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SURVEY OF CLOSED AND ABANDONED MINES IN BRITISH COLUMBIA FOR ACID ROCK DRAINAGE I: REGIONAL PERSPECTIVE

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ABSTRACT

In 1991, Environment Canada and the British Columbia (B.C.) Acid Mine Drainage Task Force initiated a project with the goal of compiling information for closed and abandoned mine sites throughout British Columbia. The ultimate objective of the study is to assess the current and potential impacts caused by acid rock drainage (ARD) on surface water quality throughout the province. In addition, in the Fraser River basin, non-mining sources of ARD (such as natural weathering, railway and road cuts and municipal developments) are also being considered. This paper presents the results of the evaluation with respect to the regional distribution of closed and abandoned mines throughout B.C. and the regional ARD potential based on a derived ranking scheme.

Three regions of the province were identified as having a high potential for ARD. There are several acid-producing mines in the Smithers and Stewart regions and Vancouver Island, and other mines are in geological settings which could allow ARD to be produced. The Kootenay region has seen extensive historical mining activity, but there is a lack of environmental data for individual mines. The presence of limestone and calcite in the mine sequences limits ARD potential in the Kootenays, although this mineral is not always closely associated with ore minerals.

In general, the Fraser River basin has less historical mining activity than the rest of B.C, partly as a result of glacial drift cover. The potential for ARD in the basin also appears lower than elsewhere due to the common occurrence of calcite-bearing volcanic rocks.

INTRODUCTION

In 1991, the British Columbia Acid Mine Drainage Task Force and Environment Canada commissioned a project to compile an inventory of closed/abandoned mine sites in British Columbia. The objectives of the study were to identify all significant closed/abandoned mine sites in British Columbia, compile information on the potential for acid rock drainage (ARD) at these sites, and inspect selected sites to supplement and confirm information collected from other sources. The study also formed part of Environment Canada's Green Plan (Environment Canada 1990) which contains a commitment to improve the environmental quality of the Fraser River basin. The basin was subjected to a more detailed compilation of all closed/abandoned mine sites, and to an assessment of the potential for ARD from non-mining sources, such as, linear developments, municipal developments and natural rock exposures.

The tasks accomplished for the project include:

- compilation, using existing databases, of geological and ore production information for significant closed and abandoned mines;
- acquisition of additional quantitative and anecdotal information on geology, ore and waste production, water quality and ARD potential;
- ranking of significant closed/abandoned mines for ARD potential and selection of certain mines for site assessment;
- site inspections at nine closed/abandoned mine sites and along two major highways in southern B.C.; and
- recommendations for further studies to compile data and improve understanding of the potential for impacts due to ARD from closed/abandoned mine sites.

A project report has been completed (SRK and Norecol 1992). This paper presents the results of the compilation of mines from regional and geological perspectives. Individual mines and site inspections are not discussed.

It should be noted that past-producing mines are referred to as closed/abandoned throughout this paper. For many mines, no distinction can be "made between "closed" (not operating, but permits are effective) and "abandoned" (not operating and land returned to the Crown) mines as defined in the Mines Act, without a detailed land status review for each mine.

INFORMATION SOURCES

Mine Information

As a first step in the project, a list of all closed/abandoned mine sites in British Columbia was prepared to serve as a basis for further collection of data and initial characterization of mineral deposit types. The B.C. Mineral Inventory File (MINFILE) (Wilcox 1988) was the main source of information. Previously, the Geological Survey of Canada (1990) and the B.C. and Yukon Chamber of Mines (1991) have both produced maps depicting larger operating and closed/abandoned mines, and significant mineral exploration properties.

MINFILE contains information for more than 9300 undeveloped prospects, operating mines and closed/abandoned mines (referred to as "past-producers" in MINFILE). The database documents 1628 closed/abandoned mines for which mineral production exceeding 1 tonne was reported to the Minister of Mines. The definition of past-producer in MINFILE is not consistent with the current definition of "a mine". Currently, the B.C. Mine Development Assessment Act effectively defines a mine as capable of producing more than 10,000 tonnes of ore in a year. Exploration projects involving underground development or trenching could produce this amount of rock. Therefore, most (83%) of the older past-producers in MINFILE would not strictly be classified as mines.

For each mineral occurrence in MINFILE, data are provided on the location of the occurrence, regional and local geology (including mineralogy, age, deposit character, deposit classification, lithology and formal host rock name), and production (type of mine, commodity, rate, reserves) (Table 1). Only a portion of this information was found to be directly applicable to the quantification of the ARD potential at closed/abandoned mines. For example, concentrations of iron sulphides and common carbonates are not reported consistently. In some instances, the presence of these minerals is known but not reported.

The classification of deposit character (for example, massive, vein, disseminated, stockwork) was useful because this parameter is often related to ARD potential. If the character of a deposit is massive, high concentrations of sulphur are present and the potential for heterogeneously distributed sulphidic masses in mine workings and rock dumps is probably greater than if the sulphide minerals are disseminated. Acid drainage potential might then be greater for massive sulphide deposits. The 13 deposit character classes in MINFILE were summarized into three major groups, with decreasing ARD potential: (1) massive; (2) vein; and (3) disseminated. Inevitably, this classification is not ideal because the distribution of neutralizing minerals is not the same as sulphide minerals. For example, massive sulphide mineral deposits may be associated with limestone host rocks, and calcite may be absent from disseminated mineral deposits such as porphyries. Furthermore, MINFILE frequently gives more than one character for any given mineral deposit, but does not indicate the dominant type. For this project, these mines were assigned to the group with the highest potential for ARD.

The assigned deposit character types were later used as part of a ranking formula for ARD potential.

TABLE 1
Summary of Mineral Occurrence Description Fields in MINFILE

Description Field	Examples
Location	UTM eastings, northings and zone, latitude and longitude, NTS map sheet, mining division, tectonic belt, physiographic regions.
Geological Description	
Mineralogy	Ore minerals, gangue minerals, alteration minerals
Age	Host rocks, mineralization
Deposit Character	Vein, stockwork, breccia, massive, stratabound, disseminated
Deposit Classification	Volcanogenic, skarn, epithermal
Lithology	Granite, limestone, andesite
Host Rock	Hazelton Volcanics, Sicker Group
Production	
Commodity	Gold, zinc, copper
Status	Producer, past producer
Production rate	tonnes ore per year, grams Au/year
Reserves	in tonnes

Mine Site Characterization

After the list of closed/abandoned mine sites had been prepared, additional information on waste characteristics, site conditions and water quality was sought from water quality databases, government officials, and private companies and individuals to derive a mine site characterization.

Several databases of water quality information were considered as possible sources of information indicating ARD, such as low pH, and elevated concentrations of sulphate and metals. The Regional Geochemical Survey (RGS) conducted by the Geological Survey of Canada and the B.C. Ministry of Energy Mines and Petroleum Resources (Matysek 1987) contains single sample information for more than 38,000 stream sediment and water sampling sites throughout B.C. However, the objective of the RGS is to identify new mineralization. Sampling downstream of known mines was deliberately avoided for this reason until recently (P. Matysek, personal communication). A rigorous search of the database located only one instance of low pH water downstream of a relatively large mine in the Kootenay region.

The B.C. Ministry of Environment Lands and Parks' (MELP) SEAM (System for Environmental Assessment and Management) database was considered but was not in a form suitable for regional evaluation of water quality near the large number of mines compiled for the study. In most instances, regional officers of MELP were aware of the evidence of acid generation shown by SEAM stations, and this information was obtained. Environment Canada has a stream water database but this only contains information for major and transboundary rivers and so was not used. In summary, the water quality databases were either not appropriate for the study or were not available in a readily accessible digital format, and therefore, little information of any relevance to ARD was obtained from them.

Government officials in Victoria and in regional offices, and non-government individuals, were contacted directly to obtain file or anecdotal information on each closed/abandoned mine site. A standard format was used to record information, such as location, ore type and mineralogy, mining method, amount and composition of waste rock and tailings, adit discharge and seepage data, and receiving water data.

RANKING OF CLOSED/ABANDONED MINES BY ARD POTENTIAL

A scoring system was developed to classify mines according to their potential for generating ARD. Scoring was based on information obtained from MINFILE, government officials and other sources. The objectives of this scoring system were multiple, as follows:

- to develop a regional picture of the location of the mine sites with the highest ARD potential, and thereby focus attention on key areas;
- to rank less well understood sites and compare these with the better known sites to compare the potential severity of ARD;
- to confirm that no other ARD generating sites exist that have previously not been recognized; and
- to assist government in focusing on the higher ranking sites from the perspective of further investigation, remediation and reduction of environmental impacts.

The components of the overall ARD score are shown in Table 2. Four categories were chosen which are considered to directly influence the magnitude of ARD potential: deposit character (D), ARD significance (A, a classification according to geological environment), production rate (PR) and total production (P_T). Of these, the most important was considered to be ARD significance. The best combination of weights and scores was found to be:

$$\text{ARD Rank} = D + 3A + P_R + P_T.$$

This combination generally gave a high rank to closed/abandoned mines with known ARD, and a low rank to sites lacking ARD potential. Large mines with high ARD significance scores are ranked the highest in terms of ARD potential. Small mines with high ARD significance and

TABLE 2
Summary of Scores Used to Classify Mines According to ARD Potential

Deposit Character Score (D) Score 3 if mineralization occurs partly in massive form. Score 2 if mineralization is not massive but occurs partly in veins. Score 1 if mineralization occurs partly in disseminated form. Score 0 for unconsolidated and non-sulphidic minerals deposits (for example, placer mines) Production Rate Score (P_R) Score 1 for daily production greater 1000 tonnes, otherwise score 0. Total Production Score (P_T) Score 2 for total ore production in excess of 1 million tonnes. Score 1 for total ore production between 100,000 and 1 million tonnes. Score 0 for total ore production less than 100,000 tonnes.	ARD Significance Score (A) Score 1 if the mineral deposit is hosted by limestone or other strongly calcareous rocks. Score 2 for mineral deposits containing an excess of carbonate minerals compared to sulphide minerals. Score 3 if geological features do not preclude the development of ARD, of if information is not sufficient to determine ARD potential Score 4 if the potential for ARD appears to be high due to abundant sulphide minerals and absence of calcite, but ARD has not been recorded. Score 5 if ARD is being produced and significant changes in the receiving have been observed. Maximum Score - 21

large mines with low ARD significance have roughly the same score. This recognizes that small mines with poor quality drainage can have a significant impact on sensitive environments. As mines lacking data were given an ARD significance score of 3, this score was considered the cutoff for further consideration of individual sites.

REGIONAL DISTRIBUTION OF CLOSED/ABANDONED MINES

The geographical distribution of closed/abandoned hardrock metal mines according to tonnage of ore produced is shown in Figure 1. Closed/abandoned mines are clearly concentrated in certain regions of the province, partly as a result of favourable geological environments and accessibility.

Closed/abandoned mines are concentrated on Vancouver Island, and in the Smithers and Stewart areas, and in the Kootenay region where extensive production of lead, zinc and silver from numerous small to medium size underground mines has occurred. Despite these regional concentrations, over half of the total production from closed/abandoned hardrock metal mines came from closed sections of porphyry copper mines located in the vicinity of Kamloops.

Coal mining has also been concentrated in a few areas of the province (Figure 1) because coal occurs in very specific geological environments. Figure 1 does not show coal mine tonnages because this information is not consistently reported in MINFILE. The main areas are southeast coal, northeast coal, Bowser Basin, Nanaimo-Comox-Cumberland (Vancouver Island) and Merritt-Princeton. The eastern mines are associated with limestone, whereas the western and central mines tend to be associated with sandstone, siltstone and shale. The western and central mines probably have the greatest potential for ARD; however, no cases of acid generating coal mines have been reported in B.C.

The Fraser River basin has a relatively lower density of both closed/abandoned hardrock metal and coal mines compared with the rest of the province. Most of the northwestern part of basin lacks any recorded mineral production. This plateau region is blanketed by thick glacial drift deposits which limit the exposure of bedrock. In addition, the western portion of the basin adjacent to the Coast Mountains is not easily accessible.

POTENTIAL FOR ARD FROM CLOSED/ABANDONED MINES

Closed/abandoned mines in certain regions of the province yielded high ARD ranks. A figure or table showing actual ARD ranks has not been reproduced for this paper because the classification of individual mines is considered preliminary and subject to verification, and the information has yet to be made public. Closed/abandoned mines in the Stewart and Smithers areas have high ARD potential (ARD rank around 70%, as a percentage of the maximum possibly score of 21) due to a general lack of acid neutralizing host rock, although some mines may have sufficient calcite associated with mineralization to prevent the formation of ARD. Mines is this area tend to be remote and consequently conditions for many sites are not well known.

Regional ARD potential is high in several different parts of Vancouver Island (ARD Rank greater than 70%) associated with unrelated geological sequences. However, numerous iron and copper mines are associated with a regional band of limestone and have not been known to produce ARD (ARD Rank less than 45%).

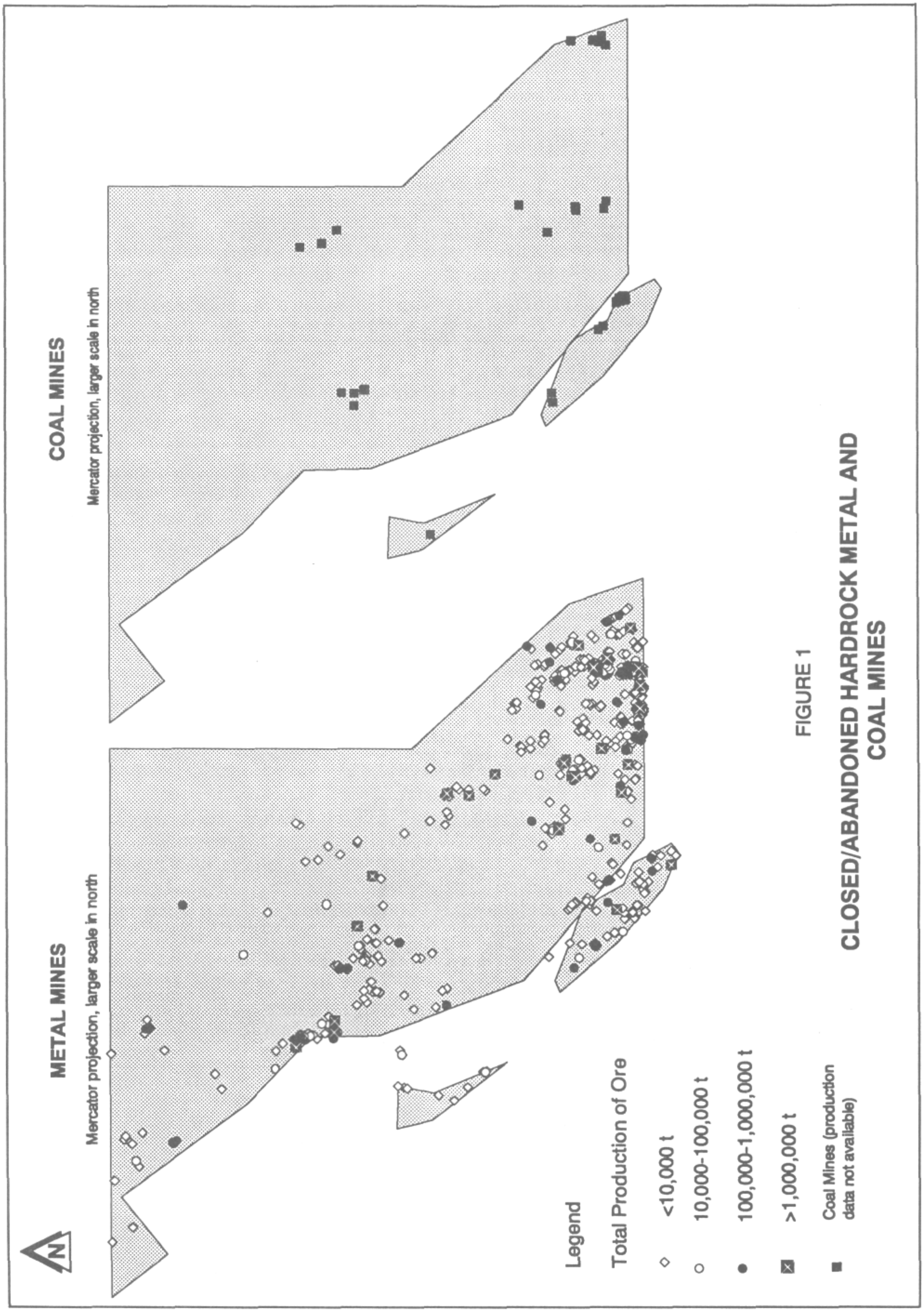

FIGURE 1

CLOSED/ABANDONED HARDROCK METAL AND COAL MINES

Despite the large number of closed/abandoned mines in the Kootenay area, the ARD potential in the region appears to be lower than elsewhere in the province. Mineralization tends to be hosted by limestone, or contains abundant calcite. Specific water quality data are lacking for most mines in this area, and useful geological data is rare. Therefore, relatively high ARD ranks (greater than 61%) were obtained because many of these mines were given ARD significance scores of 3 (Table 2). Towards the eastern edge of the Kootenay region, the potential for ARD may increase since limestone is less abundant.

Significant closed/abandoned acid generating mines have not been identified in the Fraser River basin (ARD rank less than 50%) perhaps due to the relative abundance of calcite-bearing volcanic rocks, and the low density of mines. However, elevated concentrations of metals not associated with ARD (such as arsenic) may be a concern at specific sites. Acid rock drainage, if present, is probably associated with granodioritic intrusions, as shown by two examples of ARD from naturally weathered mineral deposits in the western part of the basin.

Although coal mines are known to generate acid in other regions of North America, closed/abandoned coal mines do not appear to be a source of ARD in B.C. One report of ARD was obtained for a coal mine on Vancouver Island. However, a subsequent field visit failed to confirm the report. Rocks associated with Southeast and Northeast coal deposits tend to contain abundant calcite and low concentrations of sulphur, and therefore, these large mines are very unlikely to be sources of ARD.

CONCLUSIONS

From a regional perspective, the survey of closed/abandoned mines has shown that mines in the Stewart and Smithers areas, the eastern Kootenays and Vancouver Island, in particular, have a potential for generating ARD. The Fraser River basin and western Kootenays appear to have a lower regional ARD potential.

The survey did identify several closed/abandoned mines with a sufficient ARD potential to warrant further investigation. However, most of the these were already known to some degree, and no new high potential sites were identified. This conclusion should be considered preliminary as data were lacking for several sites, the majority of which occur in remote central and northern areas. More information is also required for mines in the Kootenay region to determine the potential for ARD.

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BIBLIOGRAPHY

B.C. and Yukon Chamber of Mines. 1991. Mines and Advanced Projects in B.C. Map. January 1991.

Environment Canada. 1990. Canada's Green Plan. Supply and Services Canada Cat. No. En21-95/1990E.

Geological Survey of Canada. 1984. Mineral Deposits and Principal Mineral Occurrences of the Canadian Cordillera and Adjacent Parts of U.S.A.

Matysek, P.P. 1987. A new look for the Regional Geochemical Survey data. B.C. Ministry of Energy Mines and Petroleum Resources, Geological Fieldwork, 1986, Paper 1987-1 p.387-394.

Steffen Robertson and Kirsten (B.C.) Inc. and Norecol Environmental Consultants Ltd. 1992. Survey of Closed and Abandoned Mine Sites in British Columbia for Acid Mine Drainage. Report prepared for Supply and Services Canada and B.C. Ministry of Energy Mines and Petroleum Resources. 68pp and Appendices.

Steffen Robertson and Kirsten (B.C.) Inc. 1988. Acid Mine Drainage in British Columbia. Analysis of Results of Questionnaire from Acid Mine Drainage Task Force. Report prepared for the B.C. Acid Mine Drainage Task Force. 60 p and Appendices.

Wilcox, A.F. 1988. New MINFILE - A mainframe and personal computer based mineral inventory database. B.C. Ministry of Energy Mines and Petroleum Resources, Geological Fieldwork, 1987, Paper 1988-1, p.549-554.