A Geoscientist's Perspective on Developments in the Tatshenshini Wilderness: Can We Eat The Filling But Keep The Cake?

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Introduction

In an Old Testament tale, King Solomon must decide which of two women is the mother of an infant boy. Before the days when DNA-fingerprinting could have solved the dilemma, the King proposed a simple but bloody solution. Dividing the baby was certain to satisfy neither woman but Solomon's legendary wisdom was established by his correct prediction. The real mother relented and he thus solved the case.

The debate over industrial development in wilderness areas renowned for their natural beauty calls on our governments to display the wisdom of Solomon. Both sides demand a clear solution. The mining interests (Geddes Resources, partners and stakeholders) propose to mine the copper-cobalt-gold deposit at Windy Craggy Mountain with minimal damage to the environment. Environmental groups (Tatshenshini Wild coalition and individuals) as well as the river rafting companies condemn the mine, its access road and bridge as ecologically destructive. They argue that development will degrade wilderness values and the valley should be left undisturbed. To them a compromise solution would be the same as a mutilated baby.

Scientific research has merely a supportive role in this debate. How society values wilderness is the real issue and public sentiment could influence the outcome. The protagonists, however, each anchor their case upon scientific research, as well as the economic costs and benefits. Both sides have commissioned on-going environmental studies. What information can come from geoscientists?

Geoscientists working for government (in particular the B.C. Geological Survey and Geological Survey of Canada) strive to

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provide impartial data on earth resources. Their job is neither to directly promote nor discourage mining, but to portray the geologic elements that could affect development of the region. They produce geological maps and reports[1] that describe the age and distribution of rocks and show the location of faults and other structures. Some modern maps depict the susceptibility of areas to environmental problems such as acid generating sulphide minerals.

These maps are also for sale to the public. To the skilled user, these maps show where mineral deposits might be discovered and where they are unlikely to be found, as well as the location of physical hazards. The maps are useful regardless of changes in policy or swings in popular sentiment.

The following are descriptions of geological terms, the importance of the Windy Craggy deposit, the economics of mining it, and some environmental considerations. My objective is to shed light on these aspects of the mining proposal for those without geologic training. I have not visited the Tatshenshini wilderness, but my main sources, listed in the notes, are accessible to the public.

Geology

The Windy Craggy deposit does not cover a large area. All the rock worth mining forms two bodies that together are less than 200 m wide, 1,600 m long and 600 m deep.[2] These ore bodies lie within a mountain 2,000 m above sea level on the divide between the Alsek and Tatshenshini rivers. Glaciers fill most of the high valleys as a result of abundant snowfall (1,100 cm/yr water equivalent[3]). The rocks are well exposed on steep slopes but their structure and geologic history is complex.

Windy Craggy is near the southern end of the St. Elias Mountains. These mountains are composed of numerous *terranes,* which are tectonic fragments that have accreted to the edge of North America during the last hundred million years. The terranes are like pieces of a jigsaw puzzle that have been swept to the side of the playing table: they are juxtaposed, overlapping and have deformed each other. In the field, geologists recognize terranes by the faults that separate them, and by deducing that adjacent rock sequences have had different geological histories and so must have originated in distinct places. Windy Craggy is part of the Alexander terrane (named for a group of islands in the Alaska Panhandle underlain by the same rocks) that collided with the rest of North America about 65 million years ago.[4]

The main rocks in Alexander terrane are 250 to 300 million-year-old siltstone and limestone mixed with a succession of volcanic flows several kilometres thick. The rocks contain fossils and textural details which suggest that they were deposited around island volcanoes in a shallow sea. Later the islands subsided and were buried beneath younger marine sediments. During burial, water trapped in the volcanic rocks transformed some minerals to clay, and siltstone became brittle argillite. These changes are called *greenschist metamorphism.* Later, perhaps during the collision with continental North America, this package of rocks was faulted, tilted and uplifted. In the last 65 million years, several kilometres of rock have been eroded to expose the mountains visible today.

Windy Craggy is a *volcanogenic massive sulphide* deposit. It is a concentration of sulphide minerals precipitated from underwater springs at the time when the ancient volcano was active. The deposit is a mass of the iron sulphide minerals pyrite and pyrrhotite, but within it is chalcopyrite, which contains copper and trace amounts of gold, lead, zinc, and other metals, bound in the molecular structure. The significance of Windy Craggy is both the size (about 114 million tonnes) and the richness or grade of the massive sulphide (1.9% copper, 0.08% cobalt, 0.20 grams/tonne of gold and 3.7 grams/tonne of silver).[5] At today's metal prices the Windy Craggy deposit, if mined, would be worth about fifteen billion dollars.

Windy Craggy deposit is also unusual for its association of gold and cobalt. Cobalt is a strategic metal, essential for medical and defence industries, and the world demand for it has exceeded supply for the last five years.[6] The current proposal for mining the Windy Craggy deposit does not include the costly extraction of cobalt, which lies within the molecular structure of pyrrhotite. If, however, the supply of cobalt from the main producers (Zaire and Uganda) were threatened, deposits such as Windy Craggy could assume greater importance.

The Windy Craggy deposit and its host rocks, the Alexander terrane, bear greater geological similarities to islands like Japan than to the rest of North America. Japan contains many volcanogenic massive sulphide deposits, known as Kuroko type, upon which its early industrial prominence was based. The

Alexander terrane may therefore likely to host additional massive sulphide deposits.

Economics of Mining

It is important to distinguish between a *mineral deposit,* which results from fortuitous geology, and an *ore deposit,* which depends upon a favourable economic forecast. A mineral deposit is a concentration of metallic elements that are normally sparsely distributed throughout the earth's crust. "Mineral deposits," as many a prospector has declared, "are where you find 'em," meaning that humans cannot control where they are. It is the challenge of the miner and mining engineer to find an environmentally safe and economic way to extract the valuable minerals.

The definition of *ore* is whether the minerals can be extracted at a profit. The feasibility of a mine commonly depends upon non-geological factors such as the method of mining, the distance that the waste rock and ore must be transported, and the cost of environmental protection. These expenses to some extent also determine the size of the ore deposit, because, as the costs of extraction rise, only the richest parts of the mineral deposit remain ore.

The economics of mining Windy Craggy are delicate because the ore deposit must be large enough to pay back the cost of building the 104 km access road, as well as a slurry pipeline to transport the ore to Haines, Alaska. To return the investment over a reasonable time a large operation is required. Geddes Resources Limited (the owner of Windy Craggy) calculated a production rate of 20,000 to 30,000 tonnes of rock to be mined each day.[7]

At this rate of extraction, a mine at Windy-Craggy would last about twenty years, after which the machinery would be removed and the site rehabilitated and the mine closed. The many defunct mining camps in British Columbia attest to the fact that ore bodies are not infinite. Unlike the old hulks and decrepit towns, modern standards of clean-up and land reclamation would determine how Windy Craggy is left once mining ceases.

Environmental Protection

Can the Windy Craggy deposit be mined safely? No development is allowed without permits. For various aspects of the access road, mine, mill, and transport of the ore, these permits will have to be issued by five independant jurisdictions: British Columbia, Yukon, and the state of Alaska, as well as departments of the two federal governments. As long as the deposit appears economically viable and venture capital is forthcoming, Geddes Resources Limited or other companies will face this challenge and attempt to secure approval. Development proposals will be revised and re-submitted in an iterative process to address the concerns of the environmental impact review panels. This process can result in use of environmentally appropriate technology and encourages careful pre-planning.

Most new mines in Canada and in other developed countries are "designed for closure," which, recognizing the fact that the mine will, one day, be shut down, therefore requires that site rehabilitation be planned from the outset. By planning for closure, mining by-products are situated where they can be rendered environmentally benign. Waste rock and tailings (ground-up rock) that have potential to cause acid are the principal risk. Unsightly, sterile waste heaps and contaminated streams are the too-common legacy of badly abandoned massive sulphide mines from the pre-'designed for closure' days.

Massive sulphides (pyrrhotite and pyrite) produce sulphuric acid when simultaneously exposed to both air and water minerals.[8] When the runoff is sufficiently acidic, and if the temperature is warm enough, certain bacteria will thrive on the sulphide, further increasing the speed and temperature of the reaction. In the process, heavy metals (arsenic, cadmium, cobalt, copper, iron, nickel, zinc and others) are leached from the dissolving massive sulphide and can reach high concentrations in the drainage water.

This naturally occurring, heat-producing chemical reaction would be a prescription for environmental disaster, but it is controlled by several factors. Other rocks that are alkaline, such as limestone, consume the acid and act as a buffer to neutralize the drainage. When the water is neutralized or sufficiently diluted, most heavy metals are precipitated.[9] Some rocks, initially affected by acid, form a crust which prevents further reaction. Red Creek, which drains Windy Craggy Mountain, is naturally acidic[10] as a result of oxidizing pyrite in its headwaters. The acidic water is neutralized by limestone near the deposit and no elevated metal content or increased acidity is evident downstream. As long as the volume of exposed sulphide is small, the surrounding rocks can buffer the acid generated and the natural environment is not affected.

Open pit mining at Windy Craggy would increase the exposure of acid-generating sulphides, so precautions will need to be taken. In the Canadian climate the accepted method is to keep the sulphides under water, which inhibits the free access of oxygen required to drive the reaction. The proposal for mining at Windy Craggy indicates that rock which has the potential to generate acid will be pulverized and fed into a tailings pond. The rock particles settle to the bottom and the water will be reclaimed and pumped back to the mine. Throughout mining the pond will gradually fill with tailings to a depth of 140 m. The water level, rising as the tailings accumulate, will remain about 4 m deep — enough to cover the tailings and prevent the production of acid. Acid-consuming rock, which poses no threat to the environment, will be piled in two places outside the open pit.

An open pit is planned for Windy Craggy because it is the least costly mining method. The disadvantage of this method is that additional rock must be removed as the pit becomes deeper to prevent the walls from collapsing. This waste rock contains pyrite and would be stored in the tailings pond. To reduce this volume of unwanted rock and to reach the bottom of the orebody, mining will go underground after ten years.[11] Acid-generating waste rock will then be stored in disused tunnels.

After the ore is exhausted and mining ceases, the underground spaces and pits will fill with water. Eventually the pit will probably lie beneath permanent ice. Only the tailings pond will remain and its earth-filled dams and water chemistry are to be constantly monitored.

Conclusion

Windy Craggy is a unique deposit in a remote and spectacular setting. The concerns raised by environmental impact review panels and in the hearings have resulted in a greater awareness of the need to understand the natural conditions. Geddes Resources Limited has provided environmental baseline studies and a database for informed decision-making. The permitting process is lengthy but Windy Craggy provides a rare opportunity. It is a deposit whose impressive size and grade justifies the expenses of applications and required environmental safeguards that have not been attempted until recently. Furthermore, it is a bell-wether for the mineral exploration industry in British Columbia and western Canada. Many companies await the fate of Windy Craggy to weigh their own chances of success in gaining permits for other smaller and lower grade deposits.

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NOTES

1 Two regional studies are: R.B. Campbell and C.J. Dodds, *Geology of Tatshenshini map-area*, Geological Survey of Canada, 1983, Open File 926; D.G. McIntyre, *Geology of the Alsek-Tatshenshini Rivers Area (114P)*, B.C. Ministry of Energy, Mines and Petroleum Resources, 1984, Paper 1984-1.

2 Windy Craggy deposit geology is summarized in three papers in the *8th IAGOD* (International Association on the Genesis of Ore Deposits) *Symposium Field Trip Guidebook 14*. (It is published as Geological Survey of Canada, 1990, Open File 2169, available from: Exploration and Geological Services Division, Northern Affairs Program, 200 Range Road, Whitehorse, Yukon, Canada, Y1A 3V1).

3 Geddes Resources Limited, Windy Craggy Project: *Stage 1: Environmental and Socioeconomic Impact Assessment*, submitted January 1990 (to the Mine Development Steering Committee, Ministry of Energy, Mines and Petroleum Resources, #105 - 525 Superior Street, Victoria, B.C. V8V 1X4. Comments on the proposal should be sent to this address).

4 P.J. Coney, D.L. Jones and J.W.H. Monger, "Cordilleran Suspect Terranes", *Nature*, 27 Nov. 1980, Vol. 288, pp 329-333.

5 B.W. Downing, M.P. Webster and R.J. Beckett, "The Windy Craggy massive sulphide deposit, northwestern British Columbia", *8th IAGOD Field Trip Guidebook 14*, 1990, pp 25-29.

[6] Roskill Information Services Ltd. report in a bulletin of U.S. Bureau of Mines, 1991.

[7] Geddes Resources Limited, Revised Mining Plan for the *Stage 1 . . . Assessment*, submitted November, 1990.

[8] $FeS_2 + 15/4\ O_2 + 7/2\ H_2O \longrightarrow Fe(OH)_3 + 2\ SO_4^{2+} + 4\ H^+$
(Pyrite + air + water —> rust + sulphuric acid)

[9] British Columbia acid mine drainage task force, *Draft Acid Rock Drainage* (ARD) *Technical Guide*, 1989, volume 1. (Available from: Steffen Robertson and Kirsten (B.C.) Inc., 801-1030 West Georgia St., Vancouver, B.C. V6E 2Y3.)

[10] Geddes Resources Limited, Windy Craggy Project, *Stage 1 . . . Assessment*, 1990, Volume 2: Environmental Baseline Studies, Section 7.

[11] Geddes Resources Limited, Revised Mine Plan, *Stage 1 . . . Assessment*, 1990.