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COST COMPARISON OF UNDERGROUND AND SURFACE MINING OPTIONS FOR POTENTIAL WESTERN MESABI RANGE IRON ORE RESOURCES

Submitted by:

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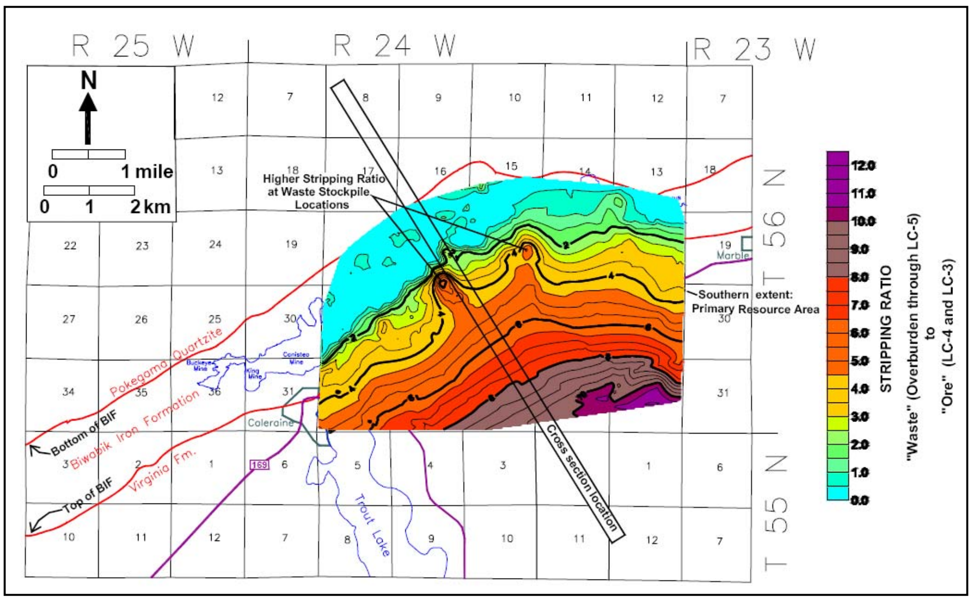

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Cover Photo Captions
"Waste" (overburden through LC-5) to "Ore" (LC-4 and LC-3) ratio (stripping ratio) within area of interest (Zanko et al., 2003).

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INTRODUCTION

This summary report compares capital and operating costs associated with hypothetical underground and surface mining operations located on Minnesota's Western Mesabi Iron Range. Spreadsheet cost models developed by the author are used for generating the comparative cost data.* The models are based in part on underground and surface mine cost information provided in InfoMine USA, Inc. *Mining Cost Service*. Model output is intended to provide ***only an approximation*** of capital and operating costs associated with both underground and surface mining, and should be viewed accordingly.

The following figure is taken from Zanko et al. (2003). The figure illustrates the stripping ratio (waste to ore) if surface mining were to progress down-dip within the Biwabik Iron Formation. "Ore" is considered to be restricted to sub-members Lower Cherty 4 and Lower Cherty 3 (LC-4 and LC-3). Note that the stripping ratio increases from about 4:1 to 6:1 approximately one mile to the south of the Biwabik Iron Formation's southern subcrop extent. Currently, the stripping ratio at active Minnesota iron ore (taconite) surface mining operations is at about 1:1. Based on the Biwabik Iron Formation's overall dip of 5-10° to the south in the area of interest, for every mile that mining progresses down-dip, the depth to ore increases by about 700 feet. Therefore, the ore zone (LC-4 and LC-3) of any mine developed more than one mile to the south of historic iron ore mining activity will be more than 1,000 feet below ground surface.

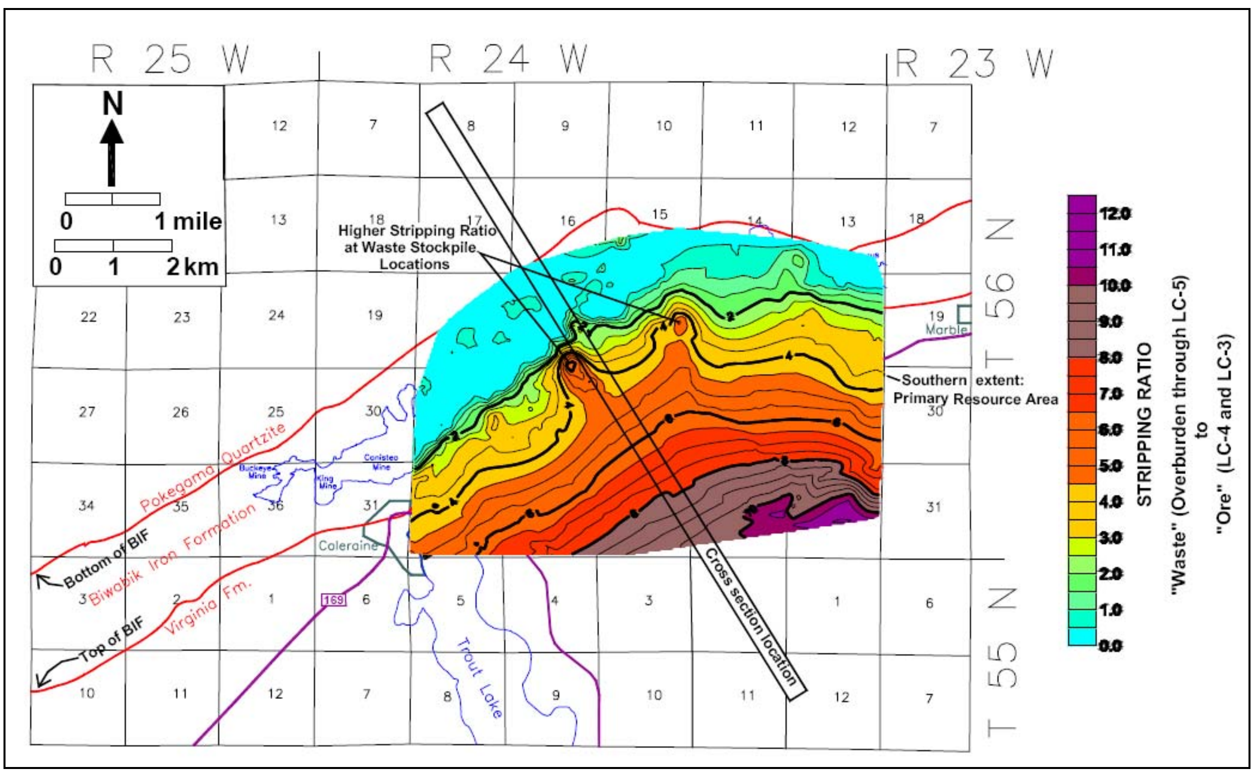

Figure 1. "Waste" (overburden through LC-5) to "Ore" (LC-4 and LC-3) ratio (stripping ratio) within area of interest (Zanko et al., 2003).

MINE MODELS

The selection of an underground mining method is dependent on the geology and geometry of the ore deposit, its depth, the vertical (hanging wall to footwall) and lateral extent of the ore zone, ore grade distribution, and the geotechnical properties of ore and waste (hanging wall). For this exercise, it is assumed that room and pillar (R&P) and possibly open stoping-type underground mining of Mesabi Iron Range iron ore/taconite could satisfy the selection parameters just described and offer the level of production needed to make underground mining an economically feasible alternative to surface/open pit mining. Production rates that can be realistically expected from these two mining methods range up to about 20,000 metric tons (tonnes) per day, or up to about 7 million tonnes (Mt) per year. It is possible that higher production rates could be achieved, but it is felt that taking a conservative approach to this exercise is more instructive. Furthermore, the available cost data presented in InfoMine USA, Inc. *Mining Cost Service* for the two underground mining methods are limited. To model costs at production rates beyond 20,000 tonnes per day would be an exercise in extrapolation and result in increasingly tenuous cost estimates.

Therefore, a range of capital and operating costs are presented for production rates of 5,000, 10,000, 15,000, and 20,000 tonnes per day. These costs are compared to the cost of surface mining at increasing stripping ratios (Table 1). It is assumed that ore from either mine would be transported to an existing iron ore/taconite processing facility.

RESULTS

A simple comparison of capital and operating costs alone shows:

- Underground mining exceeds the cost of surface mining unless the waste to ore (stripping) ratio for surface mining is about 6:1 or greater.
- Of the two underground methods modeled, Room & Pillar has a lower capital cost than Sublevel Stoping when production exceeds 10,000 tonnes per day, and a lower operating cost when production exceeds about 12,500 tonnes per day.
- Any economically realistic underground mining scenario should consider a minimum production rate of 15,000 tonnes per day for at least 20 years. Therefore, a Room & Pillar-type operation would be the most likely choice. This mining method was the choice of Pfleider and Scofield (1967) in their assessment of underground mining of Minnesota taconite.

Table 1. Capital and operating cost comparison of underground and surface mining.

Underground Mine		Production (tonnes per day)			
		5,000	10,000	15,000	20,000
Room & Pillar	Capital Cost	$86,696,373	$115,258,698	$129,477,598	$137,989,118
	Operating Cost ($/mt)	21.79	16.74	13.79	11.69
Sublevel Stoping	Capital Cost	65,252,958	112,586,040	157,594,356	201,213,433
	Operating Cost ($/mt)	16.73	15.49	15.08	14.87
Surface/Open Pit Mine		**Production (tonnes per day)**			
Stripping Ratio		**5,000**	**10,000**	**15,000**	**20,000**
1 to 1	Capital Cost	$20,206,243	$27,887,565	$35,688,081	$43,607,792
	Operating Cost ($/mt)	5.32	4.45	3.61	3.23
2 to 1	Capital Cost	24,119,797	37,636,507	51,272,411	65,027,510
	Operating Cost ($/mt)	6.97	6.02	5.09	4.65
3 to 1	Capital Cost	28,377,903	47,730,001	67,201,293	86,791,781
	Operating Cost ($/mt)	8.53	7.54	6.53	6.04
4 to 1	Capital Cost	32,980,562	58,168,047	83,474,728	108,900,603
	Operating Cost ($/mt)	10.03	9.03	7.96	7.42
5 to 1	Capital Cost	37,927,772	68,950,646	100,092,714	131,353,978
	Operating Cost ($/mt)	11.48	10.51	9.39	8.81
6 to 1	Capital Cost	43,219,534	80,077,796	117,055,253	154,151,905
	Operating Cost ($/mt)	12.91	12.01	10.84	10.23
7 to 1	Capital Cost	48,855,849	91,549,499	134,362,344	177,294,383
	Operating Cost ($/mt)	14.33	13.53	12.33	11.70
8 to 1	Capital Cost	54,836,715	103,365,753	152,013,987	200,781,414
	Operating Cost ($/mt)	15.76	15.11	13.89	13.24

CONCLUSION

From a pure mining cost basis, it is unlikely that underground mining of iron ore will be pursued unless stripping costs, land availability/access, and/or environmental concerns dictate otherwise. This is not to say that underground mining cannot be economic; if iron ore persists at the $100 per tonne (or more) price range, it could. However, surface/open pit mining will be ***more economic*** than underground mining, at least until the stripping ratio approaches the 6:1 range. It is not so much that a price point exists for iron ore where underground mining is cost-competitive with surface mining; rather, it is the cost associated with developing a mine at a satisfactory ore production rate that will dictate the choice of mining method.

From a pumped hydro energy storage perspective, future value could be derived from an underground storage cavern following mining. On the other hand, surface/open pit mining that progresses down-dip could have a similar end-effect, in that the elevation difference between an upper reservoir and a water body that forms in a mined-out pit may provide sufficient head to support a pumped hydro power generation facility.

It is the author's view that if potential magnetic taconite resources and/or oxidized taconite resources of the Western Mesabi Iron Range are to be developed, then that development should first focus on surface mining options. For example, the area west and south of the Arcturus Mine would provide almost immediate access to those potential resources. Before large-scale underground mining of the Biwabik Iron Formation can be considered, rigorous geotechnical work will first be required to assess how (and even if) this geological formation could be developed using underground mining methods.

REFERENCES

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