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Distribution of Bedded Leads in Relation to Mining Policy.*

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For purposes of study, the gold-bearing veins of the province may be roughly divided into two general classes, as regards their relation to the country rock—bedded leads, with their accompanying "angulars," and cross veins. This grouping is in part arbitrary, and real or apparent exceptions will occur to any one acquainted with more than a few of the gold districts. But it contains the essential elements of a true classification—the genetic principle. For from another point of view, the veins may be regarded as (1) those formed during the period of folding of the rocks, practically group one as given above; and (2) those formed subsequent to the folding, in cross fissures, joints, or faults, which would be group two.

The phrase "fissure vein" is to be avoided as far as possible in discussing either of the two classes. For, in the first place,

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we have yet to prove that any of them were formed after the manner of "true fissure veins"—that is, by wide-spread and deep-seated disruption of the rocks; and second, whatever some of the cross veins may be, others give distinct evidence of not occupying true fissures, but only shrinkage or torsion cracks due to local influences, and confined in strike definitely to a certain portion of the strata, dying out at either end as other strata are reached.

Third, in one sense all are fissure veins; that is, all were formed in pre-existing cavities or places of weakness.

The present paper undertakes only to consider some characteristics of the mineral deposits under group one. Certain of these have been emphasized, chiefly verbally, by Mr. E. R. Faribault, of the Geological Survey of Canada. It is difficult to speak too highly of Mr. Faribault's work, extending over a long term of years, and carried on patiently under most trying conditions, not the least of which has been a totally inadequate supply of funds.

Here the author begs indulgence for a momentary disgression. We are accustomed to grumble at the amount of study alloted to this province by the Geological Survey. Observation of work done in other parts of the Dominion convinces me that, in proportion to its apparent economic importance, Nova Scotia has received in the past, and is still accorded, more attention from the surveying staff than any other part of Canada. The Maritime Provinces are the only considerable division for which were early planned, and are now being executed, inch-to-mile geological sheets. Other regions have been mapped upon this scale, or even a larger one; but they are limited in extent, and generally embrace some distinct economic district, covered by a few map sheets. Except the parts now in progress of being surveyed, the areal geology of the province is mapped already, in a manner not perfect, it is true, but eminently satisfactory when the financial resources at command are considered. What the Survey does *not* do, is to attempt problem studies of geo-

logic or economic units. Its work is still too largely areal. Whenever the far-sighted policy is adopted of allowing it an annual appropriation more nearly commensurate with the needs of the Dominion, we, in common with others, will reap the benefit. Until then, with others, we must wait for the fulfilment of some of our ambitions for Nova Scotia. There is reason to believe that the maps we already possess are used with intelligence by a very small number of those interested in the mineral economics of the province.

Returning once more to the subject, we find that the problem permits of division into two parts—the relations of gold-bearing districts to each other, and the relations between the veins. Let us look at the distribution of bedded-lead gold districts as known at present. The discussion is here confined to that part of the province east of the great granite mass which, starting near Halifax, runs north and west to near Windsor; there meeting the Carboniferous rocks, and thus cutting off the eastern sedimentary part of the gold-bearing series completely from the western. The reasons for this delimitation of the subject are that the country is better known to most, the workings are more numerous, older and on a larger scale, hence give greater opportunity for study, and the rocks are much less influenced by granites.

In this region, which is approximately 200 miles east and west by 8 to 60 north and south, and embraces roughly 3,000 square miles, there are 26 well-marked anticlinal axes. Some of these extend many miles east and west, and a few are very local. In no way, however, do they run and die out *en echelon*, after the manner of axes in the Appalachians. From south to north, the anticlines on which gold districts lie, are (1) the Tangier fold, with Ecum Secum, Harrigan Cove and Tangier; (2) the Ecum Secum fold, a very local one, with a part of Ecum Secum; (3) the Lake Catcha-Salmon River fold, including Liscomb Mills, Salmon River, and Lake Catcha; (4) the Mooseland-Gegogan

fold, including Mooseland and Gegogan (Lawrencetown may be on a westward continuation); (5) the Wine Harbour fold, with Wine Harbour; (6) The Montague-Isaacs Harbour fold, with Montague, Gold Lake, Killag, Goldenville, and Isaacs Harbour; (7) the Moose River-Beaver Dam fold, with Beaver Dam, Upper Seal Harbour, Ragged Falls, and Moose River; (8) the Waverley-Fifteen Mile Stream fold, with Waverley at the west, running through Moose River, where it parts company with 7, to Fifteen Mile Stream; (9) The Caribou fold, containing Caribou, Cameron Dam, Crow's Nest, and Cochran Hill; (10) the Oldham fold, with Oldham; (11) the South Branch Musquodoboit fold, with an unnamed dome and Little Liscomb Lake mine; (12) the South Uniacke fold, with South Uniacke; and (13) the Mt. Uniacke fold, with Mt. Uniacke and Renfrew. Thus exactly half the anticlines have domes which are being worked, or which have been operated in the past.

It will be noted that there is a great variation, from one to five, in the number of known domes on individual anticlines. There is much difference, also, in the length of these anticlines —from 4.5 miles, in the local Ecum Secum axis, to about 105 miles in the Waverley-Moose River-Upper Seal Harbour fold. Further, the variation in interval between adjacent domes on the same axis is considerable. The two nearest together, unseparated by a fault, are Ecum Secum and Harrigan Cove, about 6 miles apart. This is the only instance of its kind, however, and Harrigan Cove has not a very good dome structure. The two adjacent districts farthest apart without an intervening fault, are Goldenville and Killag, about 34 miles distant. Mapping the domes upon one large sheet, so that the relations can be seen at a glance, it at first sight looks as though there were a tendency to an oblique northeast-southwest alignment of domes, the districts lying slightly farther east on each successive axis northward. Close inspection, however, shows that the tendency is really present in but two cases, and may well be accidental in these. To sum up, therefore, it appears that any

attempt to frame an exploration policy upon a supposed periodicity of situation of the domes is likely to end in failure.

In rebuttal, it must be said that we may not be acquainted with all the domes existing upon the various folds. This is undoubtedly true; yet it but emphasizes the inability of distribution to contribute prophetically to our knowledge. On the other hand, it enforces one aspect of the case which should appeal to moneyed men interested in the problem of developing our mineral industries. All the main anticlinal axes have been quite accurately mapped for the eastern half of the province by Mr. Faribault, and the sheets for the most part published. While small local folds may become known in the future, as the second one at Salmon River was discovered after operations at the Dufferin mine had proceeded far enough; and while some of these may prove economically important, yet it is improbable that there are many arches unnoted by Mr. Faribault's careful traverses. But one or two cases of gold-bearing bedded veins are so far known to exist in the trough of a syncline; and from the mechanics of the mountain building and attendant vein phenomena, it is not to be expected that such deposits will occur along the synclinal axes to any extent. So that, while our evidence upon this important point is either circumstantial or negative, it is probably safe to neglect these folds entirely in exploring for new deposits. Moreover, many of the synclinal axes outcrop in the overlying black slates, and therefore in rocks in which abundant gold-bearing leads would not be sought.

Again, while a few instances of isolated bedded veins are known in the transverse interval between an anticline and a syncline, and at a considerable distance from the axis of the former, they are rare; and they are not to be looked for to any considerable extent. It is along and close to the anticlinal axes that we know the deposits now worked, and that we should expect to find new ones; and further, it has been heretofore upon the bulged or domed parts that search has been made.

We know that in the existing districts there is a marked tendency for leads to narrow, and often to die out altogether, in passing from the plunging nose of the dome back to such distance that the axial line runs horizontally. Conversely, veins discovered so far back tend to become stronger toward and at the plunge. This principle is applicable to other than distinctly domed regions. An examination of any of the anticlines will show the inquirer that its axis does not run constantly horizontally, but undulates, plunging gently now east, now west, for miles at a stretch. In some instances, as the Upper Seal Harbour district, this long plunge is accompanied by belts of leads of proved worth; but in most sections so far exploited, such leads lie where the plunge is accentuated, frequently in both directions, into a partial or complete dome. This does not prove, however, that leads are absent or even rare, in the long plunging stretches of which we have been speaking. It is most probably because of insufficient exploration that we know so few instances like the Upper Seal Harbour district. There are many stretches along all the anticlines known to have the long gentle plunge, which may be as likely to have paying belts as the few now worked. Further, the probability of finding distinct domes in parts where they are not now known is very great. Most of the present districts have been discovered by accident, perhaps all; and none, so far as the author is aware, by deliberate, systematic prospecting, extending over a considerable stretch of country.

The point in all this is that here is the most promising field for exploration now open to us—the systematic testing of ground for miles along the plunging parts of anticlinal axes. In order to achieve success in this line, the prospecting must be undertaken progressively along the axes of the different anticlines, and must be careful and persistent. It will entail considerable expense, for means must be employed to reach bedrock wherever the structural conditions warrant; but in the end it will undoubtedly repay the company bold enough to

undertake it. Indeed, there seems to be no other way to increase greatly the known area of productive territory.

Let us turn next to the second part of the problem—the relationships of the leads themselves. Just as among many geologists there has been an unfortunate tendency to correlate rock series with one another at a distance upon purely lithological resemblances, which in reality may be repeated time and again in the long history of the world, just so some economic men have thought it possible that bedded leads in different districts might be the same. And it would be a valuable piece of information if we could verify it. This view is an old one, earlier held more strongly than of late; and many of you disbelieve in it. Nevertheless, as questions and assertions on the point have arisen often, it is necessary to discuss it briefly. Resemblances in the quartz, or arrangement of the gold, or similarity in structural relations and intervals of the leads, have all been used as arguments in favor of their supposed continuity from one district to another. Perhaps the nearest points between which such correlation has been attempted are at Moose River, between the main settlement and the part called "West Mine." A careful survey has led the author to believe that the leads which plunge westward from the main settlement cannot possibly reappear at the western locality. But this is an isolated instance, although admittedly favorable to possible continuity.

In order to view the problem impartially, let us see what evidence can be had from several districts, individually and collectively. One of the most instructive is Caribou. Here are many bedded leads, lying in a zone just below the contact of the lower formation with the black slates, the so-called Halifax formation, above. This region is, in fact, an ellipse of the former completely surrounded by the latter, owing its existence to the fact that a large syncline of the slates has been puckered up by an anticline in the middle, the latter bringing older rocks to the surface. On the south and east, at distances of a

few miles, these old rocks again emerge from their cloak of of black slates, but we look in vain for any evidence of the bedded leads.

Perhaps an even more instructive case is presented by the interval between the settlement of Moose River on the south, and the contact of the quartzite or Goldenville formation with the black slates to the north, southwest of Caribou. At about the longitude of Moose River there are five anticlines, from the Carboniferous rocks of the Musquodoboit valley on the north to the ocean on the south, and excepting the Moose River and Caribou folds. These are the Gold Lake-Goldenville, Mooseland-Gegogan, Lake Catcha-Salmon River, Tangier-Harrigan Cove, and Southern anticlines. They are all south of Moose River. Every fold except the Southern bears two or more domes; and three of the anticlines have Gold Lake, Mooseland and Tangier within a few miles east or west of the longitude of Moose River. Going from that district north to the contact, one traverses an open barren for the most part, on which outcrops are numerous. It is not likely that all the observers who have made the traverse have been deceived as to the structure, which appears to them to be that of a simple high north dip, with no folds. Nor are they likely to have overlooked entirely the large number of leads which should be there, if those of the three districts named are continuous for any distance. For a structural cross-section of the country shows that Moose River lies at nearly the lowest spot within the gold-bearing rocks laid open to observation by erosion; while Caribou lies at the summit of the quartzites, and the three other districts are situated at structural horizons intermediate between these two. It is easy enough to compute the horizons—that is, where the leads *should* come—but they are not there. Instances might be multiplied, if necessary, all giving testimony to the same end. But it is enough to state that there appears to be conclusive evidence of a universal discontinuity of bedded leads, in all directions. Single veins have been followed for a few thousand

feet; but no lead has ever been traced out of its district to another one, either on the strike of the fold, or transverse to it.

Not only is this point clear, but another equally important one is proved by the same evidence—namely, the discontinuity of the horizons of slate belts which the veins accompany, and which are invariable characteristics of the domes. All who work the leads of the various districts know that they are not to be found, except in rare cases, away from slate belts; and "whin bound" leads are generally shunned, This holds true within the districts,—that is, on the known domes,—and equally outside these limits. No prospector wastes his time on country definitely known to be all whin. Now, not only do individual leads and groups of leads fail to "carry" over from one district to the next, but the slate belts in which they are enclosed fail to be continuous, either on the strike of the folds or transverse to it. More than that, the general horizons occupied by the domes, which elsewhere (The sediments of the Meguma series of Nova Scotia. *Amer. Geol., July, 1904; vol. xxxiv, pp. 13-34, esp. p. 17*) the author has called "horizons of most abundant slate," are localized in each and every case, confined to the particular dome on which we find them. This is proved, as in the case of the veins, by structural studies.

The great importance of recognition of this fact is apparent when it is seen that, according to this, each mining district has a definite limit, not only longitudinally east and west, and transversely north and south, but vertically downward. The deduction has a direct bearing upon the problem of deep mining. To put the matter more plainly, it will be necessary to look for a moment at the origin of the leads and their environing slates. The present distribution of the slate horizons shows that each group of slate belts, each district, is isolated; and that as far as known no two are to be correlated as of exactly the same age. That is, no two were simultaneously and continuously deposited. Between adjacent domes, in all directions the outcrops show prevailingly quartzite or whin. It appears,

therefore, that in a shallow sea of very ancient date, in which for the most part sandy sediment was deposited, irregularities of current action or of depth of water, allowed mud to accumulate to a greater extent in isolated spots, alternating with the sand. Later, when all the strata were folded into the well recognized east and west undulations, those parts which had the largest percentage of shaly sediment, being most plastic, folded most and stood up higher as domes. Obviously, they must be limited in all directions by sandy beds. The upper limit has been largely worn away near the axes. The lateral margins are visible today to anyone who searches for them. The lower limit would be reached somewhere, by boring.

Comparison has often been made between our auriferous beds and those of Bendigo—sometimes in a way unconsciously to mislead us as to the true conditions here. This is one of the cases in point. In Bendigo we have, not many isolated domes each with its own problems, but one great dome, with a single general pitch but with subordinate undulations. The dome is composite, made up of several minor folds; and these folds have irregular plunges and dips. The leads, there as here, lie in slate belts at or near the contact with sandstones; but there is a very constant relation between the lead and the sandstone, which is lacking here—namely, the foot-wall is always sandstone, the hanging wall invariably slate. The most marked dissimilarity between the two countries, however, is in the fact that at Bendigo the vertical as well as the lateral distribution of the gold districts is indefinite; and it is on just this point that we seem to be led astray. The large single dome of which we have spoken is, as was said, made up of a number of anticlines and synclines, striking north 16 degrees west, and sometimes continuous along the strike for many miles. There are 15 anticlines in about two miles of width, in the central part of the 140 square miles of productive territory, with an average transverse interval of 800 feet from crest to crest of the adjacent arches. The dips average 65 degrees; and while

the folds are not symmetrical, they are not highly overturned. The slates have a strong secondary cleavage dipping 65 degrees east, so that on one side of the fold it is parallel with the bedding, on the other transverse to its dip. This explains the "false saddles" so common there, which have no analogy in this country. Unlike the Nova Scotian cases, the dips are constant on either side, giving steep straight shanks and narrow sharp crests. This corresponds to what we have on only our narrowest folds. Conditions analogous to Goldenville, Mt. Uniacke, Renfrew, and many other districts do not exist in the Australian field. The leads of Bendigo often lie, too, in "inverted saddles." Indeed, the whole dynamic condition of origin was different there from that in our own series; and dynamic history in such cases has great influence upon profitable mining methods. The rocks there were evidently under much less weight of superincumbent material, or were more rapidly deformed when folding took place; for the sharp folds have allowed far more slipping of sandstone and slate past each other than with us. The result has been a series of saddles which individually are very thick on the crest, narrow rapidly downward, and die out for the most part within a few hundred feet.

On the average, one-half the saddles in Bendigo pay. Their vertical interval is very variable. In the New Chum and Victoria mine, 30 were passed in 2300 feet; while in "180" mine only five were cut in 2500 feet, two of them lean. In the Lazarus, 24 were met in 2400 feet, 13 gold-bearing. The continuity of single leads along the strike of the folds is unheard of elsewhere, one vein having been followed continuously for ten miles. The deepest mines, over 4000 feet, show ore unchanged in character. But it is to be emphasized that no mine has made a reputation on the basis of a single saddle. In every case vertical sinking has been resorted to, and one saddle after another uncovered, as was brought out in Mr. Faribault's first paper on deep mining. No single leg there has been found to extend very deep.

Aside from the necessity of sinking, the most important feature which can be used, not for comparison but for contrast with our local conditions, is the absence of any "horizon of most abundant slate"; and the consequent diffusion of the veins not only over a very great depth, but laterally over practically the whole extent of the great dome, about 140 square miles. We have exactly the opposite—much deeper legs to individual leads, but a very limited lateral and vertical extension to the domes or zones.

It has been computed by one student of the series that the difference in size between our folds and those of Bendigo is approximately as 20 to 1; and this has been used to prophesy the possible conditions underground as regards intervals between leads not now exposed at the surface, and length of leg on individual leads. Such statistics must be used with the greatest care, if at all; and in this case they are better discarded altogether. For if we push figures like these to their ultimate end, they act as boomerangs and discourage us completely. The fact is, the two districts are dissimilar in many essentials, while the superficial similarity of both containing bedded veins has blinded students to the relative value of the totally different factors entering into the equation of the two deposits. There are other regions of bedded veins in the world besides these, and altogether too much importance has been attached to the really accidental method of occurrence. To return to Bendigo, if our deposits are on a scale of 20, we may expect to go 50,000 feet vertically in some places to strike five leads, to use Lansell's "180" mine for comparison. Again, the 4,000 feet now reached by several mines represent 80,000 feet in which we may expect to find productive veins—which is too ridiculous for comment. No! The fact that there happens to be about that difference in the scale of construction of the folds in the two countries is interesting, but utterly worthless for prophetic purposes.

We have seen that our own veins are, to some considerable extent, localized within small domed districts; that these dis-

tricts show no evidence of repeating themselves at the proper geological horizons, but are distinct units ; and further, that they are definitely bounded on all sides. If one goes out from the center of such a dome, he will proceed from a part in which outcrops and underground cross-cuts show a definite alternation of slate and quartzite belts, rather suddenly into a region in which little if any slate is to be found. This is a typical condition. In just the same way, if one could see a sufficiently deep vertical section, he would find that thousands of feet of quartzite, with little or no slate, alternate with a few zones in which slate predominates ; and here would be found the bedded leads. The non-appearance of a bedded slate district on the next anticlines transversely north and south of that district, is itself proof of the presence of a very definite bottom to the slate part of each dome. Moreover, it is known that mud sediments are never deposited as enormously thick but closely localized patches ; but that there is roughly a maximum thickness for any given extent, and this is very small in proportion to the original lateral distribution of the deposit. Judging by these conditions in other parts of the world, the downward limit of the productive part of our domes should not be many thousands of feet below the surface in any case. In one district the author has a feeling, unsupported by other than circumstantial evidence, that this bottom lies practically at the surface for part of that field. Inasmuch, however, as no borings have been made or shafts sunk on the axis of any true dome to even a reasonable depth, all the evidence on this point that can be assembled with a view to helping us in the future, is external and circumstantial. The one established fact is that there will be somewhere a downward limit to the occurrence of new saddles, on each dome.

Thus far our study has been, perhaps, apparently pessimistic. It is intended that the paper as a whole shall be anything but that. It has been necessary to call attention to certain limitations of operations ; and to sundry facts, and the

correlations of these, in order to emphasize what the author believes to be policies which in the end will work injury to the gold mining industry. And chief of these is the vague idea that somewhere below we have a limitless body of ore, and can ultimately mine about as far as we like,—up, down, lengthwise, or sideways. No one has greater faith than the author in the ultimate success of the industry, when conducted on a large scale, by modern methods, and with business enterprise yet conservatism. The past year has been spoken of by some as especially disastrous in this field. If by this is meant a small output and a high gross cost merely, it is true. But this is a near-sighted view of the matter. The peculiar status of the industry today is due largely, although not entirely, to two causes. First, we are in a transition period between the day of one-man mines and small capital, and that of large capitalization and large scale operations. We have not yet accustomed ourselves to the change—nor, indeed, yet completed it. Some good properties are too highly capitalized, yet have too little paid in to meet ordinary current expenses of development and installation. With the large scale must come careful management, and among other things the blocking out and testing of several years' ore supply in advance. Very few mines indeed fulfill these conditions. Second, in several large properties which ordinarily can be depended upon to give a good record of themselves, the year has been spent in exploration, development work, or increase of surface plant. No wonder, then, that the output is small and the cost high.

As opposed to the negative side of the gold problem outlined earlier, must be presented a few facts which should tend to encourage the worker. First, while there is an undoubted downward limit to the zone of leads which could be cut by a shaft sunk on the apex of a dome, we have no evidence that in any given district it is within the range of moderately deep mining, or that many valuable saddles may not be cut by such a shaft. The experiment has never been seriously tried. Second,

while a very definite surface lateral extent is known for each true dome, there is many a district in which there are enough paying belts to keep one or a very few large plants for more years than any of us will see. Third, while there is a definite downward limit to each leg of a saddle, at which the vein dies out, it has yet to be shown that any one has reached that limit in a characteristic case. The only vein in this class which has been mined on the slope for a thousand feet of vertical depth shows unchanged character of ore at the bottom. Mr. Faribault's contention cannot be too strongly reiterated—that the depth of the vein left for our use depends entirely upon the proportion which erosion to an accidental present level has not removed; and that this will vary with each vein. Other things being equal, leads nearer the axis of a sharp fold should hold deeper than those farther away. Yet at Caribou we have a vein at a great distance from the axis, operated at over a thousand feet vertically. The advisability of following individual leads to a far greater depth than has been done must be emphasized to the utmost; and if the agitation for vertical sinking, good as it is, has detracted from the interest in this method of working, by so much it has done an injury to the industry.

What, then, are the constructive, practical applications which can be made from the facts and principles of the distribution of bedded leads? Without attempting to arrange them in any order of relative importance, some of them are as follows:

(1) There is a great field for exploration for new deposits. This should be systematic, along recognised anticlines for long distances. Special attention should be paid to structures similar to that at Upper Seal Harbour, which are common. The conditions of distribution there are in some ways nearer those of Bendigo on a large scale than anywhere else.

(2) There is room for far more exploring within single districts, but this is preferably done by underground cross-cuts.

(3) The present districts are even now held by too many owners for economical working. There are few, even of the

large fields, situated on regular domes and not too much affected by faults, which could not be worked as one property, from one, two or at the most three central shafts, far better than by the present methods.

(4) Much more attention should be paid to deep working on single leads or belts, on the slope. This is not to be taken as indicating hostility to the best large scale method—vertical sinking and cross-cutting; but it is to bring out the fact that vertical sinking on an apex is not the only successful method, nor always the most desirable one.

(5) Boring and sinking on an apex should be used wherever the shape of the property and the structure warrant. It is undoubtedly the ideal way to initiate a large mining policy on a property capable of sustaining it. In this connection one thinks, of course, of the Government aid problem. It is to be said that conditions where the only case yet on record was attempted are not normal. The district, as has been mentioned earlier, is quite like Bendigo in certain ways; but it is not a distinct dome, and this experiment should be tried upon a true dome before declaration is made upon its feasibility. There are few districts in which it would be advisable to make the trial for purely experimental purposes; but there are some, and one of these should be chosen next. Those who realize the actual conditions in the field should have just as much faith as ever in the method, and in its ultimate success.

(6) Our ores are of so low grade on the average that large scale operations will be necessary, to make them pay for permanent investments. The industry is gradually being taken out of the realm of pure speculation, where it has been for long, and placed in that of legitimate business. To do this properly requires, for one thing, large reserves of proved ore, which an extremely small number of mines have at the present time.