Ministry of Energy, Mines and Petroleum Resources
Mineral Resources Division
Geological Survey Branch
Hon. Anne Edwards, Minister

MINERAL POTENTIAL WORKSHOP

Report of Proceedings

April 22 - 23, 1992
Victoria, British Columbia

This is a Contribution to the
British Columbia
Corporate Resource Inventory Initiative (CRII)

Information Circular 1992-22

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Mineral Potential Map Methodology Workshop

Executive Summary

The British Columbia Geological Survey Branch's workshop on mineral potential map methodology was held in Victoria on April 22 and 23. It brought together both experts on the processes and potential clients for the products. The objective was to define a methodology which would meet the goals of the BC MEMPR's mineral potential initiative. Participants from across Canada and the western United States of America were present. One day of formal presentations was followed by a day on which the delegates were divided into 4 working groups to address specific areas of concern.

The recommendations, which came from the independent work sessions, from the mineral-potential experts and end users of the potential products will form the basis of the Ministry's mineral potential assessment strategy.

The expected products for a mineral potential study are colour maps portraying the mineral potential in several values (metal in ground, in place dollar value, exploration activity, mining activity, tax revenue and employment). Each map package will contain a description of the assessment methodology along with all assumptions. Known mineral resources (producing and nonproducing) will be displayed in addition to mineral potential for undiscovered deposits. An economic assessment of the defined mineral potential and known mineral endowment will be included. Products will remain as nontechnical as possible to be usable by a diverse clientele. A public release of the data with a seminar on the findings and methodologies of the study is desirable. The term "mineral" is used in its broadest sense and includes solid, liquid and gaseous commodities found in the earth's crust which have value. The resultant database will be maintained on a Geographic Information System and accessible throughout government in compliance with the Corporate Resource Inventory Initiative.

The methodology employed to obtain the estimates of the mineral potential will be based on the work of the United States Geological Survey. The method is informally termed the Tongass method, after a study of the mineral potential of the Tongass National Forest in southern Alaska. In this method land tracts of similar geological character are defined and estimates of the mineral potential within each tract are made. Experts from government, industry and academia will be involved in evaluating all available data to determine the types and possible number of deposits in each tract. A computer simulator will use this expert input and a database of world tonnage and grade information for each deposit type (corrected for British Columbia) to perform a Monte Carlo simulation and develop probability tonnage and grade curves for each deposit type within a tract. From these curves the expected size, grade and mineral content for each deposit type will be determined. When all deposit types within the tract have been analyzed the total potential in-place mineral content is reported. This basic information may be reported in map form and\or translated into some other values such as dollars, taxes, jobs, *etc.* At various points in this process experts will be involved by inputting required parameters and auditing output. This style of quantitative analysis results in a defendable and reproducible product. It provides probability parameters for each estimate and incorporates the expertise of a varied knowledge group.

Geological information is the foundation on which the whole process rests. Complete geological map coverage at or more detailed than the scale of study is essential for selecting permissive tracts. For this study the required map data will be compiled from existing gelogical data found in the published literature, assessment reports or university theses. In addition to the distribution of rock formations, geochemical, geophysical, satellite, MINFILE, ARIS, COALFILE and Petroleum and Natural Gas information will be used in the selection of deposit types to be expected in any given tract. Accurate definition of deposit models which are valid for BC is critical to the integrity of the process. A starting point for this process will be the existing USGS models and probability curves. These will be modified where required to reflect the BC situation. Additional models will be required for industrial minerals, coal, aggregate and petroleum & natural gas.

The project team approach will be used during the initiative. In each study area, such as Vancouver Island, one individual will oversee all aspects of the geology compilation, tract selection, deposit selection and probability estimates. A wide range of additional support will be utilized to supply expert knowledge on specific subareas and deposit types. Several study areas may be active at any given time. All involved personnel must be well informed, comfortable and supportive of the project process and goals. It is expected that most geologists within the Geological Survey Branch and Petroleum Geology Branch will be involved if the project is to meet expectations. Input from Mineral Policy will be essential to address the economic impact segment of the reports.

This summary is a compilation of the recommendations from the workshop. A full description of the methodology to be employed on the BC Mineral Potential Initiative will be addressed in a later document. The enthusiastic sharing of expertise and expectations by workshop participants has been critical in the formation of a project strategy.

Ward Kilby
Manager Mineral Potential Project
B.C. Geological Survey Branch

MINERAL POTENTIAL MAP METHODOLOGY WORKSHOP REPORT

Introduction

The workshop was organized and conducted to rapidly synthesize the current knowledge on the production of mineral potential assessments from as wide an expert base as possible. About 130 people from industry, government and academia attended the formal sessions and about 65 of these individuals participated in four work sessions which addressed specific aspects of mineral potential evaluation. The comments and suggestions of all the workshop participants are gratefully acknowledged. From the Mineral Potential Mapping groups point of view the input was invaluable. This report summarizes the results of these work sessions and presentations.

Background

The Mineral Potential Mapping project is the Ministry of Energy, Mines and Petroleum Resources contribution to the Corporate Resource Inventory Initiative. This initiative, CRII, is a multi-ministry program involving those segments of government responsible for building and maintaining land based resource inventories. The other major ministries involved are Ministry of Forests, Ministry of Environment, Lands and Parks and Ministry of Tourism and Culture. Using well maintained and accessible inventory databases land use assessments can be made with as complete as possible access to all the information.

CRII Objectives:

- Develop integrated modern inventory systems for BC natural resources.
- Bring important resource inventories up to a common level or baseline for land use planning.
- Develop more detailed resource inventory sets for selected areas: Vancouver Island ...
- Enhance compatibility and operability of data sets within CLISP (Corporate Land Information Strategic Plan).

EMPR Objectives:

- Produce a new generation of interpretive mineral potential maps for BC at 1:250 000 scale.
- Use GIS technology to integrate diverse geoscientific databases (geology, geophysics, geochemistry, known mineral endowment) to facilitate the production and dissemination of mineral potential products.
- Enhance the geologic map, geochemical and geophysical inventory of the province.

MINERAL POTENTIAL WORKSHOP
GENERAL MEETING

Formal presentations on all aspects of mineral potential assessment were made on April 22 in the Newcombe Theatre of the BC Provincial Museum. Topics ranged from end user perspectives to past mineral potential assessment experiences in various jurisdictions to the motivation for the present initiative. Presenters and their affiliations are listed below. Abstracts for these presentations, where available, are in Appendix 1.

Dr.B. McRae	ADM, Mineral Resources Division MEMPR
Dr. R. Smyth	Chief Geologist BC Geological Survey
Mr. D. O'Gorman	Commission on Resources and Environment
Dr. D. Brew	United States Geological Survey
Dr. D. Cox	United States Geological Survey
Dr. C. Jefferson	Geological Survey of Canada
Mr. A. Matheson	BC Geological Survey
Mr. G. McLaren	Mineral Policy MEMPR
Dr. T. Richards	Consultant
Dr. D. Bailey	Consultant
Mr. T. Vold	Ministry of Forests
Mr. A. Lidstone	Ministry of Forests

These presentations laid the groundwork for detailed discussions which took place in work sessions on the following day.

MINERAL POTENTIAL WORKSHOP
(Discussion Sessions)

Working groups of interested individuals were formed and each group given one general aspect of the mineral potential assessment procedure which was an area of concern to the organizers. Sixty-three people participated in the four working groups. Reports of each group's discussions and their recommendations are presented in Appendix 2. Following is a list of the general topic assigned each group and the group participants.

Group 1. **Topic: Meeting the needs of the end users.**

Chair: G.Mclaren **Recorder:** N. Massey

Group Members:

P. Brobowsky
J. Ireland
M. Marchand
G. Wahl
M. Finvers
G. Goodman
P. Giblin
R. McMillan
G. Townsend
J. Rowling
A. Matheson
D. Anderson

Group 2. **Topic: Economic Potential Map.**

Chair: J. Clancy **Recorder:** R. Schmitt

Group Members:

N. Carter
J. Hamilton
W. Kilby
P. Wilton
A. Legun
S. Colvine
B. Grant
T. Schroeter
S. Swinden
B. Downing
J. Newell
I. Wardley

Group 3. **Topic: Quantitative or Probabilistic Methodology Case Histories and Their Applicability to this program.**

Chair: D. Lefebure **Recorder:** D. Alldrick

Group Members:

R. Richardson
J. Broome
G. Dirom
D. Cox
B. Ryan
K. Dawson
G. Carlson
S. Nimmo
S. Sibbick
P. Bartier
J. Vincent
J. Harrop
J. Pell
R. Longe
B. Potter
D. Bailey
E. Grunsky

Group 4. **Topic: Qualitative Methodology Case Histories and Their Applicability to this program**

Chair: B. McMillan

Recorder: V. Levson

Group Members:

D. Atkinson
C. Jefferson
T. Richards
T. Faulkner
R. Simpson
R. Handfield
B. Price
B. Coombe
R. Myers
D. Brew
R. Pinsent
A. Burgoyne
A. Matheson
P. Wojdak

Workshop Summary

A remarkable amount of agreement was reached within and among the four study groups on how the project should be carried out and what should be produced. Following is a summary, in point form, of the major recommendations made by these groups. The details of each group's discussions are contained in Appendix 2, the work session reports. Addition comments from individuals who had thoughts on the process after attending the meetings or who were unable to attend have been recieved. A general strategy incorporating all recommendations is presented in the executive summary section of this report.

Products of the Initiative

- One mineral potential map will not suffice. There must be a variety of final products which relate the mineral potential of an area to: metals in the ground, gross in place value, exploration potential, mining potential, etc.
- Final products must be presented in the most understandable format possible which will include a minimum of categories and colour maps.
- Must provide a quantification of the confidence the assessors have in the valuations of each area.
- Final products should display known mineral endowments as well as potential endowments.
- Metallics, coal, aggregate, petroleum and natural gas, and industrial minerals must be included in assessment.
- Methodology booklet is essential and must accompany each product.
- An economic and social impact analysis should accompany each product package. This analysis may be provided by Mineral Policy.
- Final map product will require presentation of mineral potential in several frames of reference such as; gross in place metal, gross in place value, exploration value (fees, taxes, jobs, etc.), mining value (fees, taxes, jobs, etc) and general non-detailed categories such as High, Med, Low.
    - Colour maps are essential.
- Legend and side notes must be kept as simple as possible.
- Possibly group commodities onto separate maps; metallics & coal, industrial minerals & aggregates, oil and gas & geothermal resources.
- All land areas must be addressed not just the high potential areas. Must make best guesses as to potential, cannot say insufficient data as then it will be taken as low potential.
- 1:250 000 scale presentation is appropriate for this study but the analysis takes place at all scales, being dictated by the data and feature under consideration.
- The constructed database must be maintained and available for analysis in the future.
- A BC Mineral Deposit Model handbook similar to USGS Bulletin #1693 should be produced.

Procedure

- A quantitative process is essential as the product must be the best possible.
- General agreement that the Tongass style of analysis is the most feasible.
- Deposit models must be selected from existing catalogues and updated and normalized to the BC environment. Some new deposit models may need to be constructed. Models for coal, petroleum & natural gas, industrial minerals and aggregates will also be included.
- When selecting permissive tracts start large based on geological map and reduce on the basis of other deposit specific criteria.
- MINFILE will require classification into deposit types.
- It is better to leave deposits unclassified than to have them misclassified. In some cases on 20% of the deposits have been classified.
- Involvement of all parties is essential; industry, academia, government surveys and client groups.
  - All personnel involved must be totally onside or they should not participate.
- Use client feedback and expert audits where ever feasible and especially early in the program.
- Use analogies from historic data to build in the economic impact of exploration and mining.
- It is essential to maintain the perception of impartialityby never overstating the case for mineral potential.
- A significant challenge will be how to compare the wide range of commodities.

Data

- Compilation of geology base is a priority item.
- Compilation and construction of BC specific deposit models essential.
- Exploration historical data.
- Geochemistry. Geophysics, satellite imagery.

Required Expertise

- Access to deposit, area, economic evaluation expertise.
- Integrate participation by industry, academia and government scientists.
- Early involvement by client groups.
- Strong link to Mineral Policy Branch.
- Participants must be positive and thoroughly familiar with the evaluation process.

APPENDIX 1
PROGRAM WITH ABSTRACTS

April 22, 1992

NEWCOMBE THEATRE, VICTORIA

Wednesday, April 22, 1992
General Meeting Schedule

Introductory Remarks

8:30 - 8:35	Bruce McRae *Introduction*	ADM, Mineral Resources Division, MEMPR
8:35 - 8:45	Ron Smyth *Purpose & Scope of Meeting*	Chief Geologist, MEMPR
8:45 - 9:05	Denis O'Gorman *A Provincial Perspective on the Value of Mineral Potential Maps to Resource Planning*	Commission on Resources & the Environment
9:05 - 9:15	*Discussion Session*	

An International Perspective: American Experiences

9:15 - 9:55	Dave Brew	USGS Alaska Division
9:55 - 10:05	*Discussion Session*	
10:05 - 10:30	♥ *Coffee* ♥	
10:30 - 11:10	Dennis Cox	USGS Nevada Division
11:10 - 11:20	*Discussion Session*	

A National Perspective: Canadian Federal Experience

11:20 - 12:00	Charlie Jefferson	Geological Survey of Canada
12:00 - 12:10	*Discussion Session*	
12:10 - 1:45	♥ *Lunch* ♥	

Provincial Perspectives: British Columbia

1:45 - 2:05	Alex Matheson *The Past*	B.C. Geological Survey Branch
2:05 - 2:25	Graeme McLaren *The Present*	B.C. Mineral Policy Branch
2:25 - 2:45	Tom Richards	Consultant
2:45 - 3:05	Dave Bailey	Consultant
3:05 - 3:20	*Discussion Session*	
3:20 - 3:45	♥ *Coffee* ♥	

Resource Management - Requirements & Expectations

3:45 - 4:00	Terje Vold *from the Provincial Agencies*	B.C. Ministry of Forests
4:00 - 4:15	Alan Lidstone *An Overall Perspective:*	B.C. Ministry of Forests
4:15 - 5:00	*Discussion Session*	
5:00 - 5:15	Ward Kilby *Wrapup Comments*	Project Leader, B.C. Geological Survey
5:30 - 8:00 pm	♥ RECEPTION/SOCIAL ♥	Cash Bar, Swans Hotel, Cafe Area

FIRSTHAND USGS-ALASKAN BRANCH EXPERIENCE WITH PROBABILISTIC ASSESSMENT OF UNDISCOVERED MINERAL RESOURCES: THE TONGASS NATIONAL FOREST AND ADJACENT AREAS, SOUTHEASTERN ALASKA

By: David A. Brew, Lawrence J. Drew, Jeanine M. Schmidt, David H. Root, Donald F. Huber, and James L. Drinkwater

Southern Alaska is a geologically complex region that contains a wide variety of known metallic mineral deposits, some of which have produced very important amounts of metals and other materials during the past 100-plus years. The Juneau district, the Chichagof district, the Kasaan Peninsula, Bokan Mountain, and the Hyder district are all well-known productive localities. In recent years major new discoveries have been made at the Green's Creek mine and the Quartz Hill molybdenite property. The U.S. Geological Survey has used probabilistic methods similar to some used in hydrocarbon-resource assessment to estimate the undiscovered metallic mineral-resource endowment of (1) the entire region; (2) the 17.1-million-acre Tongass Nationals Forest, which covers about 80 percent of the region; and, (3) that part of the Tongass open to mineral entry as of November 1990. The lands open to mineral entry are estimated to contain about 83 percent of the undiscovered locatable mineral resource endowment of the region.

Regional geologic, economic geologic, geochemical, geophysical, and mineral exploration history information for the region have been integrated to define 124 tracts that are permissive for the occurrence of undiscovered metallic mineral resources. The tracts range from about 12 to 2, 920 square kilometers in area and cover most of the region. Some tracts are wholly in the Tongass National Forest, others are partially within or wholly outside. Areas not assigned to tracts are interpreted to have no undiscovered mineral-resource endowment, based on available information. The mineral-resource endowment estimates for all of the individual tracts are combined to provide an aggregated estimate of the undiscovered locatable mineral-resource endowment of the Tongass National Forest and adjacent lands in southeastern Alaska. The mean estimate is 5.0 million metric of copper, 0.45 million metric of molybdenum, 170 metric of gold, 2.2 million metric of zinc, 7,600 metric of silver, 1.2 million metric of lead, 130 million metric of iron, 0.17 million metric of thorium, 1.14 million metric of rare-earth-element oxides, 2,800 metric of uranium, 27,000 metric of nickel, 62 metric of antimony, 0.181 million metric tonnes of tin, and 2,500 metric tonnes of tungsten. These estimates do not include the metal contained in all of the mineral deposits inferred to occur in the region because there are no world-wide tonnage and grade models for several of the deposit types. Using commodity prices based on U.S. Bureau of Mines averages for the decade 1978-1987, these estimates were converted to gross-in-place monetary values (GIPV) of the undiscovered mineral resources in Tongass National Forest lands that are presently open to mineral entry is $23.5 billion.

Based on the above information, most of the tracts in the whole region are classified into categories based on the on gross-in-place values (GIPV) of the estimated undiscovered mineral resources: (1) 13 tracts with GIPV greater that $1 billion; (2) 52 tracts with GIPV less that $1 billion and greater than $100 million; (3) 33 tracts with GIPV less than $100 million and greater that $1 million; and (4) 6 tracts with GIPV less that $1 million. Similarly, the individual tracts that are wholly or partially within the Tongass National forest and are open to mineral entry are classified in the same categories based on the on gross-in-place values (GIPV) of the estimated undiscovered mineral resources as follows: (1) 7 tracts with GIPV greater that $1 billion; (2) 33 tracts with GIPV less than $1 billion and greater than $100 million; (3) 30 tracts with GIPV less than $100 million and greater that $1 million; and (4) 5 tracts with GIPV less than $1 million.

Although the gross-in-place value (GIVP) is not a direct measure of the ultimate contribution that the finding, development, and production of the undiscovered mineral resources may make to the region, it can be compared with the following mineral-resource monetary values to further define the mineral-resource framework for the Tongass National Forest and adjacent lands in southeastern Alaska: (1) the gross-in-place value of $33.76 billion reported by the U.S. Bureau of Mines for all the discovered mineral resources in the Tongass National Forest and their $15.6 billion figure for the net present value of the 13 deposits in the Forest that they judge to be economically viable for development under today's market conditions; (2) $2.459 billion calculated in this report to be the present-day value of mineral resource produced from the region during the past 100 years; and (3) $596.82 million calculated in this report as the present-day value of mineral-resource exploration and development activities during the past 90 years. The gross-in-place value of discovered resources not in the Tongass Nationals Forest is needed to make the framework complete.

RESOURCE ASSESSMENT MAPPING AT THE GEOLOGICAL SURVEY OF CANADA:
Historical Activities and Future Trends*

by C.W. Jefferson

The Mineral and Energy Resource Assessment (MERA) process provides information for new national park proposals in the Yukon, NWT and offshore; for international commodity studies and boundary concerns; and for nuclear energy, policy. Prior to 1987 MERAs for northern park proposals were mainly based on archived data; now, field surveys jointly funded by DIAND, EMR and Canadian Parks Service update the geological database. The GSC provides technical reports to decision-makers and publishes the reports after critical review.

Trends are to increase public consultation and to make preliminary assessments of large areas (aided by the "Computerized Mineral Showings Database and Mineral Resources Map of the NWT" project supported by GSC, DIAND and NWT Government), thereby reducing conflict and encouraging parks in areas of relatively low mineral/energy potential. We are learning that 1) public consultation is vital, 2) MERA ratings are difficult to compare with qualitative attributes valued for parks, 3) as predicted, assessments are changing because of newly recognized deposit types (e.g. sedimentary exhalative Ni-Zn-PGE), new exploration targets (e.g. a known stratigraphic unit with newly discovered showings) and the surveys now being done for MERA (e.g. new mapping of supracrustal rocks and geochemical surveys which may generate unpredicted anomalies, confirm predicted targets, or downgrade preliminary assessments).

* *For oral presentation at workshop for Mineral Potential Map Coverage of British Columbia Project, Victoria, April 22-23, 1992.*

METHODOLOGY USED IN THE PREPARATION OF MINERAL CAPABILITY MAPS FOR LAND USE PLANNING IN BRITISH COLUMBIA

by Alex Matheson

Mineral Deposit-Land Use maps have been developed since 1969 by the BC Department of Miens and Petroleum Resources in response to requests for mineral resource data from non-geologists outside the exploration and mining community. Most requests originate with planning agencies in government, such as the Regional Districts, the Parks Branch, the planning division of the Forest Service, and the technical arms of the Environment and Land Use Committee.

The Mineral Deposit-Land Use (MDLU) map system was originally conceived as a means of representing mineral capability within the framework of the Canada Land Inventory series of maps which are currently used to classify land capability for renewable resources as an aid to land use planning in British Columbia. They used a seven-fold classification applied to each renewable resource sector as a measure of the capability of land to support the resource (agriculture, forestry, recreation, wildlife and waterfowl, etc.). The maps show areas classified according to exploration potential using five categories, with 1 the highest and 5 the lowest, based on the size and number of mineral deposits and the geological environment of each area. Categories indicate both the probability of exploration being carried out within the area and the size of deposit which may be discovered by continued exploration. Exploration potential is thus a measure of the expected use of the land within each area for mineral exploration and development. Relative size of deposits is indicated by the letters A, B, and C for large, medium, and small and is based on the gross value of the metal contained or expected in each deposit using somewhat arbitrary unit metal prices. Deposits of industrial minerals, coal, and gas and oil wells were shown, but rarely categorized for size.

MINERAL POTENTIAL MAPS -- PERSPECTIVES FOR THE 90'S

by Graeme McLaren

Creating the most up-to-date inventory of the British Columbia's natural resources is essential to the development of a provincial land use strategy, and to achieving the goals of sustainable development for BC's growing population. A significant expansion in land use planning and resource management, particularly at regional and local scales, can be anticipated as the means of achieving these goals. Mineral resource inventories are an integral factor in the provincial database required to conduct this planning in a balanced manner. Furthermore, the province is entering a phase of aboriginal treaty negotiations that will require accurate inventory data on all of BC's natural resources.

There was strong demand for the Mineral Deposit Land Use map series of the 1970's-early 80's by provincial land use planning agencies. It would be wise to project that land use planners, resource managers and decisions makers will be the primary user group of a new mineral potentia map series. Furthermore, land use planning is a much more open process now and many public interest groups are involved in reviewing and commenting on the values expressed in resource assessments. Accordingly, the information contained on regional mineral potential maps should be rooted in rigorous geoscience, but should be communicated in clear, succinct, non-technical terms that convey both the final mineral potential designation and the logic used in arriving at tha designation. Communication to a non-geoscientific audience must be a primary goal of these maps.

Land and resource use policies and plans in British Columbia are being created at three levels (or scales). Broad policies are set at the provincial level and they drive strategic planning for regional land and resource allocations. Local detailed land use plans are developed based on the regional allocations. 1:250,000 mineral potential maps will be used extensively at the regional level and some degree at the local levels. Providing mineral potential data to current land allocation processes, such as Forest Land Management Planning or ongoing negotiations on protected areas planning, will greatly assist in effectively managing the provinces mineral resources.

Socio-economic assessments of land use decisions are now being demanded as well, both b the public and politicians. A means of translating qualitative mineral potential statements into a measure of economic value, needs to be developed. Gross in-situ values may be useful to assess relative magnitudes of deposit types, however they do not provide meaningful information on mineral deposit contributions to local, regional and provincial economies. An economic assessment of mineral values is needed that can address known values (direct and indirect benefit from known or reasonably well defined ore deposits) and that can extrapolate these benefits into potential ore deposits. Such information will be used to either proactively portray socio-economi values of high mineral potential zones, or to react to land use options by assessing impacts on mineral values.

COMMENTS ON THE GEOLOGIC METAPHOR, MODELS AND MINERAL POTENTIAL ASSESSMENT

by Tom Richards

Potential is defined as that which is capable of being or that which may be possible. Estimated mineral potential is therefore the assessment of an area for the possible existence of undiscovered mineral deposits.

Mineral deposits are not ore bodies. Ore bodies are places where rock can be extracted from the ground at a profit and does not infer size, grade or tonnage. Todays' occurrence may be tomorrows's mine. The initial determination of mineral potential should not be influenced by economic or cultural considerations although these factors will ultimately control land use decisions. Attempts to create a mineral potential map using grade and tonnage should be viewed with caution, as the difficulty in making this appraisal when extensive drill and bulk sample data is available is well known in the industry, let along attempting it when the deposits are not yet even found.

Mineral deposits are one of the primary resources that include water power, forests, fish, farms and parks. A fundamental question presented to the mineral industry by the public is; "why is it so difficult for the mineral industry to assess its untapped potential when forestry appears to have little difficulty with this assessment." There is no simple answer to this and is complicated by the geologic metaphor, a logic that may be considered foreign to the culture as a whole.

Mineral potential assessments may be based upon the known mineral inventory and/or on geologic criteria, both of which are based upon modelling. A mineral potential map created from basic fundamental geologic principles is preferred as a first approximation as it is not biased by the known mineral inventory which is only a catalogue of that which already has been discovered. The type and distribution of known showings is influenced by the biases of past exploration. The use of the most basic geologic principles to create an initial mineral potential map will allow a set of maps to be made for the whole of the province, will assess equally areas where mineral deposits are known with those where they are lacking and allow a base map upon which may be modified by more sophisticated geologic, geochemical, geologic, remote sensing and mineral inventory data and models.

The approach used here was to create a mineral potential contour map using the most fundamental definition of a hydrothermal deposit as: "a mineral deposit formed by precipitation of ore and gangue minerals in fractures, faults, breccia openings or other spaces, by replacement or open-space filling, from watery fluids ranging in temperature for 50 to 700^{0}C but generally below 400^{0}C, and ranging in pressure from 1-3 kilobars" (AGI). This definition is the general theory of hydrothermal mineral deposits and is model with two constraints:

1. openings through which the hydrothermal fluid may flow and in which minerals may be deposits, and

2. a source that is capable of heating water.

Fracture zones, faults, shears, cleavage zones and their intersections represent openings and heat is derived from igneous rocks of all types and phyllonitic shear zones. A contoured mineral potential map is created that outlines areas of high, moderate and low potential for hydrothermal deposits only. Only those hydrothermal systems that deposit metal become mineral deposits.

This map is the base mineral potential map. All other mineral deposit models, including those for hydrothermal mineral deposits, as epithermal, mesothermal, volcanic massive sulphide and porphyry, are variants of the general theory and may modify the base map.

MINERAL RESOURCE POTENTIAL ASSESSMENT: A GEOLOGICAL APPROACH

by David G. Bailey
Bailey Geological Consultants (Canada) Limited

The geology of Cordilleran British Columbia may be described as a college of lithotectonic assemblages developed as exotic or indigenous terranes relative to North America and whose present positions are a reflection of both Pacific and Atlantic plate motions and intra-Cordilleran tectonism. Thus, for example, lithotectonic assemblages typical of island arcs may be lying on, or adjacent to, sediments of continental provenance of the North American miogeocline, or metamorphic core complexes developed in thick continental crust may be overlain by rock assemblages developed in deep ocean basins. In as much as each rock assemblage is a reflection of geological processes which gave rise to that assemblage, so too are the contained mineral occurrences.

In the assessment of mineral resource potential the fundamental geologic unit is the lithotectonic assemblage, or terrane. Each assemblage is initially considered to have equal, but undefined, potential to host mineral occurrences, the types of which reflect the geological attributes of the terrane. To avoid bias, known mineral occurrences are considered only after other geological attributes are considered. Known deposits may reflect economics or intensity of mineral exploration rather than true mineral potential. After listing the major geological attributes of a lithotectonic assemblage (e.g. bimodal calcalkalic volcanic suites, synsedimentary extensional faulting, major facies changes, shallow marine depositional conditions), models or ore deposits are considered which may form in such environments. After model selection, parameters relevant to the model are listed; the presence or absence of these parameters is a measure of the mineral resource potential of an area with respect to the model. It is at this stage that known mineral occurrences and deposits are examined to determine i) whether the model used is in fact an appropriate one and ii) other mineralization characteristics which may not have been noted by the assessor and which should be included in the assessment. Mineral assessment potential is then presented in the form of contour maps for the commodities and ore deposit types being considered. It is emphasized that mineral potential assessed by this method is qualitative, or relative, rather than quantitative, or absolute.

By not considering known mineral occurrences at the early stage of assessment, an attempt is made to avoid bias towards the known mineral deposit types. However, the method is heavily reliant on model selection and, therefore, may suffer from improper model choice or an imperfect understanding of ore deposit controls relevant to the type of mineralization being considered. Nevertheless, to some extent, the use of imperfect models may be corrected by applying fundamental principles of ore mineral transport and deposition in the mineral resource assessment process.

An example of mineral resource potential assessment using only geological parameters is given for the Quesnel Lake region of south central British Columbia, a region which is underlain by several terranes and structural and metamorphic environments. From the results of this work recommendations are made which may facilitate mineral resource potential assessment in other areas of British Columbia.

WILDERNESS PLANNING AND MINERAL POTENTIAL MAPPING

by Terje Vold
B.C. Forest Service

A mosaic of wilderness categories exists in B.C. ranging from wilderness zones in parks where subsurface resource activities are not permitted, to wilderness areas in provincial forests where these activities may be permitted. Wilderness areas are managed by the B.C. Forest Service. This mosaic is similar to the multi-agency approach of managing the national wilderness preservation system in the U.S.

The policies for allocating and managing wilderness in B.C. are outlined inn the B.C. Forest Service paper "Managing Wilderness in Provincial Forests", and in B.C. Parks' "Striking the Balance."

Wilderness planning in B.C. has centered most recently around a joint Parks/Forest Service initiative called "Parks and Wilderness for the '90's" (PW90).

Through PW90's, a number of park and wilderness study areas were proposed in two draft working maps for public and industry review and comment. 104 public meetings were held throughout B.C. in February, 1991. Over 3500 comments were received, and a summary of public response to PW90's was published in September, 1991.

PW90's is currently revising its list of study areas, and an announcement is expected this spring, 1992. The broad objectives of PW90's, in keeping with government's goal of doubling the parks and wilderness areas of B.C. is to select study areas that:

- represent B.C.'s diverse natural landscapes,
- protect important wildlife habitats and biodiversity,
- preserve outstanding natural and cultural features, and that
- offer a wide range of recreational opportunities.

PW90's is intended to complement regional land-use processes coordinated by the recently formed Commission on Resources and Environment (CORE) and subregional processes such as Forest Land Management Planning.

Mineral potential mapping is needed to help make difficult land-use trade-offs. This mapping is no doubt difficult given that minerals are considered a "hidden resource". However, it is also a challenge to describe all the complex dimensions of what constitutes the wilderness values of an area.

Land-use planning and decision making on wilderness is likely to proceed with the best resource information at the table, along with the negotiation amongst resource stakeholders. Therefore we must do the best job we can of describing these resource values.

APPENDIX 2
WORK SESSION REPORTS

April 23, 1992

MEMPR BOARDROOMS

Mineral Potential Workshop, April 23, 1992

Working Group 1: Meeting the needs of the end users

Summary Notes

Attendees:

Chair: G. McLaren, MPE
Recorder: N. Massey, GSB

Peter Brobowsky,	GSB
Peter Giblin,	Ont. North. Dev.
Jim Ireland,	Ont. North. Dev.
Ron McMillan,	Consultant
Michael Marchand,	Facet
Gary Townsend,	Forests
George Wahl,	Univ. Waterloo
John Rowling,	Petr. Geol.
Maija Finvers,	Petr. Geol.
Alex Matheson,	GSB
Gordon Goodman,	PTL
Duane Anderson,	MPE

PRIME USERS/CLIENTS

GM suggested that the focus of the session be on "end users" rather than just planners as many others will review and utilise the final products. Identified end users include planners, resource managers, policy makers, politicians, land negotiators, public and non-governmental organizations.

Even the term "planners" covers a somewhat disparate group of people and interests. They are probably best characterized by considering who has asked for and used EMPR's input in the past:

Prov Govt: CORE
Forests
Parks
Environment
Lands
Aboriginal Affairs

Federal Govt: Parks Canada
Environment Canada

Municipal and Regional Govts.

Increasingly, demand for information has also been coming from the general public and non-governmental organizations.

MEMPR also uses the mineral potential data to:
proactively get our messagew out, and
react to planning/policy initiatives of other agencies.

Scale: All of these agencies use data at the 1:250 000-scale; provincial planning agencies also require 1:600 000 maps for broad planning and 1:50 000 for detailed planning. Local governments vary in their requirements but also use 1:250 000 as well as 1:50 000 and 1:20 000.

Why? For provincial and federal government agencies the major use has been (or will be) for land-use planning of Parks, Wilderness, Integrated Resource Management, Landclaims/Co-management, Transportation corridors, Hydro/pipeline corridors. Local governments have interests also in zoning and bylaw application.

WHAT SORT OF INFORMATION IS REQUIRED?

It became obvious that several types of information, and hence several products, are required.:

1) The minimum requirement is for some qualitative representation of values (High/medium/low; A/B/C) on a map.
This should contain spatial data (tracts of similar potential, etc.) and point data.

> *MINFILE occurrences have been found by Graeme MacLaren to be very useful in helping non-geologists to appreciate and interprete the mineral potential maps used in the past - they are intuitively easier to comprehend than other sorts of geological data such as geochemical anomalies, etc.*

Extensive discussion centred on the problem of "how to deal with lack of data".

> *It was deemed essential to try to estimate the potential of all areas, regardless of the amount of data available - a designation of "Indeterminate" would, in practice, be interpreted as "low".*

Representation should also be honest, care being taken to not oversell the potential and thus undermine the validity of the whole operation. Some display of validity/confidence factors is absolutely necessary so that the users are aware of areas of "best guesses" vs areas of "best judgements".

2) Discussion ensued on what to do beyond the qualitative step. Some such action is necessary to do justice to our case, and the most sophisticated analysis possible should be undertaken. The probabilistic approach seemed most promising, based on deposit models and grade-tonnage curves, modified to reflect B.C. reality.

Some interpretation of the maps is also required to enable the end-users to understand and utilise the data effectively. In particular, an economic impact analysis is needed, which can be made as a report +/- sidenotes.

The economic impact analysis should consider factors such as:

> A) Mining: jobs, incomes, taxes, revenues to various levels of government, mine life, scale of operation - large/small, underground/open-pit, etc. These should be related to the particular mineral deposit models used in producing the potential maps. The analysis could be developed as a table, and should be based on B.C. examples where possible.
>
> B) Exploration: this should be recognised as a separate and somewhat semi-independent activity to mining. Impact analysis should recognise the dollars expended, etc. This analysis may be a problem at the local/regional scale and some sort of Provincial average of expenditures may have to be used.

Also recognise that these expenditures are dominantly of Provincial economic impact and less of local impact.

WHAT PRODUCTS?

It was recognised that several products are needed to adequately answer all the needs or to do justice to the interpretation of mineral potential. **A single map will not suffice.**

1) A methodology booklet is essential. This will document all steps of the method/s used. This would serve both to maintain consistency over the continuing life of the project, and also to build confidence in the end-users that the analysis was done with some rigour.

2) Electronic products: all the base data and interpretation layers used in the GIS model should be made available for distribution. *Some investigation of compatibility of scales and bases is necessary.* The electronic product will also allow for some flexibility and customization of products to suit the user's needs.

3) Maps: should include:
i) Physiographic and cultural data - NTS digitized base-maps sufficient
ii) Point data for "occurrences" - MINFILE; equivalent coal inventory + coal-bed methane inventory data; PIMS (oil and gas wells); geothermal; aggregates, etc.
iii) Reliability/confidence factors: how to portray? line type/screening; letter or number subscript; etc
iv) Colour maps essential; different divisions to be shown in different colours, e.g. red for high; blue for low. Also to be appropriately labelled.
v) Proportional symbology used to reflect confidence or highlight items of importance.
vi) Legend; to include the classification both in a graphic form (cf GM's triangle) as well as some sort of text/table description; a flag/note about economic impact. *Keep legend and sidenotes as simple as possible.*

At least three separate commodity group maps should be produced:

Metallics + coal
Industrial minerals + aggregates
Oil, gas, coal-bed methane and geothermal resources (+coal)

These can then be combined into a unified geological resources map. ?will this be possible? qualitatively? quantitatively?

4) Reports: Economic impact analysis should be separate to the maps.

It was suggested by the group that paper products be published in an envelope combining:
a) map/s
b) brochure with standard methodology explanation and any overflow, such as economic impact analysis, that doesn't fit on the map legend.

With well-maintained and up-to-date databases, maps could be made available on customized or on-demand bases.

Secondary products

Several secondary products could be produced as spin-offs of the construction of the mineral potential maps:

> 1) Deposit model potential maps for use by the exploration community
> 2) Metallogenic compilations
> *Et cetera.*

Their was, however, a recognition of the practical limitations of time and resources to spend producing the spin-off products, and possible diminishing returns.

Database Management

At several points during the discussions aspects of database management were raised. Two main points were made. First, it was clear that some thought is necessary to make sure that data capture did not jeopardise the use of the data in future reconfigurations of hardware or on other systems. Second, resources must be identified to make sure that databases once assembled, are maintained and continually updated.

MINERAL POTENTIAL WORKSHOP: ECONOMIC POTENTIAL MAPS

WORKSHOP 2 SUMMARY NOTES

Attendees:

Chair: John Clancy - MRD
Recorder: Rolf Schmitt - MPE

Nick Carter	- Consultant
Brian Grant	- GSB
John Hamilton	- Cominco
Tom Schroeter	- GSB
Ward Kilby	- GSB
Scott Swinden	- Nfld Geol. Survey
Paul Wilton	- GSB
Bruce Downing	- Granges
Andrew Legun	- GSB
John Newell	- Consultant
Sandy Colvine	- GSC
Ian Wardley	- MPE

ECONOMIC POTENTIAL MAPS:

What are they?

- they need to be flexible, responsive to changing geology and economics

- need to target policy clientele
- 3 aspects to consider: scientific integrity
  process to prepare them
  ease of explanation

- consider other benefits

- consider the tradeoffs between flexibility and need for a product with a useful shelf-life; with an electronic database, products could be produced on demand

- perhaps maps should qualify the timeframe of usefulness

- the display method should not discount long-term economics; what do we target? 5 - 25 - 100+ years?

- scale must suit client needs yet be credible from standpoint of industry and useful for planners. 1:250K is a good median scale, however we recognize the maps will be used at 1:2M and 1:50K scales.

Economic Potential vs. Economic Feasibility:

- discussion determined that economic feasibility was too complex to represent and we should stick to potential

- economic potential was desirable, keep it simple;
  - gross reserves / values
  - make assumptions explicit
  - be cognizant of available methods

Nomenclature:

- what do we call the maps?

Recommendation: Mineral Resource Potential Maps

- desirable to consider 2 products; a mineral resource potential map and an economic-type overlay to provide public with implications of mineral potential

Confidence Portrayal:

- portrayal of confidence in assessments is desirable

- eg. if data displayed in $/ha or $/sqkm, then confidence could be portrayed as:

A - high degree of confidence
B - moderate degree of confidence
C - low degree of confidence

- confidence criteria would have to specified to be consistently applied, shy away from using percentiles such as 90%, 50%, 10% levels of confidence.

- use confidence to advantage in communicating product, and in identifying data gaps

Purpose of Mineral Resource Potential Maps:

- display known endowment

- display estimates of undiscovered resources

- consider focussing on areas of lowest endowment

- priority input is geological database

What do we want maps to display?:

- some estimates of value of undiscovered resources

- incorporate PNG, Coal, Industrial minerals

- Industrial minerals will require knowledge of marketability dynamics, some IM may be handled as metallics

- Sand and gravel will need to be addressed in more detailed analysis

How do we display economic potential?:

- use several training regions with perhaps several hundred geological tracts across different lithotectonic environments as start

- determine GIPV as per Tongass study, determine range of $/sq km based on rolling mean of last 10 years commodity prices. include all commodities in estimate

- scale range (which is likely logarithmic) and display as 5 or so categories, each with similar area representation; eg 20% of province in each category.

- other considerations include;

- steer away from feasibility
- identify areas of low and exhausted potential
- how do we address unsuccessful exploration vs successful exploration? look to ARIS for clues

Terms of reference for industry input:

- recognize importance of expert judgement from people with deposit and specific area knowledge

- recognize need for perception of impartiality in final product

- probably best informally in developing product, but need to consider peer review of draft products

What should the working group look like?:

- Project leader (Kilby)
- Senior committee of experts to ensure consistency
- Specialist for certain areas, eg Nick Massey - V.I.
- Technical support - ARIS, MINFILE, GIS, Geochem/geop, publication
- links to peer review with GSC, UBC, Industry to primarily identify data gaps but also to interrogate interpretation
- strong iterative links to Mineral Policy land use and economists

Time Frame:

- ambitious, will organization and commitment to achieve

- given time frame, product may not be Cadillac, but since product is dynamic there will be ongoing opportunities for updates

- need significant allocation of resources 12 - 18 py

- establish role of consultants

- District Geology (GSB) role is essential

SUMMARY OF RECOMMENDATIONS:

- see John Clancy report

Notes taken by R. Schmitt

Supplement to Workshop 2 Report

1) The subject maps which will quantify mineral potential should be called Mineral Resource Potential Maps, rather than Economic Potential Maps. The rationale for this is that the latter terminology could give rise to expectations on the part of the reader or user which the maps in turn would not deliver.

2) The Mineral Resource Potential Map at 1:250,000 should express the Gross Value In Place on a $ per square kilometre basis and should be a consolidation of metallic minerals, industrial Minerals and coal. Separate maps should be prepared for Petroleum, natural gas and coal-bed methane.

   Aggregates should be approached as a Separate issue and plotted on a much smaller scale, 1:250,000 or 1:20,000 where appropriate. Placer minerals and off-shore mineral resources are not recommended for inclusion.

3) Categories of minerals resource potential should be scaled from 1 to 6, with the upper level (6) and the threshold levels being determined by establishing a distribution of areas, primarily Vancouver Island but including two areas (1:250,000 map sheets?) from each mineral terrain across British Columbia.

   Each category of potential value would contain between 15% and 25% of the provincial land area.

4) Confidence in the category (1 to 6) could be portrayed in three rankings A, B, C representing high, medium, low.

5) Use of a D ranking should be considered where an area is considered unratable through lack of information. A "low" potential category would therefore distinguish between poor potential computed from good geological knowledge and poor potential based on scant knowledge.

6) The project group should consist of the following:
   - project leader;
   - ministry geologist most familiar with the area;
   - staff knowledgeable in MINFILE, RGS, data retrieval;
   - person qualified in geophysics.

   This group should be augmented by outside experts, i.e. mine geologists, in appropriate areas.

7) A review group from outside the ministry should review material prior to publication.

8) Time-scale for the project should be:
   - Vancouver Island by end-1992;
   - Work commencing on Kootenay and Cariboo Mountains in anticipation of 1992 program; and
   - other areas, see point 3, in order to establish category levels and to test methodology for the Vancouver Island portion.

9) Manpower needs to complete the process across British Columbia in 3 years - an estimate of 12-18 person years was made.

WORKSHOP #3: Quantitative or Probabilistic Methodology Case Histories and their applicability to our program

Summary Notes

Chair: D.V. Lefebure
Recorder: D.J. Alldrick

Participants:

Rick Richardson	(ARC)
Pradeep Singh	(U Vic)
John Broome	(GSC)
John Vincent	(Cheni)
Gavin Dirom	(Consultant)
John Harrop	(CyberQuest)
Dennis Cox	(USGS)
Jennifer Pell	(Consultant)
Barry Ryan	(GSB)
Robert Longe	(MineQuest)
Ken Dawson	(GSC)
Bob Potter	(Consultant)
Gerry Carlson	(Consultant)
Dave Bailey	(Consultant)
Stewart Nimmo	(Placer Dome)
Eric Grunsky	(GSB)
Steve Sibbick	(GSB)

AGENDA

A. HISTORY

B. LESSONS FROM PREVIOUS EXPERIENCES

C. FLOWCHART FOR THE MINERAL POTENTIAL EVALUATION PROCESS
- Quantitative vs. Qualitative Methods

D. QUANTITATIVE METHODS

E. COMPONENTS OF THE QUANTITATIVE METHOD
- Data Required
- Expertise Required
- Computer System/Hardware/Software Required
- Scale(s) Required

F. ANALYSIS OF ECONOMIC POTENTIAL

G. RECOMMENDATIONS

H. SPIN-OFFS AND PERIPHERAL BENEFITS

A. HISTORY OF METHODOLOGY DEVELOPMENT

1960s -- Alaska/USGS contoured areas of high potential

1970s -- Canadian provincial and federal initiatives:
- GSC "Operation September" for the whole of the NWT area. This comprehensive, quantitative resource assessment by the GSC was never published, never circulated. The project generated very large dollar-value numbers on tracts of land by first predicting the mineral potential. As the first attempt of its kind, the reports, maps and numbers were judged to be too controversial and liable to misconception to be released.

- A later study of the Bridge River camp by John Harrop has also never been published.
- BCDM MINLU maps; then MINFILE was developed from this database.
- Fritz Agterberg developed his "Grid-Cell Method" of dividing the area into cells and then evaluating the probabilities of mineral occurrences within each cell. This type of study was done in the Abitibi Belt, in Nova Scotia and in Snow Lake. Then 10 years later it was redone to test for any significant changes. (see a paper by MacKenzie et al. in the CIMM Special Volume on the mineral industry.)

1975 -- Alaska/USGS evaluated grades, tonnages and probabilities for map quadrangles

1979 -- Denver Meeting organized by John Wilson; Industry Deposit Models (Kennecott, Anaconda & others). Recognized this as the key to a new approach not tied to existing local reserves.

1970s-1980s -- John Erikson produced a USGS Open File Report that documented the characteristics of mineral occurrences.

1981-1985 -- USGS Bulletin 1693 "Handbook" was developed by Don Singer (ex Kennecott) and Dennis Cox. It was started as part of a resource assessment of Central and South America. In part required because there are very few economic geologists in the USGS that they could call on for a range of expertise.

late 1980s -- Drew et al. published a report reviewing all the quantitative methods of ore deposit study in Economic Geology.

1985-1986 -- Larry Drew developed the "Mark III" simulator (a version of a Monte Carlo simulator modified for application in the estimation of oil and gas reserves).

1986 -- Northern B.C. and Yukon study

1986+ -- USGS has undertaken mineral potential studies of Wyoming, Tongass (S.E. Alaska), East Mojave desert, and Colorado Wilderness areas.

B. LESSONS FROM THESE PREVIOUS EFFORTS

There must be access to all data for all users, right from the start.

Before developing deposit models you must ensure you have a good geological database.

You have to start with deposit models to do a mineral potential map.

You will need 4 to 6 geologists to develop and refine these models. Too few, or too many both present problems

Mineral Potential Maps <u>are not</u> exploration guides. They indicate "the potential value of the land" and that "there is an endowment of mineral potential in the ground".

We will have to male our own (significantly revised or 'customized') version of the Cox and Singer models to our British Columbia study.

Cox & Singers mineral deposit models show significant differences to Eckstrands recent (DENAG) models. Russian ore deposit models (and ore deposits!) are different again. Both as deposit models and as grade-tonnage models for specific deposits. B.C.s Alkalic Porphyry Cu-Au deposits are anomalously rich in Ag and PGEs and may be a separate classification.

Beware of breaking down deposit models into sub-types if it is not necessary for the purposes of the study. (eg. Kuroko type vs. Sierran type VMS deposits in California.)

For the people involved in the quantitative estimate, one of the biggest problems is conveying an understanding of the method to the 'layman' (which may often include geologists in other fields of research)....so Watch Out! Even knowledgeable geologists can misunderstand the process (especially the quantitative assessment) and openly challenge the credibility of the results. "Expect misquotes, expect sabotage....you should even expect lawsuits."

For the benefit of all those outside the process you must systematically document the steps, and document the reasons behind each choice or 'decision tree'.

Public presentation of the results is important...to get feedback/allow for comment/explain or clarify. NB. "almost any type of final data presentation will confuse or mislead someone, but we have to choose one (or more) outputs"

Defining and refining the deposit type models and assigning these models to actual mineral occurrences is the most time-consuming part of the process by far. <u>Must</u> have BC-specific models derived from USGS/GSC/CIS models.

Data input into a computer system is the next most time-consuming. (We have a tremendous head-start with computerized MINFILE, TRIM maps, digitized provincial aeromagnetics.

Industrial Minerals have been ignored in all previous studies. This cannot continue, despite difficulties it presents. See Charlie Jeffersons evaluation of the Industrial Mineral potential of South Moresby island.

C. FLOWCHART FOR MINERAL POTENTIAL EVALUATION PROCESS

(i) Qualitative (subjective) Step

Break entire study areas into tracts using general geological data (not mineral occurrences or deposit models)

(ii) Qualitative (subjective) or Semi-Quantitative Step

Sequentially, within each tract, define the most favourable (or permissive) areas for any and all deposit types. Can employ the "Delphi" method *or numeric* "Weights of Evidence" method. Delphi method is purely subjective; Weights of Evidence (0/1) is semi-quantitative. Some WOE methods use (-1/+1).

(iii) Quantitative Step

Develop Interpretive maps using the USGS "Three-part" method or the GSC "Grid-Cell" method. These can yield any and all of:

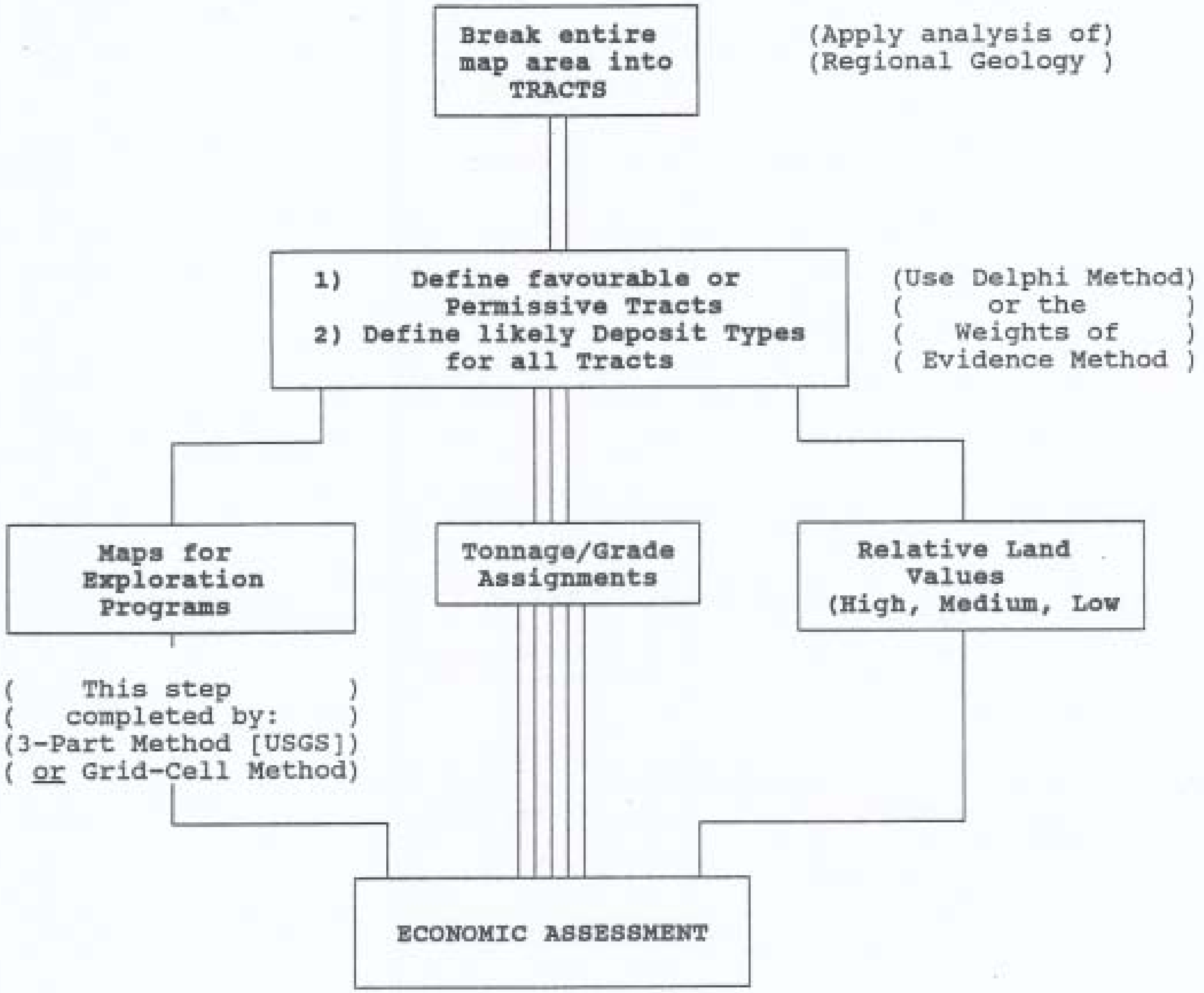
Deposit-type Potential Maps for exploration applications
Tonnage-Grade Potential Maps (necessary to assign $ values
in step (iv).
Relative Land Value Maps ("High-Medium-Low")

(iv) Quantitative Step

Economic Assessment Maps. Assignment of $ values.

Must involve a mineral economist.
Treat this step as a separate project.
eg: Gross In-Place Value (Gross In-Situ Value)
Net Extractive Value
USGS uses "Mark III" Monte Carlo simulator (Drew et al, Econ. Geol, ~1986)

FLOWCHART FOR MINERAL POTENTIAL EVALUATION PROCESS



Quantitative Vs. Qualitative methods??

NOT AN ISSUE. Both are essential components of the process.

D. QUANTITATIVE METHODS

(i) Define Areas

Method I - delineate or draw favourable areas by subjective geological analysis as though preparing an exploration map; consider genetic models and deposit models. This process/criteria must be standardized (in our case, for the whole province).

Method II - separate the entire area into tracts of homogeneous geology.

Method III - Agterberg's Grid-Cell method

Method IV - Three-point method developed by the USGS.

Method V - Expert system (eg. "PROSPECTOR") which provides a score for any showing; or for any area. Also "KNOWLEDGE SEEKER", a system which defines its own criteria. Dick McCammon has revised PROSPECTOR by building in the Bulletin 1693 deposit models and then running the USA Mineral Occurrence File through this program to assign deposit models to showings.

Method VI - Bayesian Logic or Weights of Evidence numeric analysis.

(ii) Quantitative Estimates:

Use tonnage and grade models to put dollar-values on all delineated tracts.

The Mark III Simulator uses Cumulative Probabilities to estimate the value of the ground

John Harrop used a semi-quantitative method in his study of the Bridge River camp. For example, he assigned an area proximal to a fault a value of "1" and an area away from any faults would be assigned a value of "0" for this criteria. Graeme McLaren and Alex Matheson have applied versions of this approach which is essentially a "Weights of Evidence" method.

Note that the forestry industry could produced similar maps placing a potential dollar value on unharvested timber. But mineral potential values will overwhelm timber values. For any district the dollar values of the land would be skewed in the favour of the mineral potential. We might end up alienating the Ministry of Forest and the forestry industry. (Which leads into some debate around the question of whether our output and our message will really be wanted.) To reduce the huge numbers that would be create as dollar-values we could quantify the value as "tons of metal" or "dollar-value/year" at a reasonable mining rate. What does the end-user need for Land-Use planning??

E. COMPONENTS OF THE QUANTITATIVE METHOD

E.1 DATA REQUIRED**

- Geological Maps (most important of all data). Need 1:250 000 coverage everywhere, and 1:50 000 coverage wherever it is available.
- Mineral Occurrence Database. Our "MINFILE" or equivalent [MRDS or "CRIB" in the USGS]. This must be prepared at an expert level. It is a job much like logging drill core; it's dirty, boring and takes a long time; but you have to put only your best geologists on this or you risk missing an orebody. Put only your best people on this work. (Note that Jim Roddick has modified MINFILE software to speed it up considerably.)

- B.C.-specific Mineral Deposit Models
- Interpretive maps delineating favourable geology or all homogeneous geological tracts
- Regional Geochemical Surveys. For integration with other information it is better to work with "interpreted" maps (plural) than the raw data. BEWARE, every geochemist interprets data differently. Always keep in mind that they represent "anomalous drainage maps". Make use of multi-element associations for each deposit-type (Appendix in Cox & Singer). Synthesize this multi-element data into anomalous areas too. Cox commented that our geochemical coverage in B.C. (already in computer format) is "marvellous, in its extent of coverage, range of elements and form of database". Drainage basin topography should not be a problem at 1:250 000-scale studies, but will be a factor to be taken into account at larger scales. [There is a satellite pixel method of correlating RGS-type data by catchment basins.]
- Regional Geophysics (primarily aeromag; gravity & resistivity not much help. Airborne radiometrics would be definitely helpful..how much is available??) Get industry aeromagnetics to complement and supplement our patchy provincial coverage.
- Satellite Imagery (Thematic; Radarsat)
- Topographic base (TRIM)

** Dennis Cox was clearly impressed that we were so far along in the existence, and the computerized availability, of most of these components.

TIP 1: Start **thinking** about deposit models right away! RIGHT NOW!!

TIP 2: Make a major effort to get industry geophysical data to complement or supplement available government aeromagnetics.

TIP 3: Once again, the most time-consuming part of the process is the assignment of mineral deposit types or models to each mineral occurrence. WARNING! Only make positive calls. If you are not sure, take the time to check with someone who has visited the property. If uncertain, leave it "unclassified".

!! In some areas, only 20% of mineral occurrences might be confidently classified!!

E.2 EXPERTISE NEEDED

- "Economic" Geologists

Need a 'Project Chief' for each mapsheet

Entire team must be very knowledgeable. Must have local expertise; therefore team membership will be continually evolving.

Need to be able to conceptualize several types of deposits

Set up a team of 3-5 for each mapsheet; 6 is probably too many.

Must have Economic Geology training/Industry experience. "Geologists with regional mapping experience would not be suitable."

Bring in temporary consultants where needed. eg. UBC/MDRU/GSC/Industry (eg. Nick Carter for the Kitsault/Alice Arm area)

Those with disinterest/objections are not suitable.

Make use of consultants/UBC/MDRU to expand knowledge base

ALL MAPS (geology, geochem, geophysics) MUST BE INTERPRETED BEFORE COMING TO MEETINGS

Final maps may be at (say) 1:250 000, but work at 1:50 000 scale wherever you can

E.3 COMPUTERS (SYSTEMS & SOFTWARE)

- Placer-Dome is applying these concepts globally (but restricted to 5 deposit-types only [Porphyry Cu-Au, Archean gold vein, Carlin, and 2 others]) using an EXPERT system algorithm on UNIX (vs. DOS). System is installed on a Sun workstation. This system uses "Bayesian Logic", which is similar to "Weights of Evidence" except that it allows for negative values (W-O-E does not recognize negative parameters).
- previous G.I.S. experiences were mentioned
- "PROSPECTOR" (Vic Hollister); others

- The biggest problem at the computer end of the process is getting the data in, and into useable format.
- Our system must be GIS-based; must have image-processing capabilities; must be able to do modelling (eg.SPANS; Weights of Evidence); must have vector capabilities.
- Expect to need 1.5-5.0 gigabytes storage. Can save considerable space if you work with interpreted data (polygons/lineaments/points).

E.4 SCALE(S) REQUIRED

- Work at, think at, all scales (iterative process). Don't consider one map sheet in isolation.
- Must **work at** a scale that allows integrity of data. eg. precise deposit locations; show presence of tiny plutons (Ajax Moly), etc. This is independent of scale of **final presentation**.
- The end use of the final product will define the final scale; make final scale conform to maps already in the hands of users.
- Anticipate 'projection" problems. It can be a "nightmare" converting between map projections -- standardize as soon as possible.
- 1:250 000 is the best general goal for Land-Use applications. Might generate 1:50 000 scale maps for exploration applications and 1:20 000 scale maps for Forestry applications.
- Must provide output at scales compatible with users current projects -- or they won't use it.
- Keep careful records of the sources and of the **scales of the sources** of all your original data.
- Be sensitive to the possibility of "artifacts of scale". eg. the zones of highest potential might be the zones with the best/most detailed geological coverage.
- Beware of changing scales within G.I.S., Things may move relative to each other.
- Another concept of scale: should express the number of undiscovered mineral deposits as a number per permissive tract. NOT as a number per mapsheet; NOT as a number per region (eg. Vancouver Island); because all of these will have significantly different confidence levels associated with them and you should use the units of area that offer the highest confidence limits (permissive tracts).

F. ANALYSIS OF ECONOMIC POTENTIAL

- This step MUST be done. But it is not a time-consuming process.
- Need mineral economists [a "must"] (involve our Mineral Policy group). DO NOT leave this up to the economic geologists.
- Treat this stage of the process as a separate project (disband previous team).
- May focus on specific geographic areas (eg. parks) as well as on geologically coherent tracts
- Be concerned/careful/cautious/paranoid about how resulting "values" may be perceived/used/misused
- You can make a mineral potential map (or Dollar-Value Map) using geological data alone...or by using mineral occurrence data alone. Do both! Then compare and re-evaluate and refine the results.
- Tom Gunther, USGS, Washington, has software for this process that we might be able to obtain. Gunther's system takes the # of undiscovered deposits, the likely tonnage, and the likely grade; and then applies gross mining costs, gross exploration costs, gross infrastructure costs and puts in metal prices.
- Should keep this process in-house if at all possible.
- Always keep and open mind to the possibility of a negative "sensitivity analysis"! There may be no deposits in a tract, mapsheet (or the whole province?) that are economic....due to factors like taxation, environmental costs. Have we already seen this at Mt. Milligan and at Eskay Creek?
- At some point should compare our economic analysis of an area to similar economic appraisals by Forestry, Fisheries and others.

G. RECOMMENDATIONS

Get started in areas where you already have in-house expertise.

For the GIS system; get help from the cartographers in Forestry or Environment right at the outset.

Try to avoid bias due to variable data abundance.

Do not start out in the most complex or most "important" or most sensitive area.

Accelerate the upgrading of MINFILE now; put our most knowledgeable geologists on it.

Set up and maintain ongoing communications with all participants and other agencies

Don't let the interim database get 'buried'.

The product must be clear; the product must be clearly for the client.

Use colour for maps.

Minimize the "Butterfly Effect". Test our results in-house, or inter-institute before public release.

Put a special emphasis on determining the mineral potential values where we have the least data (least mineral occurrences).

Throughout the process use CAUTION as a byword; make all steps iterative processes; care and quality are essential.

Remember: we are only one part, one component of the whole resource potential process.

H. SPIN-OFFS/PERIPHERAL BENEFITS

Global Strategy:
We are preparing a specific product that is needed <u>now</u>.
We are establishing/enhancing a database for the <u>future</u>.

Create a small Deposit Model "War Room" with wall-mounted charts, tables, model diagrams (from GSB Short Course) and model compilations (eg. Bondar-Clegg). Set up file cabinet(s) with our deposit model system for ready reference by successive mapsheet project teams. This will evolve and improve through the 3-4 years of the program and be a permanent resource for staff and public.
(Could be/should be the office of the compiler of the GSB Deposit-Model Handbook...if any).

Be sure to make the refined deposit models, databases and interim maps available to the public (mining/exploration industry).

Allow some funds for field checks of important/enigmatic occurrences.

Use this opportunity to update MINFILE to the expert level
(We are approaching this;
eg. skarn project; geocoders with local experience)

MINERAL POTENTIAL WORKSHOP
WORKSHOP 4 - SUMMARY NOTES

TOPIC: QUALITATIVE CASE HISTORIES

PARTICIPANTS:

Chair: Bill McMillan (GSB)
Recorder: Vic Levson (GSB)

Dorothy Atkinson	Dave Brew	Al Burgoyne
Bill Coombe	Ted Faulkner	Robert Handfield
Charles Jefferson	Don McIntyre	Alex Mathison
Rick Myers	Robert Pinsent	Bryan Price
Tom Richards	Ron Simpson	Paul Wojdak

The first question posed was "should we even bother doing this exercise in evaluating qualitative methods?".

- qualitative assessments (high, medium, low potential) are a necessary precursor to quantitative evaluations (# of potential deposits, tonnage and grade estimates, gross in place value); some way of incorporating the expected sizes and grades of potential deposits is important
- the degree of quantification should be defined by the end users; the maps may be used for everything from influencing potential park sites to park boundary refinements to determining payouts for expropriated lands
- quantitative data may make the end product more marketable and allow for comparison with other land users (e.g. Foresters) who can place dollar values on the resources they are interested in
- high, medium and low categories need to be qualified for different deposit types and commodities
- the level of data required for park proposals varies from that needed for general land-use planning (e.g. Parks and Wilderness proposals) to detailed quantitative data for determining value of land for expropriation purposes; areas under pressure will need special emphasis/priority.

DATA COLLECTION:_What do we need? Where can we get it? Who has the expertise to evaluate it?

a) geologic data(rock units and structure)
b) geochemical data
c) geophysical and remote sensing data (airborne geomagnetics, lithoprobe transects, landsat, radar)
d) public economic geology data
- mineral occurrences (Minfile); a caveat - care must be exercised to avoid overemphasizing what is already known relative to undiscovered deposits
- exploration data (assessment reports, claim data, industry maps and reports)

e) private sector economic geology data:
- industry has excellent data for specific areas
- must convince industry that it is in their best interests to provide access to their data; most proprietary industry data is sensitive for only a limited time.
- industry data may conflict with public data due to a difference in interpretations but give a different perspective and can be valuable in refining mineral potential estimates in well explored areas
- industry can also provide quality control and should review the maps before they are released

NOTE: we should get one or more of the Vancouver Island mineral potential maps out (even if preliminary) as soon as possible for client feedback -ie- vet the first maps closely to refine methods that we use to complete later maps

Compilation Scale:

- if possible, compilation scale should be more detailed than the scale of the final product, given the limitations of time and data; 1:100,000 scale would be good if possible but may end up having to use the publication scale (1:250,000)
- more detailed (larger scale) information may be required for site specific assessments (e.g. to refine proposed park boundaries)

Other Points:

- digitize geologic maps as early as possible
- landsat data can be used to trace structure, locate exposed rock and can be used with RGS data but time devoted should be monitored because in instances results may be of questionable utility
- utilize government, industry and university sources although practical limitations may preclude the use of some data; it is important to give industry the opportunity to provide additional pertinent information
- claim data was useful in evaluating mineral potential in the NWT but there are limitations in British Columbia due to blanket staking, existence of crown grants which have low maintenance fees, and time consuming (manual) recovery of historical records; claims are, however, a useful indicator of past activity
- having known mineral occurrence location points on the map may be useful but be careful that the focus is on geologic potential, not known occurrences
- assessment report quality varies but the data should be included as much as time permits
- ongoing interaction between geologists, geophysicists, geochemists and geo-economists essential
- the team approach requires compatible members to be effective; participants shouldn't be coerced

Defining tracts with permissive geology

- tracts in Tongass study were defined first by geologic characteristics; initially they are large and then they are slowly reduced in size using all other criteria available; a "funnel" approach - start large and gradually whittle the area down - is recommended - ie- the tract could be the entire greenstone belt, then, in the gold deposit evaluation, reduced to those areas with shear zones crossing the greenstones
- this is a criteria based approach; different deposit types will have different criteria - e.g. geophysical data may be used only for some deposit types; each "test" produces an overlay or GIS layer that subsequently is combined with others to produce the final mineral potential map
- tracts should not stop at existing land-use boundaries (e.g. park boundaries)
- multiple layers are required
- an 'unknown' category is needed; it should be placed high on the list, not last, where it will be ignores or misused

Defining deposit models

- put priority on deposit model selection and on adjusting them to reflect the British Columbia experience

- begin with all 90 known USGS-defined deposit models and use an iterative approach to define those applicable in a specific permissive tract (tracts may cross map boundaries)
- 36 deposit models were used in the Tongass study to "filter" the permissive geologic tracts for areas of better potential for mineral deposits; 15 were used for the Moresby Island marine park study for all minerals. We must ask the question: "what might be here". For example, are there placer gold deposits at the base of the Nanaimo Group?
- known deposits must be used as a factor
- deposit models can be grouped or dealt with as clans
- the analysis should include industrial minerals, coal, oil, gas, geothermal, aggregate, etc.
- we must be prepared to update models 'missing' or unknown deposit types are discovered. The mineral potential maps are not the final word; periodic updating should be part of the production design
- non-geologic factors (e.g. socioeconomic factors) could be considered late in the process (e.g. The USGS is presently focusing on base-metal deposits since they typically have a wide geographic distribution but this focus of effort is not yet final.)

Final products: mineral potential maps

- tracts (GIS polygons) need quantitative assessments (i.e. dollar values) as a 'lowest common denominator' for comparative purposes but it should be emphasized that the values are 'qualitative' in that they are really statistical probabilities of undiscovered resources
- grade-tonnage estimates for each tract are based on existing grade-tonnage curves with 50% above and 50% below the estimate; this helps keep the numbers realistic
- a series of maps and a synoptic map could be produced
- mineral potential values will fluctuate with commodity prices
- to make estimations semi-quantitative, analogies with present or historic deposit types in similar settings in the Cordillera may be useful

Problems:

- a major problem recognized is that of combining values estimated for different commodities into a single final map. For example, is it valid to combine layers for different deposit types? Is a tract that has low potential for several different deposit types equivalent to a tract with high potential for one deposit type? How do you evaluate the relative value of gas or oil against copper or gold or against dimension stone or limestone?
- how are deposits of low dollar value but high profile (e.g beach placers or argillite that could be exploited by native people on the Queen Charlottes) to be dealt with?

Other Points:

- using probability estimates is the key to defining quantitative criteria but an adequate level of detail is not always available; criteria should be standardized
- quantify in terms of historical production and applicable analogues elsewhere; key in on size as well as potential
- could use 'creative' general models (such as Tom Richards method of using heat and faults) to help predict unexpected deposit types and world examples that could be here
- fewer categories are better than too many, especially at the regional planning level; more detailed information (e.g. subcategories) can be provided for more local or site-specific planning

- socioeconomic analysis may be required as a last phase and should involve mineral economics and geologic input; there should be good communication between geologists and policy people
- we may need to be able to assess the larger economic impact e.g. survival of a community, the number of jobs, taxes generated, etc.

Product Delivery:
- product delivery is essential and should be included in the project plan
- final products should be combined with a socioeconomic analysis perhaps in conjunction with economists in mineral policy
- it is essential that the geologists involved in map preparation be involved in delivery of the results to the users
- final product should be able to address the needs of a broad spectrum of users

Comments:
- areas under pressure should be given priority coverage
- if qualitative methods are used, the layers of data used must be carefully and clearly defined and identified in non-technical terms, preferably with a graphic representation as well
- some way to show possible impact on the global provincial economy is needed -ie- direct jobs, money spent on infrastructure, spin-off jobs, etc.
- the problem of depicting multiple commodity potentials on a single map is one that requires careful consideration depending upon the required final product

Reports Tabled:

1) Brew, D.A. 1992. Decision points and strategies in quantitative probalistic assessment of undiscovered mineral resources. USGS Open File Report 92-308.

2) Jefferson, C. and H. R.Schmidt. 1992. Assessment of mineral resource potential; Phase 1 in the proposed area of Gwaii Haanas / South Moresby National Marine Park Reserve. GSC Open File 2480

3) Charts showing MEMPR qualitative rating scheme presently used by the Branch for recreation area evaluations

NOTE: The USGS MARK3 software is available through Dave Root, USGS, MS 920,Reston, VA, 22092.

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