MINERAL POTENTIAL PROJECT - OVERVIEW

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INTRODUCTION

The Mineral Potential project was initiated in 1992 to meet the need for current regional mineral potential information in regional and sub-regional land-use planning. These planning processes have the responsibility of making recommendations on protected areas, as described in the provincial Protected Areas Strategy (PAS). The goal of PAS, created in 1992, is to protect representative examples of the province's natural, recreational and cultural heritage features. A provincial target of 12% protection has been established; when PAS was announced, 6% of BC was considered protected. Mineral exploration and mining are not allowed in protected areas, hence decisions on which areas to protect need to fully account for mineral values.

Part of the mandate of the Commission on Resources and Environment (CORE) is to run regional land-use planning processes and to make recommendations to government on their findings. Initially, three regions, Vancouver Island, Cariboo-Chilcotin and the Kootenays, were selected for evaluation and land-use planning (Figure 1). Recommending protected areas is one of the more controversial issues in the CORE process.

To provide readily useable mineral resource information to this process, the land within each region was ranked with respect to its mineral potential using quantitative analysis. The CORE process necessitated the upgrading of all resource and cultural inventories in the province to facilitate informed land-use planning. This project is one of more than twenty inventory projects undertaken by seven ministries. The project is operated by the Geological Survey Branch of the British Columbia Ministry of Energy, Mines and Petroleum Resources and was designed to meet CORE's timetable. The project will complete the mineral potential assessment of the province within a four-year time frame and will meet the information needs of other land-use processes in addition to CORE's.

This paper provides an overview of the methodology used to assess the mineral potential and report on the progress of the project.

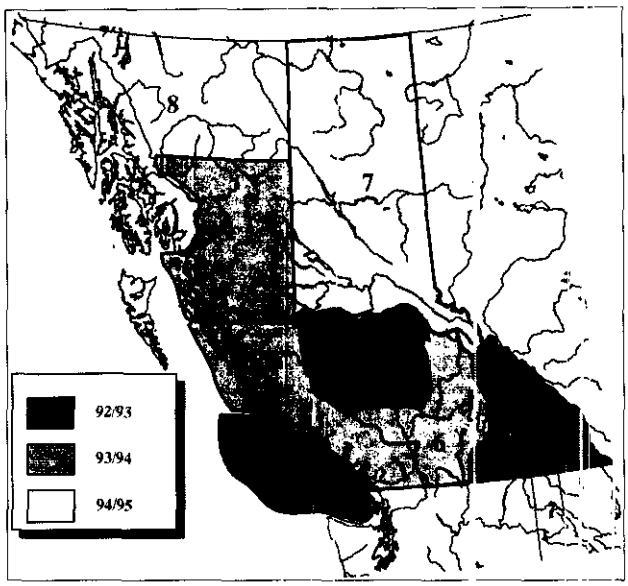

Figure 1. Mineral potential assessment regions; 1-Vancouver Island, 2- Cariboo-Chilcotin, 3- Kootenays, 4- Skeena-Nass, 5- Mid-Coast, 6- Thompson-Okanagan, 7- Northeast BC and 8- Northwest BC.

OBJECTIVES

Project objectives were three fold;

- Rank the land base of the province by its ability to support economic activity through mineral exploration and extraction.
- Produce results which are credible and understandable by all user groups, to assure the results of the analysis are used in the land-use planning process.
- Incorporate the expertise of the mining and exploration communities.

It was found that a straight forward relative ranking of the land base was more useful to decision makers than a measure such as gross-in-place dollar value of minerals in the ground. The primary concern with respect to mineral potential was, which land was the most and least important to the mining industry. The challenge was not to protect areas or not, but how to protect critical environmental and cultural values with a given percentage of a region's land base and with the least economic impact.

Mining industry representatives were participants in the regional based CORE planning processes. They were free to use whatever information they desired to represent their position. The analysis produced by the mineral potential project was one dataset available to industry representatives. To be useful and credible it was essential that the methodology used for this analysis was accepted by the mining industry and easily understandable by the other interests at the table. The use of factual historical data together with the opinions of recognized industry experts appeared to meet this criterion.

The mining and exploration industry is a major generator and repository of data related to the mineral endowment of the province. Individuals from industry were used as consultants to assist the Branch's mineral potential team prepare databases, compile geology and to provide quantitative estimates of future discovery potential.

METHODOLOGY

The assessment of mineral potential in this project takes two forms, a phase 1 and phase 2 analysis. In phase 1 historical information is used to rank the land base with respect to its mineral potential. The phase 2 analysis uses a combination of historical and subjective probability estimates by industry experts to achieve a ranking of the land base. The major steps in the analysis of a region are:

Compile geological maps.
Compile historical information.
Delineate mineral assessment tracts.
External review of geology and deposit data.
Production of phase 1 analysis and map.
Estimation of future deposit discovery potential.
Production of phase 2 analysis and map.

The method is patterned after the three-part assessment methodology of the United States Geological Survey (Singer, 1993).

DATA COMPILATION

GEOLOGY AND MINERAL ASSESSMENT TRACTS

Accurate and current geological data are the framework on which all the analysis is built. The major component of this project is the compilation of the geology of the province at a scale of 1:250 000. Geologists familiar with each region produce the compilation by integrating all existing information with current geological theories. Much of the data used in the compilations was obtained from the Geological Survey of Canada and their contributions to the Project are acknowledged. The compiled geology is captured in digital form for subsequent analysis and distribution. The digital geological information has been made publicly available, as it is produced, by means of Open File series releases (Figure 2.; Bellefontaine and Alldrick, 1994; Schiarizza *et al.*, 1994; MacIntyre *et al.*, 1994; Höy *et al.*, 1994; Massey, 1994; Desjardins, 1994). To date the geology for five regions has been released.

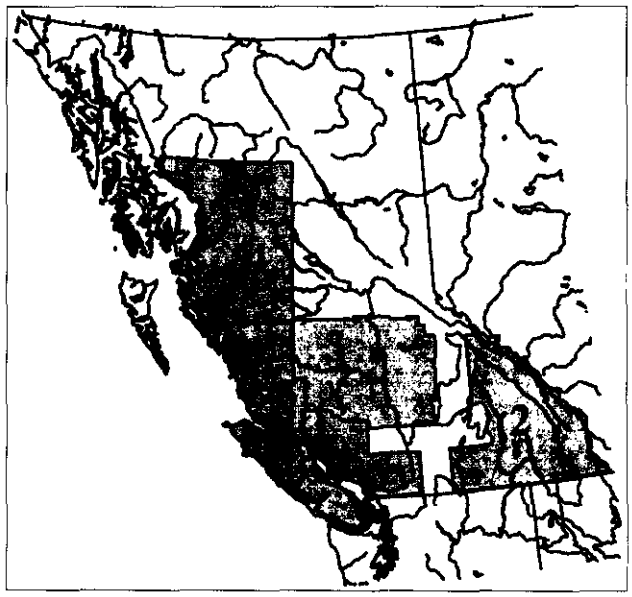

Figure 2. Areas of digital geology Open File releases; 1 - OF 1994-6, 2 - OF 1994-7, 3 - OF 1994-8, 4 - OF 1994-14 and 5 - OF 1994-17.

Upon completion of the geological compilation, the region is divided into mineral assessment tracts. These tracts are units in which the geology can be considered to be similar at a scale of 1:250 000. Tract boundaries are geological features such as faults or major contacts. Tract definitions reflect significant differences in lithology, structure and geological history, particularly where these are important to metallogeny. Once defined, these tracts become the base unit areas in which the assessments in phase 1 and phase 2 are performed (Figure 3). Articles in this volume describe in detail this effort in the various regions (Bellefontaine and Alldrick, 1995; Church, 1995; MacIntyre *et al.*, 1995; Massey, 1995).

HISTORICAL INFORMATION COMPILATION

Several large, well maintained databases describing the known mineral deposits of the province were available to the project. The Assessment Report Information System (ARIS) contains location information as well as the type and amount of exploration work performed on mineral deposits (Kalnins and Wilcox, 1994). Assessment work is reported annually so this database captures the distribution and intensity of exploration in the province. Exploration expenditure information since about 1950 is contained in this file. The existing database was augmented by compiling and digitally capturing the dollar amounts of work reported in many of the early reports. This information was captured for 15 000 of the 22 000 reports contained in the database. The dollar value of the exploration work recorded in each report was converted to 1986 dollars using the Canadian Consumer Price Index.

MINFILE is another database that was available for use by the project. It contains location and deposit information for about 11 000 mineral occurrence across the province (Jones and McPeek, 1992). Work under this project has

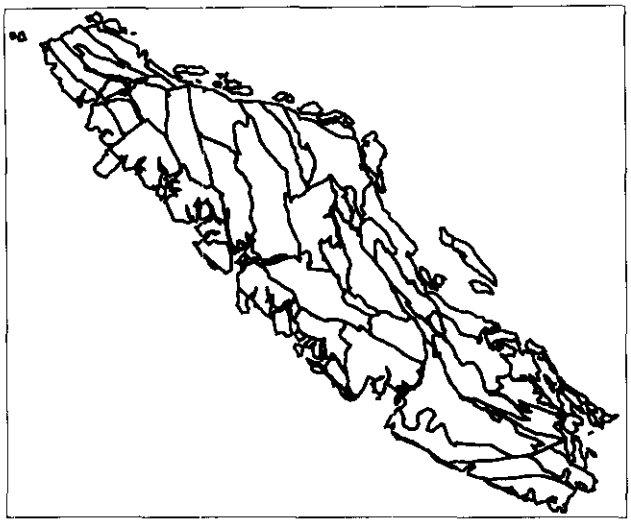

Figure 3. Display of the 59 mineral assessment tracts delineated for the Vancouver Island region

added deposit classification information to the file and significant effort was devoted to bringing reported reserve and resource information, as well as past production values, up-to-date. The value of remaining resources and past production for each deposit was calculated. Commodity prices were determined by using the average market value of the commodity for the years 1980 to 1989, reported in 1986 dollars.

A third important database dealing with the mineral resources of British Columbia is maintained by the Mineral Policy Branch. This database contains the reported production by commodity and year for each producer in the province. These data were valued as described above and correlated with the appropriate MINFILE occurrence to provide a geographic location.

Historical information describing the mining and exploration activity in the province was largely available in digital form prior to the initiation of the project. Some important information was added to these databases by the project and the required information from the databases was integrated and geographically referenced.

PHASE 1 ANALYSIS

Phase 1 analysis is the prediction of the relative future value of the land base by analysis of historical information. Four parameters were used in this analysis; value of past exploration, value of known resources, value of past production and number of discovered mineral occurrences. To date, only the six major metallic commodities; gold, silver, copper, molybdenum, lead and zinc have been used in this analysis. In the future, all metallic and industrial mineral commodities will be included in the phase 1 analysis.

Within each tract, the value of each of the four parameters was calculated. These parameter values were normalized by dividing them by the areas of the tracts. Tracts were then ranked by each normalized parameter and given an ordinal value related to the ranking. The ordinal values for each parameter range from 1, for the lowest ranking tract, to n, the number of tracts in the region, for the highest ranking tract. Each tract then had four ranking values, one for each of the parameters. These rankings were then multiplied by a weighting factor proportional to their perceived importance in predicting future value, and summed for a final ranking value.

The weighting factors used were; 25 for known resources, 10 for exploration expenditures and 5 for each of past production value and number of mineral occurrences. It was felt that discovered commodities in the ground was the most important indicator of future economic activity. To a lesser extent, the amount of exploration performed in a tract indicated where the exploration community, during the past 40 years, has felt the best ground is located. Value of past production and the number of mineral occurrences were given the least weighting but both are important as indicators of favourable geology.

The final ranking was used to order all tracts within a region from most to least potential. This type of analysis makes some very large assumptions and must be used with these assumptions in mind. To a large extent it assumes that new resources will be discovered near previously discovered resources. This assumption neglects the possibility that new types of deposits, completely unrelated to known deposits, may exist or that the importance (value) of commodities may change over time. The rankings are based on the market value of commodities. Market value may not be the best indicator of the value of a commodity to the province's socio-economic well being. In the future, nine-head value of commodities rather than the market will be used to get closer to the true value to the province of the commodities it produces. This is also how the provincial mineral statistics have traditionally been quoted.

PHASE 2 ANALYSIS

Phase 2 analysis evaluates both known resources and predicted future resources. The value of known resources is compiled from the literature and, as described above, was added to the MINFILE database. The amount of resources to be discovered in the future was obtained by soliciting probabilistic estimates from individuals with expertise in the area to be assessed or in the deposit types believed to exist in the area. The methodology used for these predictions is similar to the Three-part methodology of the United States Geological Survey (Singer, 1993).

In our methodology, tracts are based on geology rather than the possibility of a specific deposit type occurring, as in the Three-part methodology. For each combination of tract and possible deposit type, probabilistic estimates of the number of deposits to be discovered or proved in the future are made. These estimates are made individually by several experts for each combination of tract and deposit. No attempt to reach consensus between estimators is made as the range of thinking within the geological community is important.

The estimators were instructed to use the median deposit size and grade as the basis of their estimate. Grade and tonnage distribution curves, together with descriptive characteristics for each deposit type, were supplied to them. Where possible these curves were from British Columbia deposits, but in many cases there are insufficient deposits reported in the province to develop a meaningful curve and data from around the world were used. These world deposit grade and tonnage distributions were generously supplied by the United States Geological Survey (Grunsky, 1995; Cox and Singer, 1986). It is most important when using data from outside province, to assure that the relative economic importance of the deposit types remains true to the British Columbia situation. For this project a deposit is defined as a mineral occurrence which contains the same or more of a commodity than the smallest deposit reported in the associated grade and tonnage distributions. To make a probabilistic estimate for a particular deposit type in a tract, the estimator actually makes several estimates at different probability levels. The value reported for each of these estimates is the probability of at least a specified number of deposits being discovered or proved in the future. The first question estimators asks themselves when making an estimate is: "What is the chance of at least one more deposit of this type being discovered or proved in this tract?". This value is then recorded on a linear scale from 1 to 100% probability, with a "1" indicating at least one deposit. Estimators then ask the same question with respect to increasing numbers of deposits until they reach a number beyond which they feel there is no chance of that number of deposits being found in that tract in the future.

Each of the estimates are then run through the Mark 3 Monte Carlo Simulator to determine the amount of mineral commodity predicted by the estimate. The Mark 3 simulation program was developed by the USGS (Root *et al.*, 1992) and was generously provided to this project. Simply, the simulator combines the probability distribution of deposit discoveries provided by the estimators with the grade and tonnage probability distributions compiled from known deposits. The output from the simulator is the probability distribution of volume of the commodities associated with the deposit type.

As mentioned above, each estimate is put through the simulator individually. The results from multiple estimates of the same deposit type in the same tract are then combined and recorded. For each combination of deposit type and tract, the results at three probability levels are retained. The mean, maximum and minimum estimates from individual estimators at the 90, 50 and 10% probability levels are stored for each commodity included in the estimates for a given deposit type. Once all the deposit types for a tract had been simulated and the relevant values saved, the predicted amounts of each commodity are combined and given a dollar value. Finally the total dollar value of all the commodities with potential in the tract were combined to give nine values, the mean, maximum and minimum, at three probability levels (Figure 4).

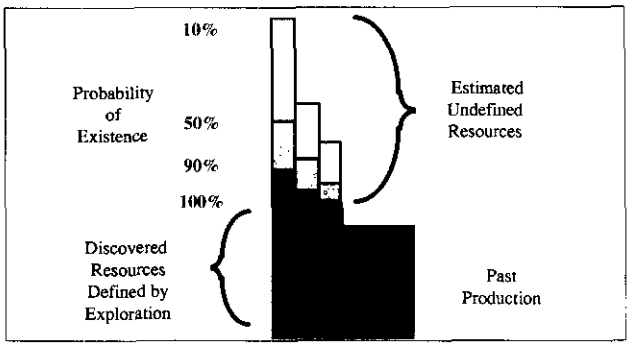

Figure 4. Graphic used to display the known and estimated resource value for each tract. The height of the bars is in dollars.

These estimated values of future discoveries, together with the value of the known resources in each tract, were used to rank the tracts within each region. The value used to rank the tracts was the value of the known resources plus the value of the mean of the estimates to the 50% probability level. Graphically displaying these values for all the tracts in a region allows easy visual comparison of the relative importance of each tract in a form useable by third parties (Figure 5).

To date, estimates have been made in an unstructured manner by experts from industry who donate their time to the project. The unstructured aspects relate to the process where the experts make estimates on the deposit type - tract combinations of their choosing. Using this format, some combinations of deposit types and tracts are missed. As the project has progressed, interest in participating on a voluntary basis has diminished. The most recent phase 2 analysis for Thompson-Okanagan (November 7-10, 1994) used industry experts as consultants and employed a structured format in which two to three estimators made individual estimates for each combination of deposit type and tract. In addition they made anonymous evaluations of each other's relevant expertise by assigning a weighting value to the other estimators.

RESULTS

Results of the mineral potential analysis have been used in three CORE regions, Vancouver Island, Cariboo-Chilcotin and Kootenay. The mineral potential is only one of at least twenty resource and cultural values incorporated into land-use decisions. They include values such as wildlife habitat, archeology sites and forest cover.

Recommendations for land-use on Vancouver Island and in the Cariboo-Chilcotin have be submitted by CORE to government and final decisions on land allocations were made in 1994. Government accepted the CORE recommendations in principle, however some boundary adjustments will be made. This boundary adjustment process is another point at which the mineral potential analysis is of use.

A comparison of the various land-use designations of the CORE recommendations with respect to the mineral po-

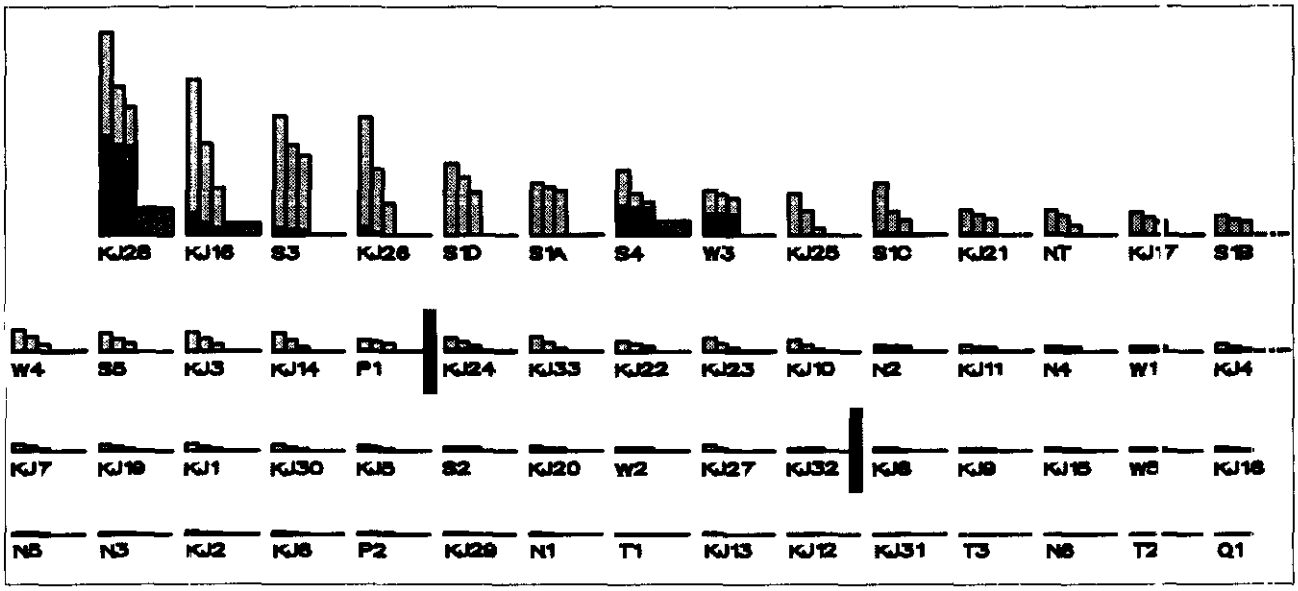

Figure 5. Graphic display of the known and estimated resource value in each tract in the Vancouver Island Region. The two vertical bars delimit the three mineral potential categories. Each contains one third of the land area in the region

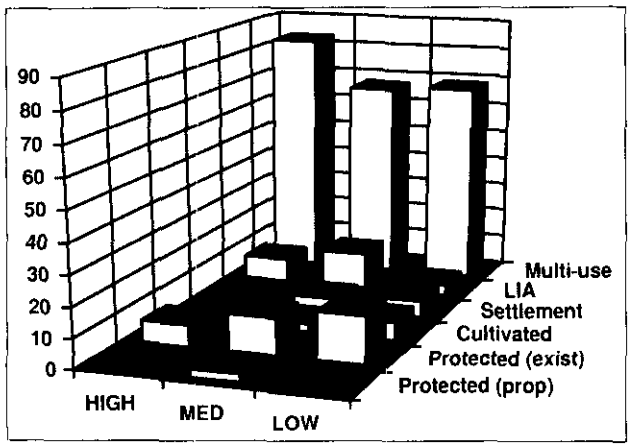

Figure 6. Graphic display showing the percent of each mineral potential category with respect to the land-use designations recommended by CORE for Vancouver Island. LIA= Low Intensity Area.

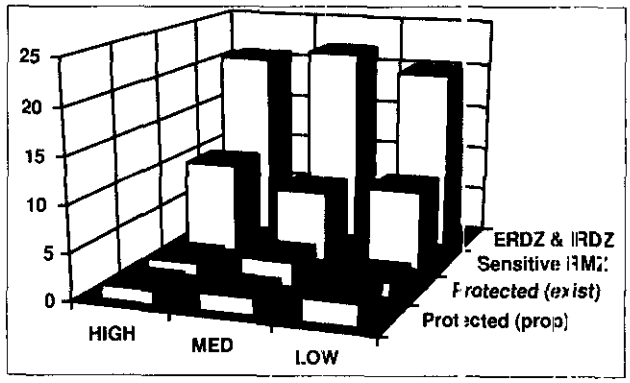

Figure 7. Graphic display showing the percent of each mineral potential category with respect to the land-use designations recommended by CORE for the Cariboo-Chilcotin. ERDZ= Enhanced Resource Development Zone; IRDZ = Intense Resource Development Zone; RMZ= Resource Management Zone.

tential values in each region was made. Figures 6 and 7 are graphical representations of the amount of land in each mineral potential category that CORE recommended for placement in the various land-use designations. The three mineral potential categories: high, medium and low, each contain one-third of the land area of a region. In both cases the proposed protected classification (no mining) contains less high-potential land than medium-potential land. In the Vancouver Island recommendations, more high mineral-potential land than medium-potential land was recommended for placement in land-use classifications which permit mining. The Cariboo-Chilcotin CORE recommendations show the same trend with more of the high mineral potential land being placed in "mining allowed" land designations than medium mineral potential land.

FUTURE

Geological compilation, phase 1 and phase 2 analysis will be completed for the whole province by 1996. Northwestern British Columbia, the last region to be evaluated, will be processed in 1995-1996.

Following the initial region-by-region compilation of geology, it is planned to merge all the geology into one seamless database. This digital database will then be available for a wide range of analysis and display purposes.

The mineral potential analysis currently uses monetary value of commodities to determine the relative importance between commodities and deposit types. The dollar value of *in situ* resources and estimated future resource discoveries may not accurately rank the importance of a tract with respect to the socio-economic well-being of the province. For example, the economic activity generated by a given value of a precious-metal resource will be less than the equivalent value of a bulk commodity. This is due to the greater amount of activity required in extracting, processing and transporting the bulk commodity.

The analysis is also based on the assumption that all commodities have a ready market. This assumption is definitely erroneous, but future markets are difficult to quantify. In general, precious metals and base metals have a ready market, with some price fluctuations, while some industrial minerals require extensive marketing.

The current analysis uses the monetary value of gross in-place resources, both discovered and undiscovered, to rank the land base. This is similar to the majority of mineral assessment processes. However, a more meaningful ranking for land-use planning would be based on the socio-economic impact of the resources in each tract, both discovered and undiscovered. Marketability, economic ripple effects, mine feasibilities and taxation structures must be determined for each deposit type to obtain this type of analysis. It is in this direction that mineral potential methodology is evolving.

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