Mining Pipe-Shaped Ore Deposits

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Abstract

This paper provides a rough comparison of two mine plans for a hypothetical, pipe-shaped ore body. The geometry for the ore body is based on stylized example of an auriferous tourmaline breccia pipes associated with porphyry deposits, which can have great vertical extent and relatively small surficial expression. I suppose the pipe outcrops on a hillside and can be accessed from the base of the hill, allowing the miner to enter the pipe at the midpoint of the vertical extent. Accessing the pipe in the middle allows the miner to either go up or downwards and this paper explores one mining method for each case. I calculate basic statistics associated with each method and compare the two models for mining method.

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JEL Codes: C00 General; G00 General; L72 Mining, Extraction, and Refining

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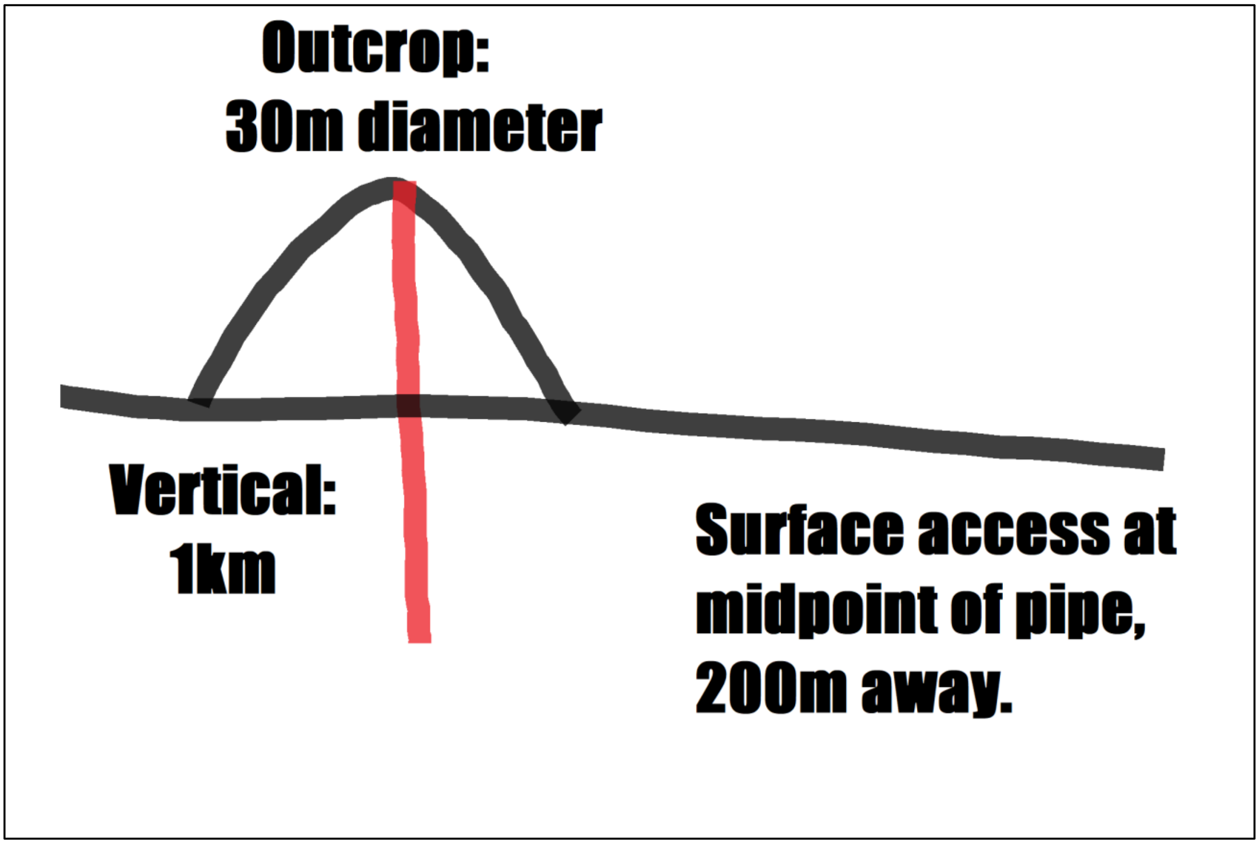
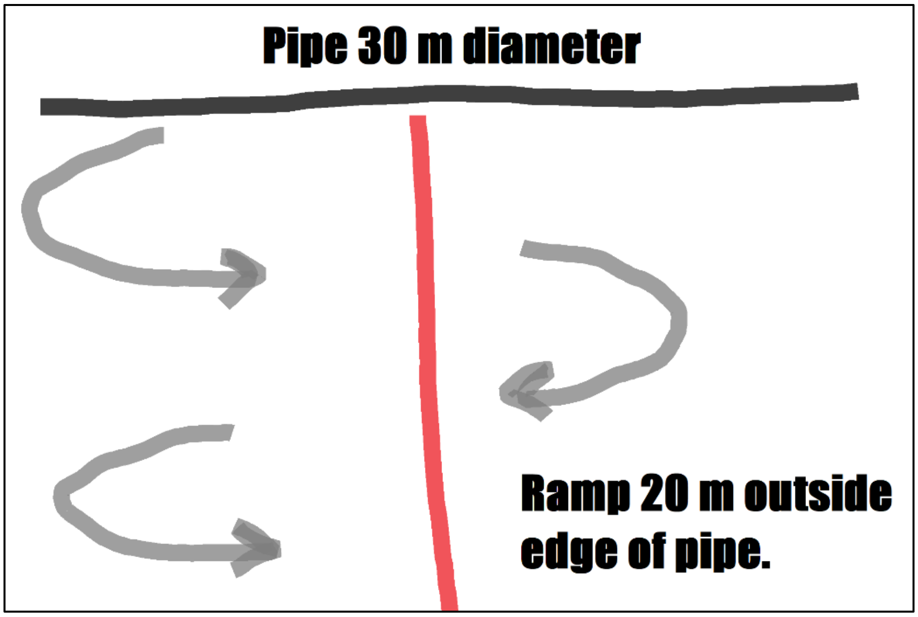
I assume the mineralized pipe outcrops on a hilltop with diameter 30 meters. I assume it extends 1 kilometer straight down and the ore is homogenous across the ore body. I also assume that the valley nearby gives access to midpoint of vertical extent through 200 meters, say, of horizontal distance from surface to the pipe. The picture below shows a cartoon of the deposit in the wild at time of discovery.



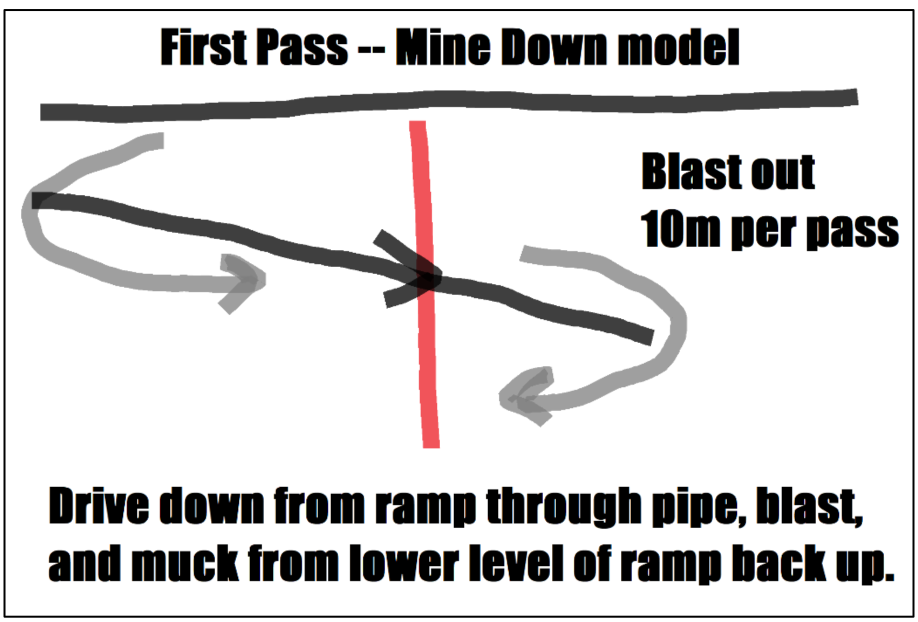
The geometry of the deposit described here introduces certain geotechnical constraints. How best to mine the deposit? I consider two answers: "Mine Up" and "Mine Down". It may be possible to do both at the same time, but I consider each separately for now.

Mine Down

To mine the pipe, I assume the mining method uses a single ramp going down around the pipe at a set distance with periodic adits crossing between levels of the ramp through the pipe to blast and muck ore. See a diagram showing the ramp going around the pipe below. Please note that the ramp is meant to descend around the pipe in a helix shape.



I assume that this mining method pushes the blasted ore into rail cars "down and through". An adit connects from one side of the ramp to the other side of the ramp at a lower level, then allows the pipe to be blasted down into the adit and pushed into waiting railcars to bring the ore to surface. I am uncertain if this is realistic but assume this works as in the diagram below.



Dimensions of the ore pipe and ramp can be used to calculate volumes of ore production and underground development required for each pass of mining. The numbers I use are as follows. The pipe has diameter 30 meters, the ramp goes down another 20 meters outside that, and periodic drifts go down from the ramp through the pipe to allow blasting to remove the entire pipe over 10 meters vertically. For each pass of this mine method, you generate roughly 7,000 cubic meters of ore (10 meters vertical, circle with diameter 30 meters).

Mine Up

Coming in at the bottom of an orebody is not typical, but possible with ore pipes based on the geometry I've described here. As such, I will take this opportunity to propose a new mining approach that uses very little underground development. I assume there is some new technology to implement this mining method, which is partly inspired by what Anaconda Mining is working on with narrow vein mining for gold in Newfoundland. As I understand it, they drill one hole with sensors to track the vein down dip and then come in with progressively larger drills to extract the ore. There is potential for very little dilution with such a method, which is a key feature that I use in what follows.

The entry point is the same as the "Mine Down" model, but the ore is overhead this time. The miner starts by building an initial staging area for the underground work program, which takes out the entire pipe 30 meters diameter and has vertical extent 15 meters. The purpose of this staging area is to give space to setup a drill rig to install blasts into the ceiling, then allow the ore to fall to the staging area and be mucked to surface. In this way, the Mine Up model may be seen as a kind of caving mine method.

I assume the mining method is as follows. Build the staging area. The first pass of mining blasts out the middle of the pipe, 20 meters diameter and 10 meters of vertical extent. This ore falls to the staging area and is mucked along a flat or even downward sloping adit to surface. The second pass of mining takes the next 10 meters above the first blast from the middle of the pipe. Please note that mining out the middle of the pipe in this way moves the face of the mine upwards and away from the staging level. I assume that a hydraulic lift can take the drill to the rock face and install the next blast as the mine face moves upwards along the vertical extent of the pipe.

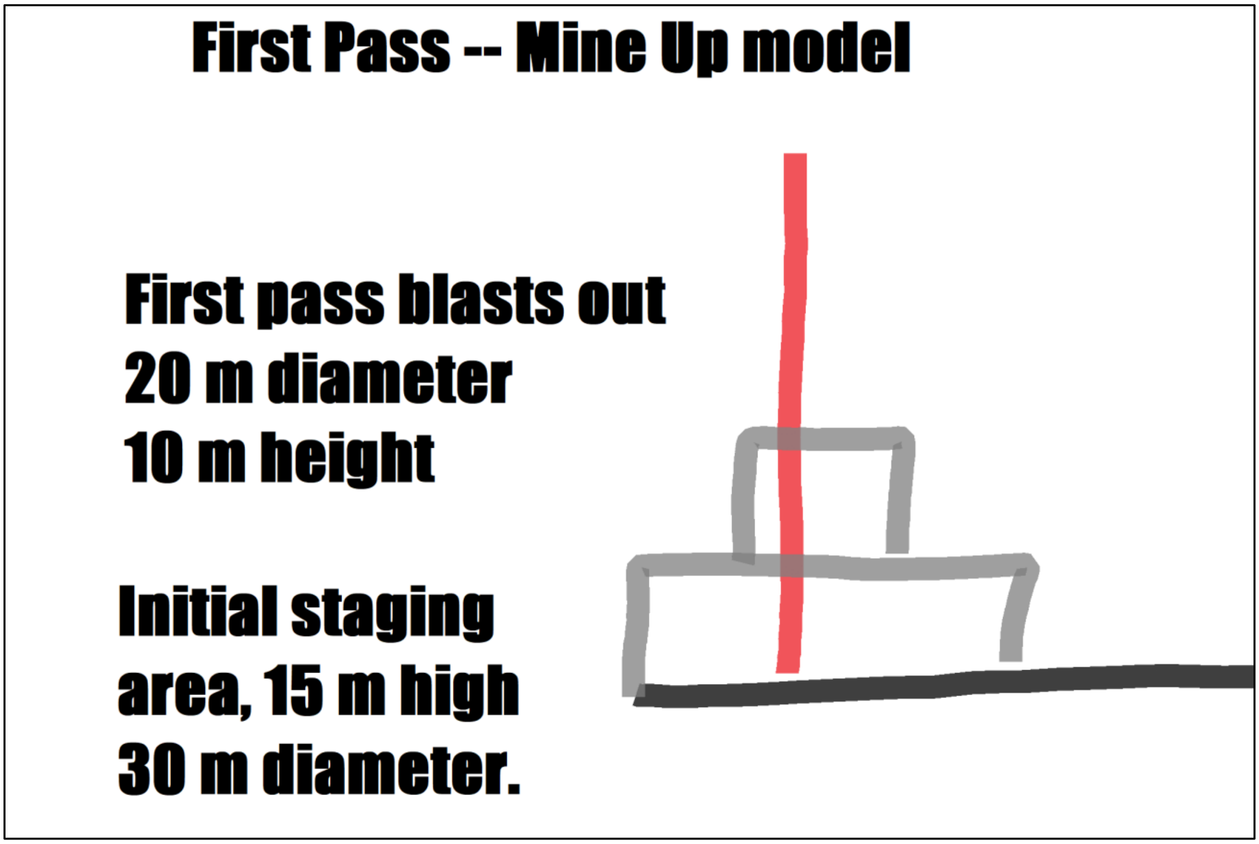
I also assume the Mine Up model allows ore to fall from the mine face to the initial staging area without causing any problems. That may be unrealistic as I have assumed the pipe extends for 1 kilometer vertically.

Another possible problem is clearance for drill rods underground. As you Mine Up, you have to work in a space that is only 20 meters in diameter. It may be a challenge to get a drill in there to place blasts as the drill rods may limit your possible drilling angles. The Coiled Tubing Drilling for Mineral Exploration project by DET CRC (2018) may help in that regard as it replaces drill rods with tubes.

I assume the rock responds well to blasting and blasting can remove a circle with diameter 20 meters from the middle of the pipe. This leaves 5 meters of ore on either side of the pipe unmined, which creates opportunity to come back with different technology in the future. It may be quite difficult in practice to blast out the middle 20 meters of a 30-

meter pipe! I also assume that the ore falls down into the initial staging area and is then mucked to surface along a horizontal adit, as in the Mine Down model.

See a picture of the first pass on the Mine Up model. There are many details to consider with this assumption, but I will simply assume it can be done for now and proceed with some relevant calculations for illustrative purposes.



The relevant volumes for the Mine Up model are as follows. The staging area is a circular room with diameter 30 meters and height 15 meters, which is approximately 10,000 cubic meters. The first pass of mining removes a block of ore with diameter 20 meters and height 10 meters, which is approximately 3,000 cubic meters of ore. At a specific gravity of 3.0, this is approximately 10,000 tonnes of ore. With grades of 3 g/t Au as in Bell (2018), this is approximately 1,000 ounces 30 meters for the first pass of mining.

Comparing Mine Up and Mine Down

This paper presents some basic calculations on the volume of production over time for each model. I leave cost and revenues for future exercises. Both models start at same place, how can we compare them? One way to do so is to establish the amount of work required to accomplish one pass and then the number of passes possible in a year. Another way is to determine how much work required for the first 100,000 cubic meters of material?

In what follows, I investigate how much work required for the first 100,000 cubic meters of material. As before, the Mine Up produces an initial 10,000 cubic meters of ore from excavating the initial staging area and then 3,000 cubic meters of ore per pass. The Mine Down produces 7,000 cubic meters of ore per pass.

To get 100,000 cubic meters, Mine Down needs 15 passes. That takes the mine down 150 meters. It requires a lot of underground development to go along with it, approximately 300 meters along the ramp per pass. That's a fair amount of underground development, but not unreasonable.

To get 100,000 cubic meters, Mine Up needs 30 passes. That takes the mine up 300 meters. It requires very little underground development, just the initial staging area and a drill bay to store the drill when blasting or mucking in the initial staging area.

Now that we have a sense for how many passes are required to produce the same amount of ore for each model, how long does each pass takes? I have no basis for this but assume each pass in the Mine Down model takes 3 weeks total from 2 weeks for development and 1 week for mining. I assume each pass of the Mine Up model takes 1-week total. Based on this assumption, the Mine Up model is 3 times quicker than Mine Down.

It is possible to compare the speed of a single pass from each model with the number of passes required to produce 100,000 cubic meters of ore. Mine Up requires 30 passes, which is equivalent to 10 passes from Mine Down as the Mine Up model is 3 times quicker than Mine Down. Mine Down requires 15 passes. Therefore, the Mine Up model is “quicker” than the Mine Down model.

Conclusion

This cartoon economic analysis of the underground mining of an ore pipe considers two methods. One goes up from the midsection of the pipe, the other goes down. Using broad assumptions, I find that the Mine Up model produces ore more quickly than the Mine Down model. In addition, the Mine Up model requires less underground development. However, the Mine Up model assumes that it is possible to mine-out the middle 20 meters of the pipe over a great vertical extent, which may be unprecedented or unrealistic.

I mentioned coiled tubing drilling from DET CRC (2018) because long drill rods may be problematic for the Mine Up model but would go even further to suggest that it may be possible to implement the Mine Up model in a way that doesn’t require any human to be underground at all!

This highly simplified descriptions of geotechnical aspects of situation provides a useful demonstration of relevant economic calculations for considering mining methods. It is possible to expand on this analysis by including cost and revenue numbers.

References

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