.17	by difference.
	100.00	

From these results, and from others previously given, it will appear that silica and lime are almost the only slag-producing materials contained in these ores. Iron is present in small quantity, but without previous calcining, which in this case is inadmissible, it would go to the formation of the regulus. The compounds of silica with lime are all but infusible; but these substances form with iron oxide, easily fusible slags, which are frequently produced in copper smelting works. In smelting the Acton ores, therefore, a flux containing iron oxide, such as puddling slag, or roasted iron pyrites, is indispensable. The cost of these would not add very materially to the expense of smelting; but it would of course be better, if such could be had in the neighbourhood, to use in place of these fluxes, poor pyritous copper ores, previously calcined.

The total product of the Acton Mine during the period to which this paper has reference, viz., from September 1st, 1861, to September 30th, 1862, was 2336 tons of 2,352 lbs.; or 2,747 tons of 2,000 lbs, the average copper contents of which amounted to 12.0 per cent. This is equal to an average monthly production of 179 tons of ore of 2,352 lbs., or 211 tons of 2,000 lbs. In reality, however, the production was much greater in the summer than the winter months. For instance, the total produce during July, August and September last, was,—

$366\frac{1868}{2352}$	tons	first quality ore.
$80\frac{1012}{2352}$	"	second " "
$150\frac{922}{2352}$	"	ragging
$312\frac{2076}{2352}$	"	hutch-work
$84\frac{882}{2352}$	"	buddle-work

$994\frac{2064}{2352}$ tons in all, or 331 tons monthly.

With regard to the future of the mine, I see no reason to doubt that it will be as successful as its past; provided always that a due amount of prospective work is done, and that arrangements are made for saving freight, and increasing the value of the poorer ores, by smelting the products of the mine on the spot. To this must of course be added prudent and economical management, without which even the richest mines yield little profit.

In conclusion, I have to remark, that it may seem to some, that in the foregoing, I have been unnecessarily minute. I have, however, thought myself justified in going into detail, by the altogether exceptional character of the deposit. As far as I am aware, there is no instance known of a mineral deposit bearing even a moderate resemblance, in its various relations and characters, to that of the Acton Mine; and, consequently, it is impossible to draw on any stock of experience gained elsewhere, for guidance in exploring it. That the future of the mine may be successful, and its permanency established, no fact, however seemingly trivial, observed in its earlier working ought to be regarded as unimportant. That other deposits of a similar nature may yet be discovered in the district is not impossible; and in the working of such, the experience gained at Acton may not be altogether valueless. For these reasons I have, in the foregoing paper, mentioned details and minutiæ, which few may find useful; but at the same time I trust there will be found in it matter of more general interest.

Actonvale, Canada East, 28th October, 1862.