TGS → Britannia

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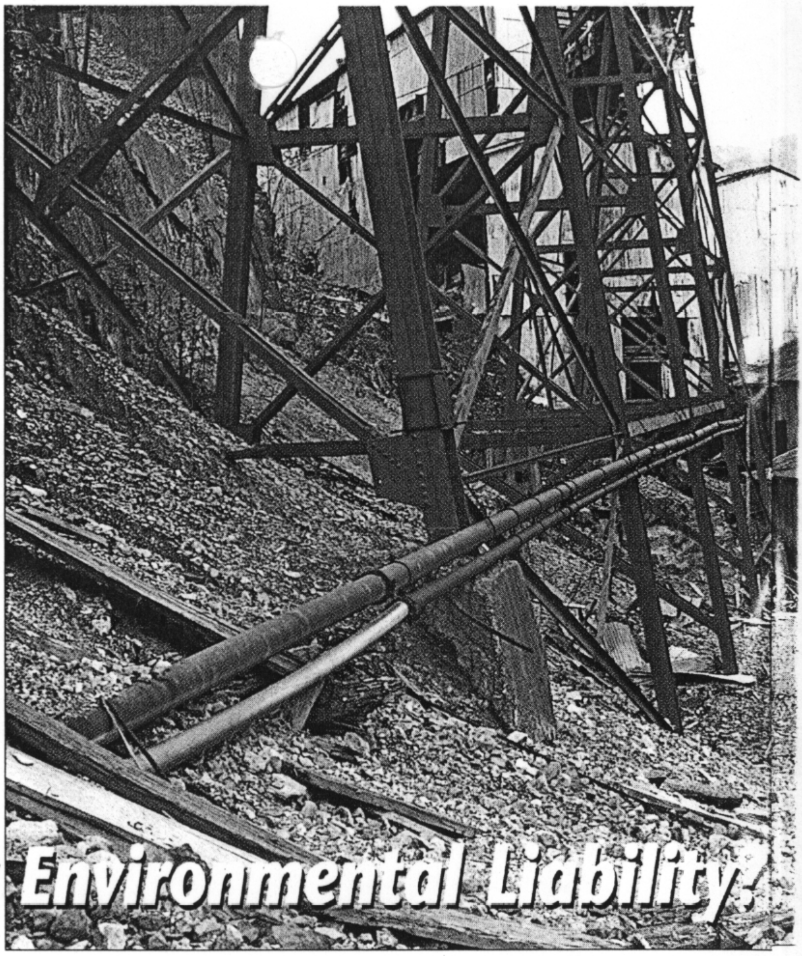
# The Britannia Mine



## Historic Landmark or Environmental Liability?

Robert G McCandless PGeo

Probably every BC resident has, at one time or another, driven past the Britannia mine site located at Britannia Beach on the Squamish highway, some 50 km north of Vancouver. Few may appreciate that this abandoned underground copper mine, although a popular tourist attraction and a designated National Historic Site, probably represents the worst point source of pollution of any mine in the province. Large flows of highly toxic waters are released into Britannia Creek and Howe Sound, threatening aquatic life and vegetation on the adjacent shoreline. Examining the causes of, and probable solution to, this problem incorporates the current state of knowledge on one of the mining industry's most persistent issues: that of acid mine drainage.

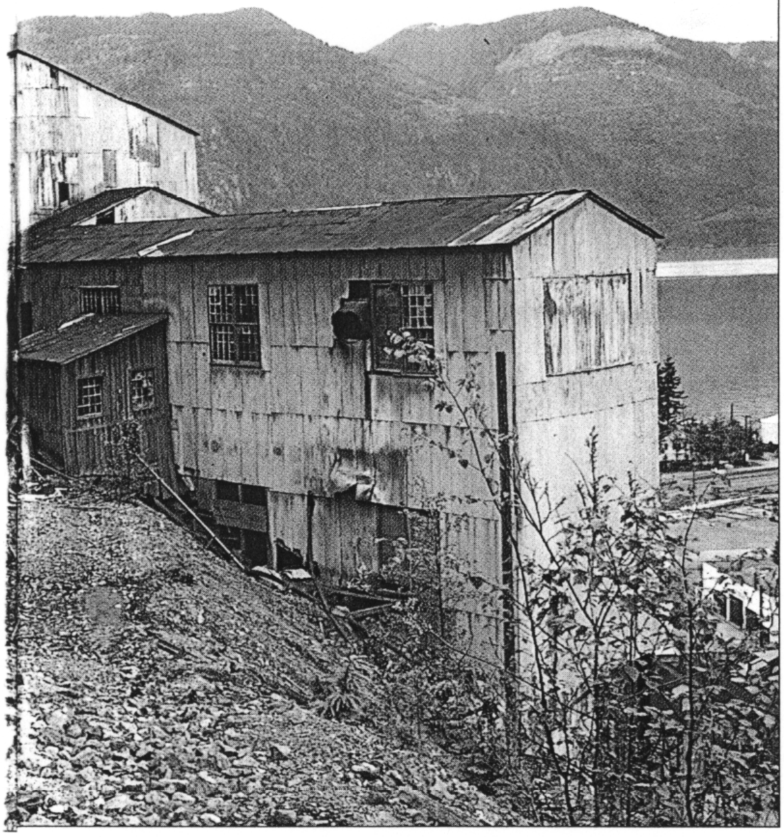
Rectifying the problem might seem to be a straightforward task — building a treatment plant for the mine waters — but it raises the question of who will cover the associated costs. For now, the resources of the provincial and federal governments are limited to what their shrinking budgets will allow. In addition, the legal and policy issues surrounding the mine ownership and liabilities present almost as big a problem as the acid mine drainage itself.

### The Formation of Acid Mine Drainage

Understanding the Britannia mine problem requires a basic overview of how acid mine drainage is formed. The most common metallic minerals, iron sulfides like pyrites (fool's gold) and pyrrhotite, oxidize in air and water to form iron oxides with their distinctive rusty colour. The sulphur becomes oxidized to sulphate. When the rock lacks sufficient carbonates (eg, limestone) to buffer oxidation, this sulphate forms sulfuric acid, which dissolves associated sulphides of copper and zinc. The water that carries oxidation products from high-sulphur ores or waste rock is referred to as acid mine (or rock) drainage, or AMD.

The oxidation of pyrites proceeds in stages: most of our knowledge is based on decades of research into the high-sulphur coals of Pennsylvania. As iron sulfides undergo weathering by air and water, iron enters the solution slowly as the ferrous ion Fe++. This in turn slowly oxidizes to ferric iron [Fe+++], especially when the solution becomes more acidic (ie, a pH of less than 5.5). The presence of acid-loving bacteria like *Ferrobacillus ferrooxidans* greatly accelerates the oxidation process. The ferric iron that is released percolates downward and, in turn, attacks the remaining primary sulfides, thereby accelerating their dissolution and releasing more ferrous iron in a cascading reaction.

Rock piles containing sulfides can literally "ferment" and release enough heat, under the right conditions, to raise temperatures above 40°C and begin slowing the bacterial action (miners will recall such an extreme case at the Sullivan mine near Kimberley). Termed "hot muck", the oxidation reaction, probably triggered by a spark, heats massive amounts of sulfide ore to the melting point and releases dangerous levels of sulphur dioxide.



**Back view of the mill building visible from the Squamish Highway shows iron-stained, high-sulphide waste rock.**

Some researchers have begun to investigate the possibility that the actions of bacteria in the downward percolation of acidic solutions through broken rock may lead to "chaotic" or self-regulating composite systems. The mound of waste rock, or ore, may contain two or more rates of oxidation whose inherent stability resists the effects of changes in heat, water or oxygen conditions within the mound. In other words, once started, the process of AMD resists being halted. At present, it is known that a thick impervious overlay of glacial till will prevent the AMD reaction from accelerating to critical rates. A safer but more costly method is to place reactive rocks and mill tailings beneath a permanent water cover, which virtually eliminates their exposure to oxygen.

## Britannia Mine Layout

The layout of Britannia's ores and the mine workings present ideal conditions for the formation of AMD. Formed in vertical tabular masses of iron, copper and zinc sulfides, the ores are surrounded by "haloes" of pyrites in the host volcanic rocks. Unfortunately, the lack of carbonates in the rock allowed the formation of AMD soon after mining commenced. Throughout the mine's operation from 1905 to 1974, this AMD had great value: the miners led the copper-rich solution through "can plants" or concrete trenches where the copper replaced the iron in scrap metal. However, present-day copper concentrations of about 15-30 mg/l are too low to allow for economical recovery, but they remain highly toxic to aquatic life.

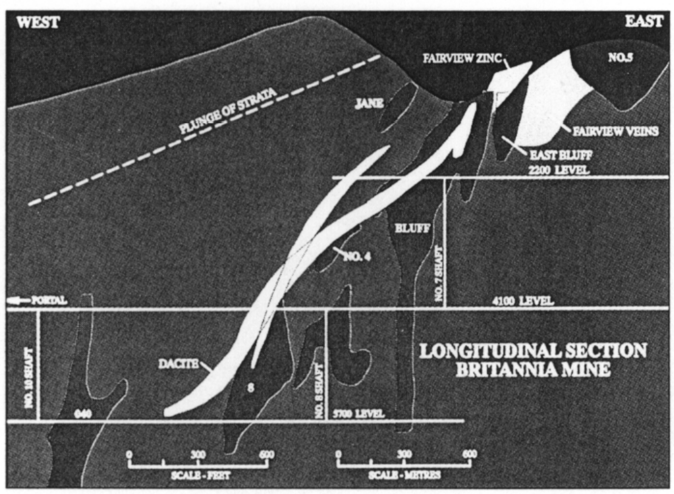
The most difficult problem lies with the mine's architecture. The ore bodies are exposed near the summit of Mineral Ridge, a limb of Mount Sheer to the east of the mine. At this summit, the original mine stopes, or "glory holes", allowed easier mining of surface ores to take place. Towards the end of the mine's life, open pit mining deepened these sites into the large basins found there today, which trap very heavy snows and rain and funnel them into the mine.

## Drainage

The runoff created by the collection of snow and rain in Britannia's surface excavations forms a continuous flow of 400 to 600 $m^3$/hr of toxic water from the lowest level, the six kilometre-long 4100 adit leading to Britannia Beach. A second portal at the 2200 level (1,900 feet above the 4100 adit) leads into the mine from the old Mount Sheer townsite, five kilometres northeast of Britannia Beach. It also carries AMD flows that discharge into Britannia Creek, pollute it, and stain its rocks with the rusty colour seen there today. Even worse, the creek's warmer, fresher waters discharge into and float above the heavier saltwater of Howe Sound. Since juvenile salmon tend to favour brackish water and sheltered inlet areas, the Britannia pollution may threaten salmon survival.

At present, the 4100 adit drainage flows into a concrete pipe buried beside Britannia Creek and discharges 50 metres below the surface of Howe Sound. This reduces the impact of AMD on surface waters, but does not solve the fundamental problem.

In the late 1980s, a dam was built deep inside the 2200 adit in an attempt to divert the flow into an internal shaft (winze) down to the 4100 level. This worked initially, but its eventual collapse rendered the dam ineffective. One option that has been considered is collecting the 2200 drainage and conveying it by surface pipeline to Britannia Beach.




**A schematic section through the mine shows its depth of over 900 metres (3,000 feet) and Jane Basin. The 5700 level is about 450 metres below sea level.**

*Above:* **The southwest wall of Jane Basin show outcrops of high-sulphide ores; the basin to the left drains into the mine workings.**

*Right:* **Copper-rich waters draining from the 2200 level used to replace the iron in scrap metal.**

## Treatment Options

Although it might seem impossible to seal the mine's surface openings on Mineral Ridge, perhaps plugs or bulkheads made of very thick, acid-resistant concrete with extensive rings of grouting could be used to form a permanent seal of the adits. However, plugging the drains of the basins would allow them to fill, discharging overflow acidic water down Jane Creek into Britannia Creek and recreating the original problem. In addition, the failure of a bulkhead or seal under a 600 metre hydraulic head could have catastrophic effects on the road and rail lines at Britannia Creek, to say nothing of the risk to human life.

A treatment plant offers the only feasible solution. Two other BC mines, Equity near Houston and Sullivan near Kimberley, house large plants that add lime to the AMD. Within these treated solutions, sulphate precipitates as lime sulphate, or gypsum, with iron as its hydroxide, which together scavenge the toxic copper and zinc in the resulting sludge to clean the water sufficiently for discharge. However, the construction of a treatment plant would solve one problem only to create another. While the Equity and Sullivan mines include facilities for the safe disposal of the sludge, no such option exists on the rugged terrain above Britannia Beach and the sludge characteristics could classify it as special waste. Drying the sludge to a cake for disposal elsewhere (or use in a smelter) is one option, but would add to the multi-million-dollar cost of a treatment plant. A complicating factor for the treatment plant option lies in the great variation in hydraulic flows (low in late summer and high in spring), which requires sizing of all components to handle peak flows.

In its long runs from the mine workings, the AMD becomes diluted somewhat as a result of cleaner groundwater entering the 2200 and 4100 adits from the surrounding rock. Studying the mine plans might reveal a way to isolate the AMD and transport it to a plant via an internal pipeline. More concentrated AMD allows for more efficient treatment and perhaps even the opportunity of metals recovery via sulphide precipitation, solvent extraction, ion exchange resins or, as BC Research has proposed, using natural zeolite minerals found in BC that have this property.

### Who's Responsible?

The legal labyrinth of ownership of and responsibility for the Britannia mine represents yet another impediment to solving the AMD problem. The vast Britannia properties underwent a change of ownership from Anaconda in 1974, at a time when the government took a somewhat different view of mine pollution. The new owners sold some of the mine properties and operated the facility on the strengths of equipment rentals and gravel extraction. By 1994, a mortgage holder had foreclosed on the properties for a debt of $6 million plus interest.

A Court-appointed receiver presently manages the Britannia properties. Repeated efforts to find a new buyer through the Court (the files are piled over a foot high on the Judge's bench) have not as yet succeeded. Not surprisingly, potential buyers are reluctant to assume the environmental liability associated with the mine, especially since its probable cost has yet to be estimated by government.

Environmental problems aside, the property itself — containing some 250 mineral claims, foreshore

**Elevated iron 2200 level drainage mixes with cleaner waters of Jane Creek and causes the precipitation of iron oxides both here and in Britannia Creek immediately below.**

property, timber, gravel reserves and even hydropower — could offer a significant development opportunity. However, it seems unlikely that capital gains after site development could manage the cost of resolving the AMD problem.

### A Lesson Learned

Understanding the formation of AMD as it has occurred at the Britannia mine will greatly assist mining engineers in planning less costly methods to prevent its occurrence in the future. This is a critically important factor in the environmental design of mines containing the high-sulphide ores that are common to BC.

The provincial and federal governments have recently taken steps to identify a solution to Britannia's AMD problem. In 1994, an agreement was signed between the BC Ministry of Environment, Lands and Parks and Environment Canada to begin design work on a treatment plant. Government funding for initial studies, let alone the construction and operation of a treatment plant, remains a contentious issue: the total cost in present dollars is estimated to exceed $40 million.

The Britannia mine pollution problem presents government and the mining industry with a Gordian knot: every possible approach leads to more complications. Although all parties would like to see the problem resolved, they are compelled to live with it while efforts continue to identify an appropriate remediation solution.

In any event, today's mining engineers readily accept their responsibility to account for the costs of AMD when planning new mines and the abandonment of mining properties is no longer considered an option in today's climate of heightened environmental awareness.

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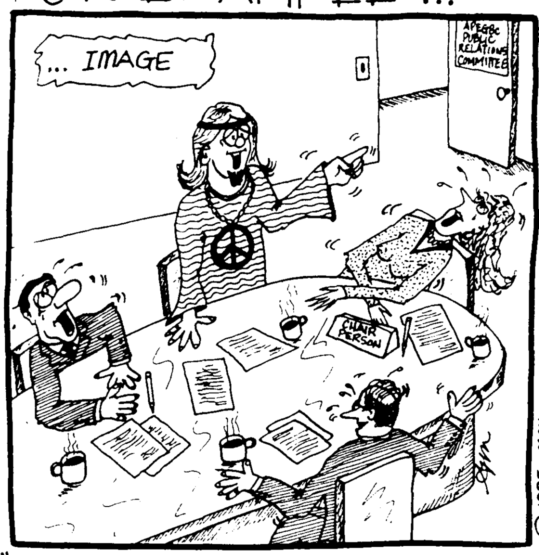
FOR EXAMPLE ...

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