Comparing Exploration Plans for a Porphyry Copper Open-Pit Mine

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16 February 2020

ABSTRACT

This paper uses stylized features of several open-pit copper mines in BC, Canada to build a toy model to compare different exploration plans. Assuming an ore body is there, would one exploration plan find it faster than others or more cheaply? This paper compares the results generated by three different exploration plans with the same budget, where key parameters are calibrated to mines in BC. A first plan drills holes on a uniform distribution across the search space and produces results that are worth less than they cost. A second plan uses a geochemical survey to narrow the area of drilling and yields greater value from exploration than the cost. A third plan includes a seismic survey before the geochemical and drilling, which yields less value than the second plan but increases the confidence that the drilling is in the right spot.

Keywords: Finance, Mine, Optimization

JEL Codes: C00 General, L72 Mining,

Comparing Exploration Plans for a Porphyry Copper Open-Pit Mine

Bell (2020) notes similar features of several open-pit copper mines in BC, Canada that have yielded decades of production from large porphyry-Cu deposits. These old mines typically fit into a square two kilometers wide, with the pit going 300 meters deep. What's more, the ore bodies are typically fault-related, under cover, and have higher grade zones near surface. What does this mining history tell us about the future, particularly when it comes to exploring for new mines? How can we compare the return on exploration spending with different plans of attack? If you were sitting on top of a mine, could one program find it and another one miss it? What is the difference between unsuccessful and successful exploration?

This toy model is based on a three-dimensional volume of rock that contains an ore body with an unknown location. The third dimension is largely trivial in this version of the model. Looking at a volume of rock that could eventually become a mine, it requires drilling to make a discovery. What is the best way to make a discovery?

Sometimes mining projects sit dormant for years before someone makes a discovery by taking a different exploration approach. The decisions as to which layers of geological information will be collected and considered have a major effect on the technical success and the finance-ability of an exploration program.

TOY MODEL

An open-pit with radius 1 kilometer and height 300 meters fits within a 2km square, but not all of that pit is ore. What does the ore body look like? I assume the ore body is a square 350m by 350m, starting at surface within the pit.

The exploration plan has a budget of $125,000. Each drill hole cost $5,000, based on $50/m to 100m depth. Geochem samples cost $50 each. The value of the exploration results is determined by the amount of copper contained in some amount of rock around successful drill holes multiplied by $200/t copper, which is a relevant figure for past acquisitions of copper mines around the world (RFC Ambrian, 2018).

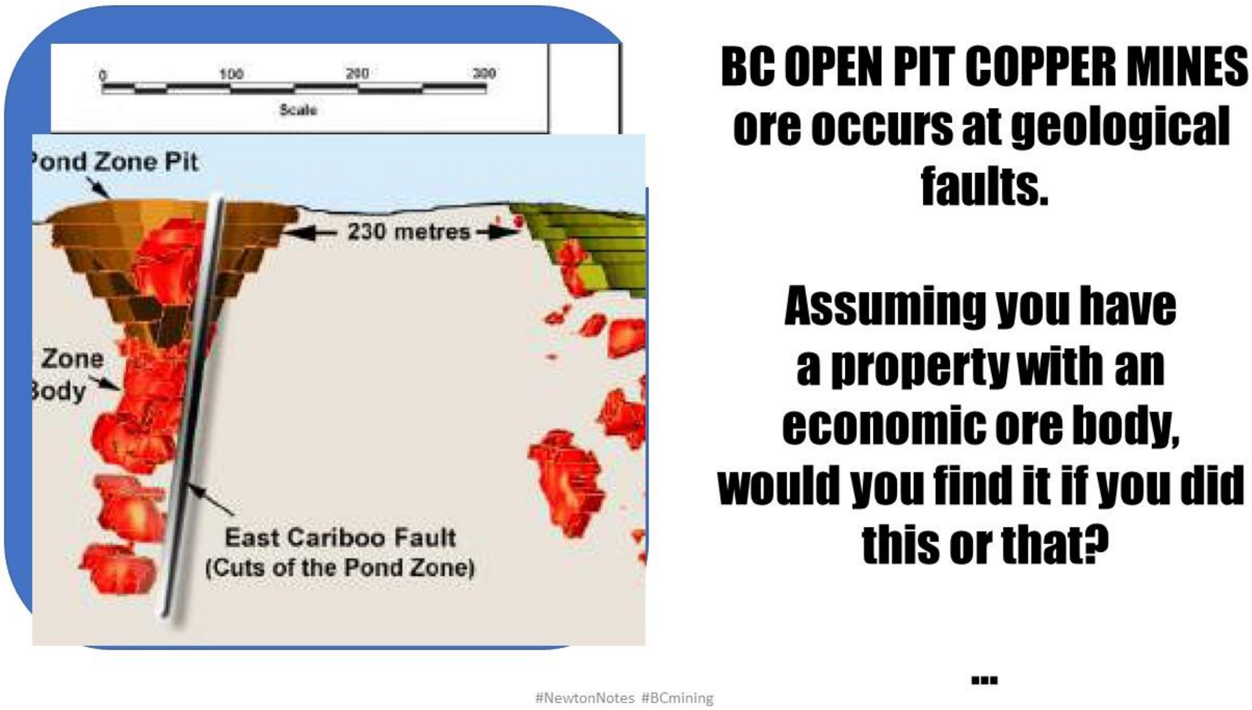
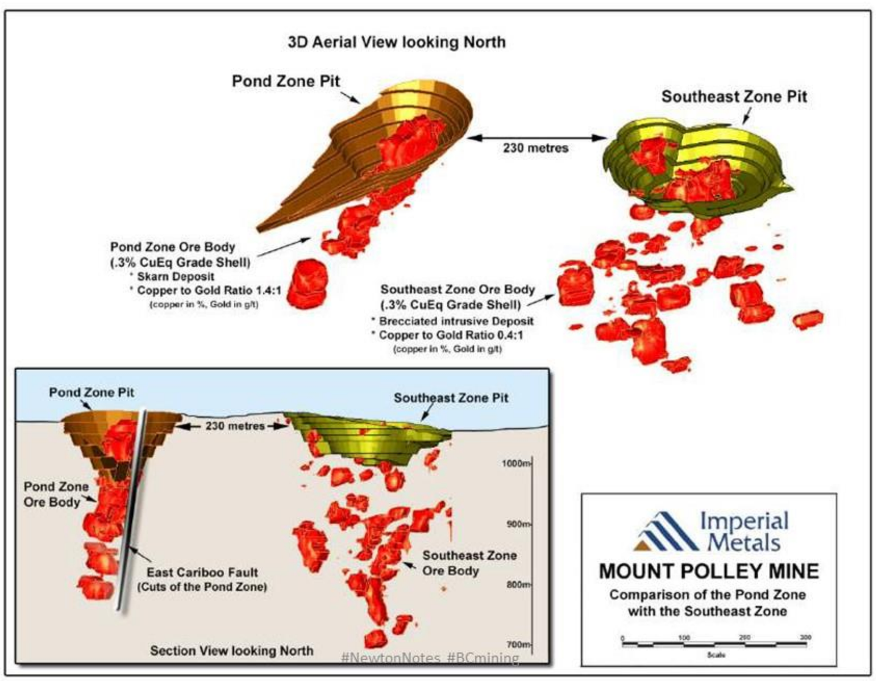


Figure 7-10 Comparison of the Pond Zone and Southeast Zone



Source: https://miningdataonline.com/property/61/Mount-Polley-Mine.aspx

UNIFORM DRILL HOLE SPACING

Consider a first-pass program of 25 holes at 400m spacing covering the 2km space. With this 400m spacing and 350m ore body, at most *1 hole* will hit the ore body. Suppose this 1 hole provides the basis to extend the same copper grades over a 20m radius around this hole, which yields a volume of 120,000 cubic meters if drilled to 100m depth. That is approximately 250,000 tonnes ore. At 0.1% Cu, this is 250t copper. Using $200/t copper, gives a $50,000 “discovery value”.

This program costs $125,000 and yields $50,000 copper value. This is not accretive. In the best-case scenario, this plan yields a loss. Furthermore, the discovery value is “low confidence” because it is based on a single hole. One hole can be enough to show existence of an ore body, but mine plans for porphyry-Cu deposits like this are based on many holes with tight spacing.

And it is not a certainty that this work program even hits the ore body! There is a 40% probability that one of the 25 holes hits, which means the Expected Value of the program is only $20,000.

To calculate the probability of hitting on one hole, consider a 2km grid at 1m spacing. With sampling on a 400x400m grid, count the number of ways that the 350x350m ore body could cover one sampling point. There are 3 different ways for that to happen: (A) Corners, 4 of these; (B) Edges, 12 of these, 350 ways each; (C) Interior, 9 of these, 350x350 ways each. Total: (4+12*350+9*350^2)=1,106,704 ways to hit, versus total number of positions (2000-350)^2=2,722,500. Approximately 40% odds of hitting 350m ore body with 400m spacing on 2km grid (1,106,704/2,722,500).

It is surprising to see the exploration value is less than cost for this plan, given the fact that an economic orebody exists here! This plan *"snatches defeat from the jaws of victory"* on this round of work in the case it does hit the ore body. And there is still a 60% chance that this program does not event drill into the ore body. Even if it did, it is unclear if the results from a single hole would be good enough to get more funding to do the subsequent work focused on the first discovery hole. This exploration plan may never find the ore body.

GEOCHEM TO NARROW SEARCH SPACE

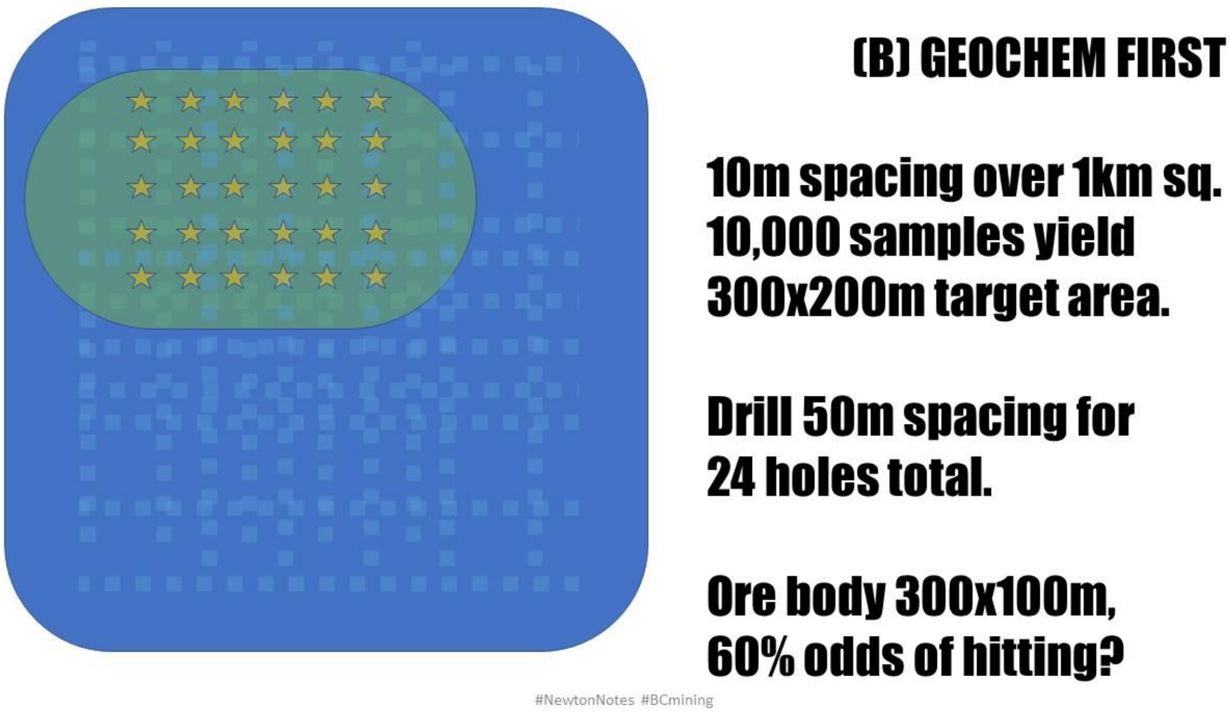
This plan uses geochemical surveys to establish a high-confidence area for the location of the ore body and then drills fewer holes into this smaller area. This first-pass program isn't meant to define the entire ore body, but it is meant to put several holes into the highest-grade section immediately.

<u>$125,000 budget:</u>

- $45,000 for geochem; 1,000 samples on 30x30 grid, 60m spacing to cover 2x2km.
- $80,000 for drilling; 16 holes on 4x4 grid, 20m spacing to cover 80x80m.

With 1,000 geochem sampling sites on a 30x30 grid at 60m spacing, this program will hit the orebody with 25 samples. There are 5x5 sampling points at 60m spacing covering the 350x350m orebody, wherever it is. There are some heroic assumptions here, like no false positives and no false negatives on the geochem surveys.

This plans budgets 16 holes over 20m spacing to cover 80x80m around one cluster of hot geochem results. This is a risky plan because all the drill holes cover one geochem hotspot. But the plan mitigates this risk by having the drill grid larger than geochem spacing; it doesn't just drill the single best geochem sample, it drills the best 4-tuple of geochem results. Within the 80x80m drill grid, there are 4 sample points from the geochem program on 60m spacing. The drill grid is picked to cover the 4 best neighbouring geochem samples out of the 1,000 total samples. This is a small feature that make the drill grid slightly more robust than chasing the single largest geochem anomaly, for example.



Assuming all holes hit 100m of 0.1% Cu, this plan yields 120m x 120m x 100m = 1,440,000 cubic meters, for 3.8Mt ore. At $200/t M&A price, the total implied value of this program is $760,000, which is much larger than cost of plan at $125,000.

This plan does not have any probability calculations in this version, so the Expected Value is also $760,000. The fact that this value is much larger than program costs goes to show why minerals exploration business continues to exist and attract investment.

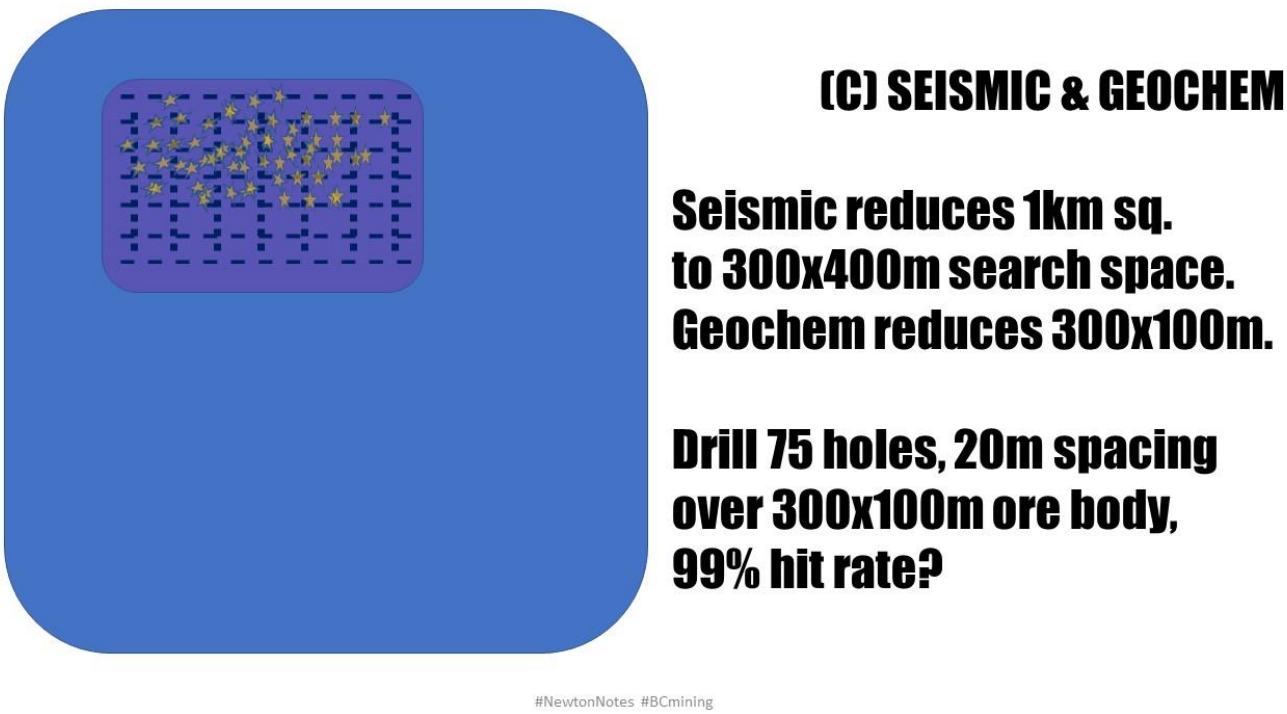
SEISMIC TO NARROW SEARCH SPACE

It is possible to do other programs that help narrow search space. For example, ground-based seismic. The areas "eliminated" by seismic may end up inside final pit, but they are not part of the ore body. The initial goal is high grade starter pit, which is characterized by supergene enrichment near surface in a fault-controlled deposit. Seismic imaging can help with tracking faults and finding the near-surface targets. After seismic reduces the search space, this plan does geochem over a smaller area and then drills.

<u>$125,000 budget:</u>

- $25,000 seismic.
- $55,000 geochem, 1,100 samples.
- $45,000 drilling, 9 holes.

Suppose the seismic survey reduces the search space from 2x2km to 500x500m, which would be a big win. Then, the plan includes a 35x35 geochem grid at 15m spacing to cover this new 500x500m search space and, finally, a 3x3 drill grid at 20m spacing.



The location of the drill grid in this case is picked to cover the hottest results from the geochemistry survey. Drilling covers a grid 60x60m in this case, which includes 4x4 different geochem sample sites. The hottest cluster of 16 neighbouring geochem samples will determine the place to drill in this plan, which increases the confidence of the drilling area because it is based on more geochemical samples (16 versus 4 in previous plan) that are more tightly spaced

(15m vs 60m). As such, the seismic work reduces the drilling budget and causes the result to be smaller tonnage *ex post* but increases the confidence of drilling ore *ex ante*.

The drill holes define 100x100x100m volume, 1 million cubic meters or 2.7Mt. At 0.1% Cu, this is 2.7Kt. At $200/t, this exploration work is worth $540,000 copper. Again, there is no probability in this version of this model and Expected Value is also $540,000.

CONCLUSION

There are many different exploration plans with equivalent costs, but different outcomes. How do they compare? Using heroic assumptions about the presence of an ore body and the efficacy of exploration techniques like seismic and geochem, it is possible to compare different plans based on their cost and benefit. How much tonnage would an exploration plan yield, if it was drilling into an ore body? Focusing on cases where an ore body exists helps reveal which exploration plans do better in best-case-scenarios.

It is possible to improve these models by including more relevant information about stylized features of the relevant ore body. For example, porphyry-Cu in BC are typically fault-related, under cover, and have higher grade zones near surface; what other types of exploration techniques other than geochem and seismic can be used to detect these key features? How would these other techniques fit into exploration plans with a fixed budget? If the budget increases or decreases overall, then does that change the prioritization of different exploration techniques?

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