

VI—DEEP MINING IN NOVA SCOTIA—BY W. H. PREST.

(Read 14th May, 1894.)

This is a subject fraught with deep interest to the mining men of Nova Scotia, a subject touched upon, theorized upon, or slighted, but never, so far as my opportunities for knowing go, examined from a thoroughly geological standpoint. Comparisons with other mining countries have been made, which have so far brought forth no definite conclusion, because the different geological conditions connected with the origin of each have not been taken into account.

Having waited for several years for the published opinion of some older and more experienced miner and geologist, I at last venture to give my views on the subject. They are the results of several seasons of geological survey work, as well as a previous practical experience in gold mining.

It has been a stock argument in the dispute "*Deep versus* shallow mining," that as deep mining is prosecuted successfully in other countries, it is reasonable to suppose that the same result would follow here. This method of argument should now be out of date. The point is, not that the inference is wrong, but that it should be based upon a different set of facts.

The old method of drawing conclusions in Nova Scotian lithology from arguments based on the study of foreign geological conditions is only leading us farther and farther from the true method of investigation. We must not forget that the geological conditions under which foreign mines came into being are usually different from the conditions pre-existing here—a consideration which renders useless the direct comparisons very often made. In order to arrive at any safe conclusions regarding the depth to which our pay streaks run, it is necessary to thoroughly understand the peculiarities of our auriferous rocks, their origin, and the different stages of world building in which they have aided. The geological history of each formation, and also of each

gold district, should be studied under the full conviction that different causes give different results, and also that the same causes in different circumstances often give different results.

DEPOSITION.

In order to consider to advantage the question of deep mining it is necessary to begin with the geological history of the formations we propose to discuss. From a knowledge of their origin and the progress of events connected with their evolution, we may then arrive at an intelligent conclusion in regard to their future possibilities.

The geological position of the auriferous formation of Nova Scotia rests upon both stratigraphical and fossil evidence, neither of which, I am sorry to say, is very decisive. Such fossils as the Eophyton and Asteropolithon (the latter of which with several other forms I have found east of Moose River mines), seem to place it in the lower Cambrian. Calcareous or dolomitic layers have been discovered, which would indicate the presence of fossils; but so far they have proved barren. The want, however, of distinct fossiliferous evidence has made its correlation with any foreign series a matter of great difficulty. Faribault, of the Dominion Geological Survey, from lithological comparisons inclines to the belief that the gold-bearing formations of Nova Scotia belong to the same horizon as the gold-bearing rocks of Quebec. Other observers have regarded them as an equivalent of the Olenellus beds of New Brunswick. The most important points to be noted in connection with the age of these rocks are, their immense thickness, the almost complete absence of fossils and the apparent deep sea origin of their upper beds. The thickness of the quartzites and slates, as estimated by me on the Sissibou last summer, is over 25,000 feet. At Molega, Queens Co., the quartzite alone shows about 15,000 feet. At Mt. Uniacke the thickness is about the same. It seems hardly possible that this great thickness belongs to the Lower Cambrian; but there is so far no evidence that it belongs to any other horizon. We would naturally expect to find fossils in the transition from the quartzites to the argillites which marked

the age of a slowly deepening sea, but only a few uncertain forms (probably concretions) have been found. The nature and order of the deposits of this formation are clearly shown in different parts of the province, but most completely so on Kejama-kuja Lake and the Port Medway and Sissibou Rivers. The succession of its beds is given below and a very rough estimation of thickness (made in the absence of notes), accompanies it :

1. Lower bluish-grey quartzite	6,000
2. Bluish-grey quartzite with plumbaginous slate. . .	2,000
3. Upper bluish-quartzite with bluish-grey slate....	3,000
4. Bluish to greenish-grey quartzite and slate of same colour.....	5,000
5. Lower greenish-grey slate	1,000
6. Lower purple slate	150
7. Middle greenish-grey slate.....	1,500
8. Upper purple slate	400
9. Upper greenish-grey slate	1,000
10. Bluish-grey and ribbanded slates.....	500
11. Bluish-black slates	2,000
12. Black slates with white arenaceous seams.....	1,500
13. Blue and bluish-grey slates	2,000
Total about.....	26,000 ft.

I may have occasion before long, from evidence lately seen, to add another intercalated member to the list.

It must be remembered that the sequence is not the same in every district. In some of the eastern districts, the upper or lower purple slates or both are absent. In some of the western districts the plumbaginous slates are absent. We can, however, be certain of one fact in this connection, viz: the order is never reversed. The lowest bluish-grey quartzite is shown only in our very widest anticlines, particularly at Dollard's Lake. The plumbaginous slates are seen on or near the anticlinal apex in many of our eastern, but not so generally in the western, districts. No. 3 is specially developed on the Sissibou; No. 4 at Mt. Thom in Musquodoboit; No. 5 in Queens and

Yarmouth Counties; Nos 6 and 8 on the east shore of Keja-makuja lake; Nos. 10, 11 and 12 around Lunenburg town; Nos. 11 and 13 on the Sissibou and north of Caribou mines. The thickness of the different beds is very variable. A member having a thickness of 2,000 ft. in one district may thin out to 200 ft. or less in another district. While the lower portion containing the greatest thickness consists of quartzites and arenaceous slates, the upper part is composed of argillites, the transition being in the green and purple slates. This vast thickness of argillites, which in other countries often contain great quantities of fossils, is here nearly barren, if not completely so. The supposed fossils before mentioned are found principally in divisions 3 and 4. The Lower Cambrian purple and green slates of Wicklow, Ireland, contain the fossil plant, *Oldhamia*; but whether our purple and green slates resemble the Irish beds in anything but colour, it remains for future research to decide.

That the highest slate beds once covered the lower strata completely, there is much evidence to show. There is no spot to which we can point and say: "Those undoubtedly were *always* the highest beds in the gold bearing series." There is no spot of which we can say: "Denudation has been very limited here." No upper series limits the upward reach of the highest beds of the auriferous formation.

Even where the highest strata are seen, indications point to still higher beds. On the Sissibou, at Weymouth Bridge, is the apex of an anticline showing some of the lowest beds in the series. Seven and one-half miles to the south-east are the highest beds in the same series, with a thickness of over 25,000 ft. of conformable strata between them. Thus, the centre of this immense ridge, after folding, was many thousands of feet above the trough of slates to the south-east.

Now is there any place where such a trough has been formed and exists in modern times unfilled with still higher beds? It may be said that the ridge may not at any time have been very high, nor the resulting synclinal trough very deep, as denudation may have kept pace with elevation. But, in this case, it must be remembered that deposition always keeps pace with denu-

dation ; so that where a trough exists it could not fail to be filled with the results of the erosion of an adjoining ridge. The softness of those upper slates would also guarantee the formation of a trough under ordinary erosive conditions. A considerable elevation also seems to be necessary to such an immense denudation, confined as it is to the comparatively short time to which it must be limited. At any rate the evidence seems to justify the conclusion that there once existed higher beds, conformable to our auriferous series as well as superimposed deposits of a later age, all having since vanished through erosion.

FOLDING.

The folds into which our gold-bearing rocks are crumpled, may be roughly divided into three classes, which merge gradually one into the other, viz:—circular domes, ellipses and parallel ridges. The first and second only are found in the western counties ; the second and third in the eastern counties. The most perfect example of the first is to be seen at Pleasant River Barrens, Lunenburg Co., while the greater part of the western mines belong to the second. Very good examples of the last are seen in eastern Halifax County, where 3 or 4 anticlines lie parallel for over 30 miles, and include the following auriferous localities. Beginning on the north, we have on the first fold, Dollard's Lake, Mt. Thom, Moose River, Cope's Hill, Beaver Dam and Fifteen Mile Stream ; on the second, Gold Lake, North Mooseland and Killag ; on the third, Cowan's Brook, South Mooseland and Lochaber. These parallel folds are sometimes cut by short sharp cross synclines or slight depressions, which, however, do not interrupt their continuity to any extent, as at Moose and Salmon Rivers.

In the western Counties, these cross-synclines are always broad and deep, often containing beds as high in the series as are found in the main synclines of Halifax County. The result is that the anticlinal domes are irregularly disposed, and the theory of "ranges," so common in the eastern Counties, is not at all applicable to the western districts.

Another distinguishing feature of the western counties is the existence of a multitude of minor folds intermingled with the larger gold-bearing anticlines. This is noticed particularly in the coast and central districts of Lunenburg Co. In Halifax and Guysboro' Counties we have very few of these minor folds.

Now let us consider the cause of this difference of form shown by the folds of the eastern and western Counties. We see the eastern folds, long, narrow, parallel, and steeply inclined, occupying a part of the province comparatively distant from continental influences, pent between the ocean and the Pre-cambrian of the Cobequids, and subject to lateral forces from the north and south, but free to prolong their eastern extensions indefinitely. Thus we can trace in their conformation and position the formative influences that gave them birth.

The western folds short, broad, distributed irregularly, and less steeply inclined, were more within the sphere of continental influences. Thus we see them acted upon in a lesser degree by the same forces as in the eastern counties, but also strongly influenced by a centre of resistance on the west. This centre, apparently the Adirondacks, was also the cause of the elevation of the older rocks of the north-eastern states. The domes and ellipses of the western counties show the effects of this additional pressure in various ways :

1st In the gradually increasing south-westerly trend of the ellipses as we go west ;

2nd. In the deeper and wider cross synclines ;

3rd. In the rounder forms of the domes, showing a more equalized pressure ;

4th. In the great prevalence of north and south, and the absence of east and west, faults ;

5th. In the gradual south-westerly trend and parallelism of the trough-like depression of the Bay of Fundy.

As to the time when this folding took place there is no precise information. It is, however, definitely limited by, and older than the granite metamorphism of Lower Devonian times. The Oriskany of Bear River is thought to be folded in by the Cam-

brian slates. But the fact that it shows a syncline even steeper than the Cambrian syncline, which surrounds and encloses it, seems to point to conformability, or at least to deposition, on nearly the same plane as the lower slates. To those who are geologists I give this problem:—The centre of the syncline, supposed on fossil evidence to be Oriskany, with a dip of from 70 to 90, is folded in a syncline of supposed Cambrian slates, dipping from 50 to 70. Could the former have been deposited on the upturned and denuded edges of the latter and then folded to such a dip by the farther crumpling of the lower system? Would it not rather indicate that the lower slates were not yet folded when the Oriskany was deposited on them, and that both were folded simultaneously in Lower Devonian times? And yet we know that between the folding of the lower slates and the deposition of the Lower Carboniferous conglomerate, there has been an erosion of those slates and quartzites to the depth of over 20,000 ft. The supposition of unconformability seems untenable; and yet the theory of conformability confines this immense denudation to the Devonian age.

There is evidence in the eastern part of the Province to show that a considerable interval elapsed between the folding and metamorphism of the auriferous rocks. At the west end of the Mooseland anticline, near its junction with the granite, the cleavage lines are seen enclosing thin dykes of granite. Therefore the time elapsing between the two events was sufficient to allow lateral pressure to increase and show its presence in the fully formed cleavage lines now seen there. The points above discussed, I hope to obtain more information upon during the coming season.

MINERALIZATION.

The distribution of gold in our auriferous veins is often designated by the terms spotty and streaky. The first is the special peculiarity of the Yarmouth County mines with their wandering maze of angulars and cross leads and their inconstant slate-bound main-leads, as at Kempt. The uncertainty in this case seems to be rather the pinching out or decrease in the

amount of quartz than the complete absence of gold. Of the streaks we will speak farther on.

The mineralization of our gold-bearing leads seems to have taken place during the folding process and before the formation of the cleavage planes. The different seams composing them show a somewhat interrupted mode of formation while polished and striated surfaces show that the folding and consequent earth movements were not complete when the deposition of vein matter began. Those veins were of course then far below the surface of the folds. The auriferous zone of Mt. Uniacke for instance was over 20,000 feet below the upper slates, and could one of our pessimists have been there at that time he would have declared that no gold existed there, and that deep mining was useless.

The hydro-thermal theory of the origin of mineral-veins now so widely upheld and based on so many well known facts accounts (as far as my opportunities for knowing go) for every peculiarity of our gold-bearing leads. The hot springs of California and the Yellowstone Park in which many minerals are now being precipitated reach down without doubt to the great internal source of heat and are active examples of the hydro-thermal mode of mineralization. If this theory accounts for our pay streaks, which is very probable, I see no reason why they should not reach down as far as it is possible for mining to be carried. We have in Nova Scotia men who while convinced of former hydro-thermal action in our auriferous veins, yet give voice to the idea that they are, comparatively speaking but surface deposits.

METAMORPHISM.

To the metamorphic influences of the early Devonian must we ascribe the origin of the gneisses, schists and diorites and much if not all of our granite. We may define the granite as the molten nucleus by which the metamorphosis of our Cambrian and Silurian rocks was brought about or we may class it as a result of the fusion of our stratified rocks. The latter seems to

be the more probable theory being supported by testimony from all parts of the Province. For example the fossiliferous, Oriskany, syncline of Bear River passes without a change of dip or position into the granite on the west and re-appears with the same fossils and dip and in the same range, a few miles further on at Mistake Settlement, near the Sissibou. The eastern extension of the same syncline passes into the granite to the east by the same gradual metamorphism and re-appears to the south of Annapolis town as a half metamorphic slate. The gold-bearing leads and rocks of Mooseland pass in numerous places into the granite, the lines of stratification gradually fading away as crystallization increases. At Hubbard's Cove, Lunenburg Co., the original bedding lines are distinguished for some distance from the quartzite. To the gold miner one important result of this period of metamorphic activity are the fractures caused by the subsequent shrinking of the fused districts. These are seen at Sherbrooke, Mooseland, Mt. Uniacke, Newbern in Lunenburg County and other places.

To summarize some of the foregoing notes, the events traceable between the deposition of the auriferous rocks and their metamorphism, are as follows:—

- 1st. Folding of the gold-bearing series.
- 2nd. Formation and mineralization of leads.
- 3rd. Formation of cleavage lines.
- 4th. Deposition of the Oriskany of Bear River.
- 5th. Farther folding of both series.

This order may, however, be altered by a decisive solution of the problem given on page 426.

DENUDATION.

Before enquiring into the results of erosion let us understand thoroughly the condition of the surface before erosion began. The upper strata, as far as denudation has left them, are the bluish-grey slates, now seen at Lunenburg and the Sissibou River. There may have been still higher strata (see page 423), but the tremendous erosion to which the Province has been

subjected prevents our knowing anything on this point. However, there is enough left to show that the original surface of the larger folds would on an average be nearly 25,000 feet above the present surface. Denudation is shown best on the Sissibou River, Mt. Uniacke, Dollard's Lake and Molega. On the Sissibou where the greatest width is shown erosion has laid bare a section over 25,000 feet thick.*

Of the vast erosion of the Cambrian rocks by far the greater portion is Pre-Carboniferous. The evidence for this is seen in Newport, Musquodoboit, Gay's River, Carrol's Corner and other places. At each of these places the Lower Carboniferous is seen overlying the slates and quartzites which have already been eroded to a depth, in some places, of over 20,000 feet. Near the head of St. Mary's Bay, Digby County, the bulk of the evidence seems to show that the Triassic sand-stones were not deposited until the Sissibou anticline had been eroded to almost or quite its present depth.

If, as has been maintained, our granites were crystallized under great pressure, then the Cambrian slates were at most only slightly eroded when the early Devonian metamorphism took place; otherwise the granite would be deprived of that immense weight necessary to its crystalline form. Under this supposition this immense denudation would all be included in the Devonian age. Even if this supposition was swept aside, the incontrovertible fact still remains that only to the interval between the Cambrian and the Carboniferous can we refer nearly the whole of this stupendous operation.

The bearing of this fact on the question of deep mining is this—viz: that even in Pre-Carboniferous times denudation had already exposed the lowest observable strata of our gold fields and had carried on deep mining to a depth of over 20,000 feet, laying bare the pay streaks which have often been asserted to be only surface deposit.

*A summary of my notes on the Sissibou section is as follows:—

From anticlinal apex in blue quartzite up to purple slates $3\frac{3}{4}$ miles. From purple slates to fossiliferous slates or beds immediately underlying them $2\frac{3}{4}$ miles. Total 6 miles. Average dip $321^{\circ} 30'$ at an angle of 65° . Resulting thickness (at right angles to bedding) 28,723 feet.

However, to cover all possible errors of measurement, unseen faults, &c., I strike off over 3,000 feet.

Of Post-Carboniferous denudation the greater part seems to have taken place in Pre-Triassic times; but as this does not seem to have affected the auriferous rocks to any great extent, I shall pass it.

The "Great Ice Age" of Post-Tertiary times once occupied in text-books a prominent position as an erosive agent, but the investigations of modern glacialists seem to have limited its action considerably. The denudation of the Lower Carboniferous of Musquodoboit and the Triassic sandstones of the Annapolis Valley reaching through Mesozoic, Cenozoic and Glacial times is, as far as my observations go, limited to a depth of not over 300 feet. How much of this can be ascribed to the Glacial age is impossible to determine. Unless the "Great Ice Age" has removed a former carboniferous covering from the auriferous rocks I can see no indications of extensive Post-Tertiary ice action over southern Nova Scotia.

CLASSIFICATION OF MINES.

Our gold mines are of three classes :

- 1st. Those consisting of bedded or main leads.
- 2nd. Those consisting of cross or fissure leads, or whose gold-bearing main leads are mineralized from fissure leads.
- 3rd. Those consisting of gold-bearing drift or conglomerate.

Those of the 1st class reached no higher than their junction with the apex of the anticline, and were covered by the upper beds before denudation was carried that far. To this class belong the most of our gold mines and auriferous localities.

Those of the 2nd class cutting across quartzite and slate alike, and not controlled by anticlinal influence, were probably first uncovered by the denuding agencies. To this class belong the mining localities of Brookfield and Broad River, Queen's County, West Rawdon, the Lake lead of Caribou, Upper Cornwall, Lunenburg County, the Kempt mine, Yarmouth County, and probably South Uniacke and a few others. Those of the 3rd class are the results of the erosion of the 1st and 2nd class. They denote that the upper part of a gold-bearing zone has been removed,

but do not mean that it has totally disappeared through erosion. To this class belong the Ovens, Gay's River and Brookfield, Colchester County.

The Eastville mine of South Uniacke seems to belong to the 2nd class, but is on the same geological horizon as the 15 Mile Brook, Queen's County, and Carleton, Yarmouth County. There are indications that the Eastville pay-streak intersects a cross-lead, at the junction with which its richest spot may be found.

DEEP-MINING PROBABILITIES.

A supporter of the theory that our mines are only surface deposits is unfortunately also committed to the following ideas :

1st. That our pay streaks were formed originally in the centre of an immense mass of barren rock without connection with either the original surface or the mineralizing influences of the earth's interior.

2nd. That the erosion of from 10,000 to 25,000 feet from our gold-bearing anticlines was carried only just far enough to lay bare the best spots in each district. For example, the removal of 10,000 or 12,000 was needed to lay bare the richest part of the Caribou veins. It was done as needed. Nearly 25,000 feet of erosion was needed at Mount Uniacke. That was also done to order. About 20,000 or 22,000 needed removing in Molega to accommodate our miners. That also was done in the most obliging manner.

3rd That the erosion of a thousand feet more would sweep away forever all the gold mines of the province. For example, erosion to the depth of 23,000 instead of 22,000 in Molega would have left only a few barren leads. An erosion of say 13,000 instead of 12,000 would have done the same for Caribou.

4th. That the denudation of a thousand feet less would have hidden our gold completely, or rendered deep mining necessary in order to reach it. Considering that different amounts of rocks had to be removed from each district in order to reach the auriferous zone, the probabilities for such generosity on the part of the denuding agencies are exceedingly doubtful.

The position of our gold-bearing zones in regard to the anticlines are as follows:—48 are on or very near the apex of anticlines; 11 are from $\frac{3}{4}$ mile to 3 or 4 miles from the apex, with a few of uncertain position.

It must be remembered that the proximity of a lead to the anticlinal apex is no certain evidence that it is gold bearing. Its position in regard to the apex is simply a geological accident depending on the size of the fold and the amount of erosion it has suffered. For example, we can see that had erosion not extended so far the auriferous zone of Renfrew would have been nearer the anticlinal apex, while Mount Uniacke, Caribou, Goldenville and numerous others would have been hidden from sight beneath their anticlinal coverings. Again, had erosion been carried several thousand feet deeper the gold bearing zone of Renfrew would have been removed much farther from the apex than it is now, while Caribou, Goldenville and Mount Uniacke would probably have borne the same relation to the apex that Renfrew now does.

Or, to explain my meaning more thoroughly, Mt Uniacke, according to an old survey, has a north dip averaging 60° , and a south dip averaging 90° , and an anticline inclining north about 75° . Assuming that the paying leads extend 600 ft. south of the apex, they would meet and fold over it at a height of 2,318.2 feet. However, as the sharpness of the apex generally decreases with its increase in geological height, the leads would curve over the anticline and be covered by succeeding layers before reaching the height mentioned. An auriferous zone which was once hidden from view in the depths of the anticline is first laid bare by denudation, and then removed farther and farther from the apex with every successive period of erosion. Therefore the distance to which the auriferous zone has been removed from the apex of the anticline marks the stage to which denudation has been carried. That the distance to which a lead has been removed by erosion has nothing to do with its poverty or richness is seen in Renfrew, South Uniacke, Whiteburn and Kempt. That the depth to which it has been eroded does not mark its richest spot is shown by the fact that an erosion of 10,000 or

12,000 feet in Caribou has reached a paying auriferous zone, while an erosion of about 25,000 feet in Mount Uniacke has not gone beyond it. Between those limits lie the paying portions of the gold-bearing zones of nearly all the other mines.

Some facts showing the existence of rich spots both above and below the present surface are as follows:—

At Killag, by far the richest parts of the leads have apparently been swept away. At Fifteen Mile Stream the richest parts of the Orion and Serpent leads have been carried away. The same may be said of the Cumminger lead of Mooseland and the Prest lead of Upper Cornwall and many others. Other rich spots have been reached only by deep mining, as for instance in the Stuart mine in Caribou.

Our deepest mines have reached a vertical depth of not much over 400 ft., the pay streak where present, being followed on an incline of course considerably farther. Some, like the Lake Lead of Caribou, once considered worked out, have been again attacked under new and energetic managers and promise a bountiful return for the future.

A reconsideration of the evidence as far as I have been able to collect it, seems to justify the following conclusions:

1st. The probability of the hydro-thermal origin and resulting great depth of our mineral veins and pay streaks.

2nd. That the original was far above the present surface and even the upper beds of the series in question show evidences of great erosion and still higher beds.

3rd. That what are now called surface deposits were then many thousands of feet deep.

4th. That denudation (or geological deep mining) has already exposed our pay streaks to a depth of 25,000 ft. below the original surface.

5th. And finally, modern mining has only exposed those pay streaks 500 or 600 ft. lower down, thus only slightly extending the former geological work.

When the question of deep mining is fully considered in all its varied geological relations, I cannot see why there should exist any doubt as to its successful prosecution. Judging future

mining from past geological work there is no evidence that our auriferous leads either decrease in size or richness with increasing depth. The cost of mining certainly increases with depth, but should not increase at a greater ratio than in foreign countries where a few dwts. per ton, often pay a dividend. Why is it that moneyed men will without any hesitation invest largely in manufacturing industries in the face of competition and the frequent possibility of a glutted market? The gold market is never glutted, neither is there the slightest evidence of the supply being exhausted. But the gold mining industry like all others needs capital, scientific knowledge, and a talent for hard persevering work, very little of which has so far fallen to its share. Money is doled out in hundreds instead of thousands. A special course of training on the peculiarities of our auriferous formation is unattainable, and the want of confidence which results in lack of perseverance is a natural outcome of the want of special knowledge and financial backing. We want foreign mining engineers among us if only for the purpose of infusing into us some of that vigorous though venturesome policy that showed itself in the construction of the Comstock tunnel in the hope of a final reward. Something of this energy has shown itself lately in the piercing of the anticline at Oldham by Mr. Hardman, and the renewal of work on the 500 ft. shaft on the Lake lead, Caribou. The sinking of the deep shaft by Mr. Hayward at South Uniacke is also a sign of the revival of mining enterprize in Nova Scotia.

Years have been wasted in begging the Government for aid in sinking a thousand foot shaft to solve the question of successful deep mining, but had one quarter of the money lost in unsuccessful manufacturing enterprises been applied to the purpose the problem would have been solved long ago.