Paper II.—NOTES ON THE COPPER DEPOSITS AT HARVEY HILL.

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We adopt Von Cotta's classification of mineral deposits into the four following divisions:

I.—Beds;

II.—Segregations;

III.—Impregnations;

IV.—Veins.

I.—*Beds* are regular deposits with well-defined limits, which were formed subsequently to the strata beneath and prior to the overlaying strata, except where the bed is still in course of formation, when, of course, there are no overlaying strata. An ore-bed, therefore, is a member of the series of rocks in which it occurs.

II.—*Segregations*, on the other hand, are irregular masses of definite limits, formed after the rocks in which they occur. Segregations of pyrites are found filling what were caves in limestones and small fissures in slates.

III.—*Impregnations* differ from segregations in not possessing definite limits, and from beds not only in not possessing definite limits, but frequently in the ore which composes them having been deposited subsequently to the formation of the rock in which it is found. Many instances of rocks impregnated with ore occur in Europe and on this continent. The ore may be distributed in sheets between the layers of slates, or scattered in grains throughout a bed of sandstone.

IV.—*Veins* differ from all these by being limited in length and breadth, but practically unlimited in depth. There are what are called *gash veins;* but these are segregations, not veins at all. True, veins fill fissures in previously-formed rock. They may be parallel with the strata, or cut them at any angle, accordingly as the rocks were split or yielded to the disturbing forces along the lines of stratification. The limit in depth of a true vein has never been reached. Veins taper away to nothing at either end, and vary in width, here bulging out and there contracting to a thread; but as yet, no shaft has been sunk deep enough to reach the point where a vein begins.

These several forms of ore-deposits are subject to endless modifications; and it is often impossible to say whether a given deposit can be classed under any of them. They also occur separately and combined, as might be expected, when we try to imagine the manner of their formation.

A bed we can easily conceive of as being formed from the mineral constituents of mineral springs, whose waters, after rising through fissures, collect into lakes. The same process is now going on, and beds of iron ore are forming in this very manner at the present day. A bed thus formed would be accompanied by a lode. The mineral sediment in the bottom of the lake would form the bed, and the same, filling the fissure by which the spring has reached the surface, would form the vein. The mineralized water would overflow the banks of the lake (unless evaporation went on as rapidly as it now does in the Dead Sea, where a vast bed of chloride of sodium is forming), and give rise to other lakes, in whose bottom the mineral would be deposited, forming beds, unassociated with veins; or, beside filling basins, it might find its way into crevices in slate-rocks or caves in limestone, and produce segregations. Subsequent geological changes might cover those beds with strata of slates or limestones, or of some igneous rock, as the case might be.

Veins and impregnations might reasonably be often looked for together.

If the stone impregnated with mineral be sandstone, we can conceive of its having become mineralized through the mineral solutions soaking through it, either from the surface or laterally from fissures in itself or neighbouring rocks. Most beds of sandstone were, however, probably mineralized at the time of their formation. The stream of mineralized water which, if sluggish, would give rise to a bed of solid ore, would, if rapid, disintegrate the rock over which it flowed, and deposit a sandy sediment with its mineralized precipitate; so we can also easily imagine the mineralized solution, if it should flow over a slatey bed, slowly percolating through the slates from the surface, and giving rise to an impregnated slate-bed unassociated with a vein; while we can as easily account for the instances in which impregnations in slates and veins occur together, by supposing a lateral percolation directly from a vein-fissure.

The mineral deposits at Harvey Hill afford a striking instance of impregnated slate-beds, accompanied by veins.

Attention was first directed to that locality as a mining region by the wonderfully rich outcrops of what appeared true lodes of copper ore. One of these was traced for nearly 100 fathoms along its strike; but they were all found to thin out in depth. Nevertheless, Mr. Williams (late superintendent of the English and Canadian Mining Company), satisfied of their being lodes, ran an adit for 248 fathoms through the Hill, midway between two principal groups of lodes. Most of the lodes run 20° E. of N., some few only nearly due E. Mr. Williams ran his adit 42° W. of N.; so that it certainly would have cut some of the lodes in depth had their course not been interfered with by the bed, as we shall subsequently see. Mr. Williams would have run his adit at a far lower level, and in a somewhat different direction, had he known what we know now; but his plans were not unwisely made from existing appearances.

In sinking a shaft, known as Frémont's shaft, on the summit of the Hill, on a lode which yielded for a time a great deal of ore, at 15 fathoms below the surface was found a layer of slate carrying copper pyrites; beneath this were some fathoms of barren slates, and then a thin layer of cuperiforous slates resting on a bed of steatite itself, sparingly impregnated with purple ore. In this part of the bed the ore is not of a workable quality; but it comes to surface in a depression of the Hill to the W., where a quantity of rich slates have been extracted.

Subsequently, another ore-bed was struck in grass-shaft No. 2 of the adit. It comes to surface at about 20 fathoms S. of the shaft. At its outcrop the slates carry about two per cent. of copper as yellow sulphuret; but when struck in the shaft, it yielded in places purple ore, and borings fairly made over an extent of several fathoms gave 3.5 per cent. of copper. It fell off in produce, though not in thickness, towards the W., and gave out altogether towards the E., so that work was discontinued at that point. This is unquestionably the same bed as was subsequently struck in Kent's shaft, 154 fathoms to the W.; and there is little doubt but that it extends over the whole intervening span, as it has been struck midway in a shaft begun by Capt. Williams, and completed since he left the mine.

Below the bed met with in the Frémont shaft (the 2nd bed), there is reason to think there occurs another, for copper-bearing slates were met with in the adit, at 20 fathoms from its extreme end.

There thus appears to be three beds, which, if they extend over the entire Hill, would exist at the following depths below the surface at Kent's shaft:

I. The uppermost bed, cut in grass-shaft No. 2, and from which a great deal of ore has been extracted by the Kent shaft, at 20 fathoms from the surface;

II. The second bed, that lying on the soapstone in Frémont's shaft, which should be at about 60 fathoms from the surface; and

III. The lowermost bed, that met with near the end of the adit, and which should be at about 20 fathoms deeper still, or at 80 fathoms from the surface.

There is, however, no likelihood of these beds being of such great extent, and it is certain they are not of the uniform richness at one time attributed to them.

It was in sinking Kent's shaft to strike two adjacent lodes, known as the Hall and Campbell lodes, in depth, that the first bed was struck, at 20 fathoms from the surface. It then yielded a percentage of copper, which tempted Captain Williams to open it up at a lower level. After, therefore, sinking seven fathoms further, he drove a cross-cut, and struck the bed, as expected, at a point where its yield was quite as good as at the 20-fathom level. At these spots, which happened to be peculiarly rich, through causes which will be apparent as I proceed, the slates, after being roughly picked over, yielded 3.5 per cent. to 5 per cent. of copper. Subsequently, levels were driven from the 20 and 30-fathom cross-cuts, both E. and W.: a cross-cut was run at 10 fathoms from the surface, till it struck the bed, and about 8,000 tons of crude ore broken between these different points. But the sanguine expectations entertained of the permanency of the yield have not been realized. Except towards the north, the bed has in no direction given out altogether; but in the other directions it has become so poor as not to repay the cost of extraction.

While working on the bed, however, discoveries have been made which have altered the whole aspect of the mine, and promise to enhance its value.

In driving the 30-fathom cross-cut, a mass of ore of irregular shape was met, which yielded 50 tons of 43 per cent. ore. It

thinned away to a mere stringer. In driving E. on the bed from the end of the 30-fathom cross-cut, another mass of ore was struck, which was concluded to be of the same description as the previous. But on following it, it proved to be a regular lode, though it was not for a long time recognized as such, so strong was the prejudice for lenticular masses. Capt. Williams drove an inclined shaft upon it for 40 fathoms, and stoped a considerable quantity of ore from the back and bottom, but abandoned operations on it till a vertical shaft should be sunk on it at a point further down the hill. Still, persuaded that the bed yielded on an average 3.5 per cent., he thought that operations could be most economically confined to it. For several years, while concentrating works were being erected, and after their destruction by fire, when on the eve of commencing work, reconstructed, no ore was raised. On their completion, last winter, the bed-ground was delivered at the works, unmixed with ore broken from the lode, and found to average considerably less than was expected.

Just then the unusual appearance of what was supposed to be a mere bunch of ore attracted attention in the slope to the W. of Kent's shaft. At its first appearance, it broke through the floor of the bed, and seemed as though it had discharged its copper into the lowermost layers of the copper slates; but, as it was followed in sloping the bed, it worked its way up through the slates, and assumed the features of a lode with well-defined walls, terminating funnel-shaped in the bed, and pouring its contents into the bed. One could trace the course of the streams of copper and bitter spar and calc spars, as they percolated from the lode among the slates. This at once created doubts of the old hypothesis, that the bed was the source of copper, and that the veins were merely gash-veins or segregations filled from the bed. One could hardly doubt the reverse being the case, or that the bed had derived its copper, quartz, lime, and magnesia, from the veins, which in that case would not be gash-veins

or lenticular masses, but must be true lodes. Subsequent operations and observations have tended to strengthen this view.

There seem to be several lodes entering the bed near Kent's shaft, all parallel in their strike, which is the same as that of most of the outcrops, viz., 20° E. of N. The only one on which much work has been done is the Fanny Eliza lode. As previously stated, where it was first noticed to carry copper was in driving E. from the 30-fathom cross-cut, at a point where the copper-bearing slates thinned away to nothing. The lode was then very small, but widened rapidly as Capt. Williams drove upon it.

The work now being done on the Fanny Eliza is at the end of the winze. The lode is from 20 inches to 24 inches in width, and very regular in both strike and dip, which is slightly to the W. The ore, as it comes to surface, yields from 8 per cent. to 12 per cent. of copper. It separates in crushing very perfectly from the gangue, and is, therefore, easily concentrated to from 40 to 50 per cent. It consists of a mixture of grey and purple sulphurets. When the lode enters the bed, it carries a good deal of yellow and no grey ore; but the yellow entirely disappears in depth. The ore occupies the centre of the lode, whose matrix consists of calc spar, some quartz, and a great deal of bitter spar, in whose composition iron replaces part of the magnesia. Very perfect crystals of bitter spar occur imbedded in the ore.

Tracing the lode upwards, but beneath the bed, and beyond the spot where it first attracted attention, it is seen in the 30-fathom cross-cut as a well-defined lode of about 8 inches wide, but carrying very little copper, and has been reached in a level driven upon it from the bottom of Kent's shaft, where, however, it is thin and irregular, though highly charged with copper. It does not enter the bed in at all the same manner as the lode previously described. In fact, the floor of the bed shews no indication of its existence beneath;

for when sunk upon, two fathoms of broken ground, consisting of alternate layers of quartz and spar, carrying rich bunches of ore and of slate, were raised before the lode assumed its regular form in strike and dip. In these shapeless masses of ore and spar are found chloritoid, sulphuret of molybdenum and quartz-crystals, with their angles rounded off as though they had been exposed to the action of a solvent. I have specimens of ore studded thickly with such crystals, some of which are several inches long, and as much as an inch in diameter, with their faces almost effaced and dimmed. The cavities in which these crystals rest are often coated with a greenish layer, which Dr. Hunt supposes to be a silicate of copper. These crystals are not found at any depth in the lode, but only in the irregular masses which occur in the disturbed slates beneath the bed, where, from some unexplainable cause, the regular fissures were interrupted by the bed; and the mineralogical solution they conveyed toward the surface, not finding a ready exit, forced its way through the slates. These, however, would act as a sieve, by which any solid particles, such as quartz-crystals, which the solution might carry in suspension, would be arrested. The only other spots where they occur thus rounded are at the outcrops of the lodes.

To the east of the Fanny Eliza two lodes enter the bed. Some work has been done on one of them. It appears to be cut by the bed, which severs it like a wedge. It runs parallel with the Fanny Eliza, and, like it, increases in size in the direction of its dip, but diminishes towards the rise. It appears, however, to proceed to surface above the copper-bearing bed, as though the bed had merely intervened without otherwise disturbing its course.

The only instance in which a lode has been found fairly cutting through the floor of the bed and retaining the distinctive characteristics of a lode, while in the copper-bearing slates, is that already referred to. It is at about five fathoms to the west of the Fanny Eliza lode, and

first appeared in the floor of the bed immediately west of the spot where that lode thins out; so that it is probably a continuation of the Fanny Eliza, which is there spliced. As it has been driven upon, it has gradually invaded the bed, spreading out fan-like, and discharging its contents in little rivulets among the slates. It carries purple ore, mixed with yellow. It is very interesting to notice how the slates gradually decrease in richness in proportion to their distance from the lode, and how the color changes from grey to black as the quantity of magnesia and lime in their composition decreases. In the immediate vicinity of the lode, the bed carries purple ore on the floor and yellow towards the roof, and the slates are nacreous. At five or six fathoms distant, there is nothing but yellow sulphuret of 32 per cent. richness, which at a greater distance changes into bell-metal ore of not over 25 per cent. produce; while the slates carrying the ore are the usual black slates of the region, and the magnesia does not to any great amount enter into their composition, but forms, with lime and the copper, very narrow bands between the layers. I shall not be surprised to find the bed cease to carry any copper as soon as the lode has quite cut through the roof. That the lode reaches the surface there is no doubt, as its position exactly corresponds with a very promising outcrop to the west of Kent's shaft.

In the eastern stopes, the bed became rapidly poor to the east of a lode, which, beginning in the roof as a little thread of ore, not three inches in width, rapidly increases in size as it rises towards the surface, which it reaches as the Hall and Campbell lodes. Probably, however, between the bed and the surface the lodes will not be found to be very uniform in width. They will probably also be much broken into branches, as the slates between the bed and the surface are seemingly less compact and more disturbed than below the bed, and would, therefore, fissure less regularly.

The characteristic features of the bed have been often described, though a thorough investigation of the composition

of the slates in the different parts is still a desideratum. But the facts above stated throw fresh light on its formation. There can be hardly a doubt that the Fanny Eliza is a true lode. It has not varied in direction or width for 40 fathoms; its dip is as regular as its strike, and, at places, distinct friction-surfaces have been observed. It is almost as certain that the veins which take their rise in the roof of the bed are lodes—not lenticular masses, inasmuch as their origin corresponds exactly in position with lodes which crop out upon the surface. It is, therefore, more likely that the bed received its copper from the lodes than that the bed fed the lodes. All appearances go to prove that the fissures which, filled with mineral, now form the Fanny Eliza and other lodes, discharged their liquid contents into the bed, and that, after percolating through the slates, what was not precipitated between their layers reached the surface through other fissures. The difficulty of explaining why the fissures did not extend through the bed and reach the surface direct, might induce one to suppose the slates and the copper they contain were simultaneously formed. In that case we might suppose the copper to have been derived from the deep lodes and precipitated among the slates during their formation. Subsequently, there might have been a further formation of slates, the fissures in which became filled with mineral derived from the bed, in the same manner as the lodes below the bed may have derived their contents from sources at still greater depth. This would not so well account for the poverty of the bed to the east of the surface lode, in the eastern stope, as the other hypothesis; for, had the surface lode derived its copper from the bed, there would have been impoverishment of the slates on both sides; whereas, the impoverishment occurs only to the E., that is, on the side furthest from the deep lodes, as though the deep fissures had injected into the slates their contents, which, being relieved from pressure by filling the surface fissure, did not impregnate the slates to any great extent beyond this fissure. There are no intrusive rocks or faults, or other marks, to

establish the relative ages of the surface and deep lodes; but the absolute uniformity in the direction of both their strike and dip would lead to the presumption that they were produced by the same disturbing force, and at the same time.

The experience gained at Harvey Hill should be of use in the exploration of other copper-beds along the same synclinal, so many of which correspond with it in their main features. At the present price of copper and cost of labor in Lower Canada, it is doubtful whether any of the copper-beds are rich enough to be mined with profit; but if they are all accompanied by lodes, in which the copper is concentrated instead of being distributed through 5 to 10 feet of slates (and the bed at Harvey Hill in places far exceeds 10 feet in thickness), many will be worked with profit. As at Harvey Hill, the vicinity of a lode will generally be detected by the increased richness of the slates, and the kind of ore hey carry.

If the two lower beds, known to exist on the Hill, extend at all beneath the uppermost, one would be anxious to know how they affect the deep lodes. The probability, however, is, that they are very limited in extent, as the second bed met with in Frémont's shaft was not cut in the adit, and that met with in the adit was not necessarily more extensive than a small bed of a few fathoms' extent close to surface to the west of Sayles' shaft, which divided its mineral from several veins cropping out through it.

Strictly speaking, therefore, these cuperiferous slates do not belong to beds at all, but should be classed as impregnations.