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# CANADA'S MERA PROCESS AND THE ROLE OF EARTH SCIENCES

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2004

Natural Resources Canada Ressources naturelles Canada

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**Presented at the World Parks Congress, Durban, South Africa, September, 2003**

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2004: Canada’s MERA Process and the Role of Earth Sciences; Geological Survey of Canada, Open File 4732, 15 p., 1 CD-ROM.

Open files are products that have not gone through the GSC formal publication process.

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Harrington Area, East Coast Boreal Region, Labrador
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## TABLE OF CONTENTS

# CANADA'S MERA PROCESS AND THE ROLE OF EARTH SCIENCES

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## 1. INTRODUCTION

Canada, second only to Russia in landmass, covers 9,976,000 km$^2$, of which 755,000 km$^2$ is fresh water lakes, 7,676,000 km$^2$ is mainland and approximately 1,543,000 km$^2$ is islands. The large number of islands, over 52,000, mostly in the Arctic help contribute to Canada's coastline of 243,000 km, making it the longest in the world. Canada exercises sovereign rights over the adjacent regions under the sea. The area within the limits of the continental slope surrounding Canada totals about 8,850,000 km$^2$. Canada is also unique in its range of latitude from 41° 26' N to 83° 07' N, less than 800 km from the North Pole. The federal MERA (Mineral and Energy Resource Assessment) process helps to balance two major facets in sustainable development of this land: maintenance of ecological integrity and extraction of nonrenewable resources. Numerous environmentally diverse and rich natural regions, together with extensive nonrenewable resources, are fundamental to the social, economic and environmental framework of Canada and the world.

Canada's national parks and other protected areas are created mainly to protect natural physical features, game species, endangered or dwindling species, recreation, biodiversity and ecological integrity. According to sustainable development theory, such protected areas are critical to the long-term health of our society, while stimulating and maintaining the economy. Mining is also recognized as critical to the well being of the economic and social fabric of Canada. Every facet of our modern civilization depends on mineral and energy resources from the earth, and these constitute more than 30% of Canada's exports to the world economy.

Mineral activities are prohibited in many protected areas and all national parks. Problems for the mineral industry may occur where protected areas are created along linear features, such as rivers, or around natural harbours, thereby restricting or preventing access to areas of high mineral and energy potential for exploration and development. On the other hand, the mining industry officially recognizes the importance of protected-area networks to both environmental objectives and sustainable development, as stated in the *Whitehorse Mining Initiative Leadership Council Accord 1994*. However, the mining industry requires assurances that, once it is given the right to explore, this will include the right to develop economic mineral resources, subject to a positive environmental impact assessment review and any associated conditions stipulated through the regulatory approval process. The Whitehorse Accord states that decisions to withdraw any lands from mineral activity, should be based on all relevant technical, environmental, social and economic information. This includes information on mineral potential, which is gained through unbiased mineral resource assessments.

The Mineral and Energy Resource Assessment (MERA) process was established in 1980 to ensure that mineral and energy resource assessments are completed on lands where such resources are administered by the Federal Government, before boundaries for national parks are determined. Provincial governments within Canada are responsible for such assessments on their lands, and have developed a range of assessment procedures that are not described here. With devolution of federal resource management responsibilities in the Yukon on April 1, 2003, the Yukon Territorial Government also assumed responsibility for resource assessments.

Federal geoscientists are essential to the MERA process. Unbiased research scientists develop mineral deposit models, collect the geoscience information necessary as part of resource assessments and play an integral role in communicating their results to stakeholders and policy makers.

This paper describes the MERA process, focussing on the geoscience aspects of resource assessment on lands administered by the Canadian federal government. We document some highlights of protecting federal lands and of developing nonrenewable resources in Canada. With the aid of case histories, we discuss the role of government geoscience and geoscience tools in resource assessments and management of marine conservation areas, and introduce the reader to some limitations of MERAs, especially concerning degrees of uncertainty and temporal change.

## 2. THE IMPORTANCE OF PROTECTING LAND AND NONRENEWABLE RESOURCES IN CANADA

### 2.1 Protecting Areas in Canada

A systematic approach to protecting a representative sample of each of Canada's natural regions was established in the early 1970s and has been evolving ever since. Parks Canada revised the National Parks System plan with the goal of a national park in each of 39 distinct natural regions based on physiography, flora and fauna. To date, 27 natural regions have been represented by 41 national parks and national park reserves, leaving 12 natural regions not represented as of August 2003. National parks currently occupy about 2.25 percent of Canada (224,000 km$^2$) while other protected areas cover about 10 percent of Canada.

Canada further recognized the importance of protecting natural regions in 1990, when its *Green Plan* identified the goal of setting aside 12% of the landmass of the country in protected areas. (Government of Canada, 1990, p. 79). In 1992, the *Tri-Council Statement of Commitment to Complete Canada's Networks of Protected Areas*, identified several areas of priority: accelerate the identification and protection of critical wildlife habitat; cooperate between jurisdictions in the protection of ecosystems, landscapes and wildlife habitat, and thereby aid sustainable development.

In response to Canada's ratification of the *United Nations Convention on Biological Diversity* in 1992, the federal, provincial and territorial governments prepared the *National Biodiversity Strategy, Canada's response to the Convention on Biological Diversity*. This strategy identifies several strategic directions for protected areas and their use in conserving wildlife and habitat.

Ecological integrity, defined as "an area that incorporates natural ecosystems that are self-sustaining and self-regulating, with a full complement of species, complete food webs, and naturally functioning ecological processes" (Environment Canada, 1991), has recently become the focus for several categories of protected areas. In 1994, Parks Canada added ecological integrity as a major consideration in the selection and management of national parks (Canadian Heritage, 1994).

The Canada National Marine Conservation Areas Act, passed in 2002, provides the legislative framework to establish and manage a National Marine Conservation Areas system. One such area has been established in Ontario and one in Quebec, with four others proposed. The Oceans Act, 1996 (http://laws.justice.gc.ca/en/O-2.4/87839.html), provides the framework for the establishment of marine protected areas.

A variety of other tools are used for protecting ecological integrity and diversity in Canada, including Canadian Heritage Rivers, territorial and provincial parks, national wildlife areas, and various kinds of legislation for managing industrial uses of land. This paper focuses only on the National Park establishment process on Canadian lands whose nonrenewable resources are managed federally: northern territorial lands and the seabed offshore.

## 2.2 The Importance of Nonrenewable Resources to Canada

The mining industry is a vital contributor to the Canadian economy. The value of nonrenewable resources (including coal, petroleum and gas) produced in Canada reached $77.0 billion in 2002. Excluding petroleum and natural gas, the value was about $19.6 billion. Canada is the world's third largest producer of natural gas and the second largest exporter. In 2002, the mining and mineral processing industries contributed $36.1 billion to the Canadian economy, an amount equal to 3.7% of the national Gross Domestic Product (GDP). The oil and gas contributions are even greater, with Canada's energy industries (including hydroelectric) contributing 6 to 10% of Canada's GDP over the past decade. The examples provided here focus on minerals.

At the start of 2003, there were some 190 principal metal, nonmetal and coal mines, over 3000 stone quarries, and sand and gravel pits, and about 50 nonferrous smelters, refineries and steel mills operating in Canada. Canada ranks fourth in the world for the production of primary aluminium from imported bauxite and alumina, producing about 2.7 million tonnes in 2002. Canada ranks first in the world for the production of potash and uranium, and ranks in the top five for the production of nickel, asbestos, zinc, cadmium, titanium concentrate, aluminium, platinum group metals, salt, gold, molybdenum, copper, gypsum, cobalt and lead. The five most important minerals in terms of 2002 Canadian production value were gold ($2.3 billion), nickel ($1.9 billion), potash ($1.6 billion), copper ($1.4 billion) and cement ($1.4 billion). Potash is the most important commodity in the nonmetals category. Canadian potash shipments in 2002 totalled 8 million tonnes and were valued at $1.6 billion. The Canadian potash industry was first developed in the early 1960s with the opening of potassium-chloride mines in Saskatchewan. As the result of a series of expansions in the 1970s and 1980s, Canada now ranks as the world's largest producer and exporter of potash; in fact, Saskatchewan's potash industry ranks as the world's most productive.

The mining and mineral processing industries directly employed 361,000 Canadians in 2002: 47,000 were employed in mining, 52,000 in smelting and refining, and 262,000 in the manufacturing of mineral and metal products. Average weekly earnings in the mining, quarries and oil wells industry in 2002 were over $1000, one of the highest levels of any industry in the Canadian economy.

The transportation of mineral products is vital to Canadian railways, providing 59% of the total revenue in freight in 2001. Over the last five years more than 65% of the volume of all products loaded at Canadian ports for international trade was from mineral-related products.

# 3. MINERAL AND ENERGY RESOURCE ASSESSMENTS (MERA)

## 3.1 Background

Resource assessment is the process by which an estimate is made of both the discovered and undiscovered resources potential of an area. Mineral and energy resource assessments use the accumulated knowledge about the earth's geological environments and their respective deposit types to predict the types of deposits and their likelihood of occurring in a given area. Reasons for resource assessments are varied. In Canada these: include national economic and strategic planning, export policy, infrastructure decisions, and government stimulation and support of exploration. They have generally been in response to requests from other government departments related to requirements of First Nations' land claim negotiations and the proposed establishment of northern protected areas. Resource assessments use a wide range of methods and deliver a variety of products.

## 3.2 The Role of Government Geoscience in the MERA Process

Government geoscientists employed by the Geological Survey of Canada (GSC) play a vital role in providing expertise and a neutral perspective on what many consider to be contentious issues of land use management. These federal scientists develop national perspectives of broad regional geological domains that provide context for more localized resource assessments. The experts' national and international knowledge of mineral deposit and hydrocarbon analogues is required to translate geoscientific data into assessments of resource potential. Such analogues include mineral deposit models (e.g. Eckstrand et al., 1995) and petroleum play histories (e.g. Osadetz et al., 2003). The field programs conducted by the federal scientists bring a consistent level of expertise and adapt national methods of mapping, and geochemical and geophysical surveying to the specific areas of interest in a consistent fashion.

## 3.3 MERA Process and Its Relationship to National Park Establishment Process

The MERA process is the primary means whereby the Department of Indian and Northern Development (DIAND), Parks Canada, Natural Resources Canada (NRCan) and the territorial governments cooperate in conducting mineral and energy resource assessments and is an integral part of establishing a national park in Nunavut, the Northwest Territories or the offshore areas of Canada. The steps in the process have been clearly laid out in the MERA Terms of Reference (Government of Canada, 1995), thereby keeping the process transparent and easy to understand. The purposes of MERA are listed below, exactly as set out in these Terms of Reference.

- To ensure that the economic and strategic significance of mineral and energy resource potential is duly considered in the national park establishment process in the Yukon and Northwest Territories [the latter is now split into Nunavut and the Northwest Territories]
- To ensure that, in making recommendations regarding the withdrawal of land for national park purposes, the Minister of DIAND is advised on the balance between the values of the land with respect to park establishment criteria and the potential for the exploration, development and use of mineral and energy resources that may inhere in the land.
- To prepare assessments of the mineral and energy resource potential of areas in the Yukon and Northwest Territories which are being considered for administration by Canada as national parks.

The MERA process is governed by two main groups: a Senior MERA Committee and a supporting MERA Working Group.

The Senior MERA Committee is composed of Assistant Deputy Ministers from the Department of Indian and Northern Affairs Canada (DIAND) (Chair), from Minerals and Metals Sector and Earth Sciences Sector (includes GSC) of Natural Resources Canada (NRCan), and the Chief Executive Officer of Parks Canada Agency. It also has senior representatives from both the Government of the Northwest Territories and Nunavut. The main responsibilities of this group are to approve terms of reference, including work plans and budgets for each MERA project, review status of proposed national parks, provide direction to the MERA working group and make recommendations to the Minister of DIAND regarding national park boundary establishment.

The MERA Working Group comprises officers from Parks Canada (co-Chair), the GSC (co-Chair), the Mineral Resources and Resource Planning and Conservation directorates of DIAND (secretary), the Minerals and Metals Sector of NRCan, and additional working-level government representation as required. The MERA Working Group provides reports and advice to the Senior MERA Committee, reviews technical reports, studies and identifies issues requiring Senior MERA Committee decisions and advises Parks Canada on the scope, scale and nature of public consultations.

The MERA process and its relationship to national park establishment is:

1) Parks Canada informs the MERA Working Group of the natural areas under study;
2) MERA Working Group provides available information on potential natural resources to Parks Canada, in order to assist it in determining areas of interest;
3) Parks Canada selects a potential park area;
4) GSC prepares Terms of Reference for the mineral and energy resource assessment. These Terms of Reference will include a work plan that identifies the studies required and a budget that specifies estimated costs;
5) Senior MERA Committee approves the Terms of Reference, and may revise them as necessary;
6) Public is informed, by Parks Canada, that a MERA will be conducted for the area of interest;
7) Parks Canada prepares documents that outline the natural and cultural resources of the area of interest, and the social and economic implications of the proposed park. These documents are available to the Senior MERA Committee and to the public;
8) At the same time, the GSC undertakes the mineral and energy resource assessment. This includes an inventory of existing data (both public and private), but more importantly, field and laboratory analyses that bring the information base up to modern standards;
9) As a conclusion to the studies and analyses, the GSC rates the mineral and energy potential of the area. These ratings and the collated information upon which they are based, are published and made available to the public;
10) The territorial government conducts a hydro-electric power assessment, if necessary, and presents the results to the Senior MERA Committee;
11) The Minerals and Metals Sector of Natural Resources Canada, and other members of the MERA Working Group, prepare comments on the strategic and economic value of the resources in the area to the territory and to Canada;
12) Parks Canada presents a park proposal to the Senior MERA Committee;
13) MERA Working Group presents technical reports and recommendations on a proposed park boundary to the Senior MERA Committee;
14) Senior MERA Committee considers all the information and makes recommendations to the Minister of Indian Affairs and Northern Development on a Government of Canada negotiating position toward park establishment,
15) Parks Canada consults with the general public on the park proposal.
16) Upon completion of negotiations with the affected Aboriginal/Inuit group to establish the national park the Minister of Indian Affairs and Northern Development may need to recommend a change in the withdrawn lands to reflect the negotiated boundary and ensure that any lands outside the park boundary but inside the interim land withdrawal of the park proposal area

become available for alternative land uses while the parliamentary procedure to include park lands in the *Canada National Parks Act* runs its course.

Although this process may seem extremely detailed, it does have the advantage of specifying the roles of the different agencies and the points in time where decisions are necessary. The last item, land withdrawal, has recently been implemented earlier in the process as an interim land withdrawal of less than 5 years, in order to assure stakeholders that third party interests (e.g. the staking of mineral claims) will not pre-empt the MERA process. In such cases, the interim land withdrawal is ideally modified to a final configuration soon after the MERA process is completed. The process is thus simplified by being itemized, but more importantly, it is made transparent, making it possible for anyone to understand and to determine when public/stakeholder input can influence/contribute to decisions.

## 3.4 MERA Process – Technical Aspects

Resource assessments are of interest at an international level and numerous methods have been applied to conduct them. These include time-rate, crustal abundance, cumulative tonnage versus grade, simple subjective, complex subjective, Bayesian, frequency, trend, geometric probability, multiple regression, discriminant analysis, modified component, multivariate logistic, cluster analysis or pattern recognition and simulation. The type of method selected is dependant on: 1) what product is needed to address the problem, 2) constraints determined by geoscience information or financial resources, 3) the level of uncertainty or bias that is acceptable, and 4) the need to verify the results. In general the question must be asked "Is the method acceptable to the resource assessment users?" (Singer and Mosier, 1981)

The method presently used by federal Canadian geoscientists in the MERA process is based on the principle of conceptual models of selected deposit types, resembling the simple subjective method of Singer and Mosier (1981). This method is described in detail by Sangster (1983). In general, a conceptual model integrates the common and obvious geological parameters of many deposits of the same type to establish an ideal model for each deposit type. The parameters are a combination of those published by geoscientists with modifications based on Canada's geoscientists with expertise with those particular deposit types. The resource estimates are therefore made directly by one or more experts based on their knowledge. The term "resource assessment" refers to the prognostication of undiscovered deposits and does not assign an economic value to the deposits.

The actual steps of conducting a MERA are described below.

### *Phase I. Preliminary research*

The initial phase of resource assessments includes one or more of the following steps:

**Step 1.** Clearly defining the study area, in partnership with the other government agencies involved in the process.

Having a clear understanding of the extents of the study area may appear to be an obvious and simple task, but this important first step ensures that the proponents do not change the objectives partway through the assessment, thereby causing expensive logistical changes. Knowing the location of the study ensures that necessary data are collected efficiently and completely. Also, geologic processes are not necessarily confined to areas defined by politics, climate, drainage, or other natural events. Especially in the case of parks that may have boundaries defined on a watershed or species habitat, it is important to know the area of study so that it can be determined if the resource assessment may depend on information from parts of geological domains that extend outside the study area. It is common practice to define MERA study areas to be larger than the park proposals. In that way, if portions of the proposed park contain high mineral and energy potential, the opportunity may be present to excise these in exchange for areas of equal park values but lower mineral and energy potential outside the original park proposal but still within the larger study area.

**Step 2.** Compilation of geoscience data from existing sources

Typical data that may be collected at this stage would include bedrock geologic maps, quaternary geology maps (surficial cover), geophysical survey data, geochemical survey data and mineral deposit/occurrence data, all from previously completed work.

At this time a partial "gap analysis" can be completed to identify where in the study area any of these data layers are missing or incomplete.

**Step 3.** Establishing potential deposit types that may occur within the study area.

Using the inventory of all known occurrences of mineral deposits/occurrences and hydrocarbon accumulations combined with an understanding of geological setting determined from the collected information, possible mineral deposit types that could be found within the study area are established.

**Step 4.** Establish "conceptual models" for these deposit types.

Descriptive and genetic models are used as analogues in the MERA process. The most recent Canadian compendium is by Eckstrand et al. (1995). The descriptive models include geological, geochemical and in some cases geophysical criteria for determining the existence of such deposit types in a given area. These criteria are considered in an iterative subjective feedback process involving Steps 2 and 3. For Step 2, the data needed to determine the existence of a particular deposit type is part of the gap analysis. For Step 3, the compendium itself serves as a check-list of all possible deposit types that may occur within the study area.

At this stage, the involvement of experts in the various deposit types can be very useful, as sophisticated decisions may be required to determine which of several possible candidate deposit models may apply to a given occurrence in the study area. For example, is a silver-lead-zinc vein part of a partially remobilized silver-rich lead-zinc Sedex deposit (Lydon et al., 1995) or is it an expression of a skarn-manto-replacement deposit system (Dawson, 1995)? If the existing data are insufficient to make such a decision, then both analogues become part of the working hypotheses. Only additional field data (Phase II) may serve to resolve such uncertainty.

**Step 5.** Prepare an initial assessment of resource potential based on the above data.

Once it has been established which deposit models are suitable for the study area, a qualitative assessment of the potential for these deposit types occurring in the study area is made. The procedure involves ranking the potential based on the presence of geological controls for the specific deposit type as defined by the deposit model and/or the presence of deposits of that type in the study area. Seven categories are defined to indicate a potential from very low to very high. An explanation of the potential rating categories is shown in Table. 1.

The federal Canadian MERA process involves active, ongoing consultation during these steps. A MERA Working Group meets every 4 to 6 months and the various departments keep each other informed of developments on a weekly to monthly basis depending on the level of activity. The GSC representatives will use their initial resource assessment, that is usually a 5 to 20 page internal unpublished document, as a means of informing the Working Group of the implications of continuing with the MERA process in the study area.

Based on the results of Phase 1, Senior MERA Committee will make one of the following recommendations: 1) the advantages of a park outweigh the value of potential nonrenewable resources within the study area and the creation of a park should proceed, 2) the study area has too much nonrenewable resource potential to remain under consideration for a national park, and another candidate area should be chosen, 3) park creation may proceed but boundaries should be modified to exclude areas of high mineral potential, 4) more information is required before a final decision is made, therefore a Phase II study should be undertaken to collect new information for the study area.

It is also conceivable that the work plan that is designed on the basis of Step 5 (*see* Phase II below) is too expensive to implement, or the political process does not allow time for Phase II work. As a result, the GSC may be requested to formally complete the Phase I review as the only assessment for publication and peer review. This was the case for the South Moresby marine park proposal, which was addressed by two separate GSC Open File publications, one on hydrocarbons (Deitrich et al., 1992) and the other on minerals (Jefferson and Schmitt, 1992). These assessments constituted the geoscience information that was considered by the South Moresby Working Group and the Senior MERA Committee along with socio-economic, First Nations', biological, archeological, and various political and environmental issues, in making recommendations for the South Moresby / Gwai Haanas National Marine Park.

**Table 1.** Explanation of mineral and energy potential rating categories used by the GSC, based on the application of deposit models (Eckstrand et al., 1995) to data bases that include only geology, available information on deposits[1] and occurrences[2], and reconnaissance geochemistry.

| Ranking Symbol | Potential Level | Criteria |
|---|---|---|
| VH | Very High | Based on deposit model:<br>Geological environment very favourable<br>Significant deposits are present<br>Presenence of additional (undiscovered) deposits very likely |
| H | High | Based on deposit model:<br>Geological environment very favourable<br>No known significant deposits present<br>Presence of additional (undiscovered) deposits likely |
| MH | Moderate to High | Intermediate between Moderate and High Potential |
| M | Moderate | Based on deposit model:<br>Geological environment favourable<br>Significant deposits may or may not be known<br>Presence of additional (undiscovered) deposits possible |
| LM | Low to Moderate | Intermediate between low and moderate potential |
| L | Low | Based on deposit model:<br>Some aspects of the geological environment may be favourable but are limited in extent<br>Few, if any, mineral occurrences are known<br>Presence of additional (undiscovered) deposits low possibility |
| VL | Very Low | Based on deposit model:<br>Geological environment unfavourable<br>No known mineral deposits or occurrences<br>Presence of additional (undiscovered) deposits unlikely |

1 "Deposit" refers to a mineral or energy resource of a size that could be developed.

2 "Occurrence" refers to a drilled or exposed mineral or energy resource that may or may not be part of a hidden deposit.

### *Phase II – Supplementary comprehensive field and laboratory studies followed by data analysis and resource assessment*

**Step 6.** Develop, approve and implement work plan for Phase II involving field work.

The Phase II part of the MERA process aims to obtain relevant additional data (geological, geochemical, geophysical ground (magnetotelluric, gravity, EM, IP, seismic) and airborne, and remotely sensed data (airborne, satellite, hyperspectral, radar, TM, etc.)). In developing the work plan, a balance is sought between the time and resources available to do the work and the need to acquire data for those deposit types most likely to be present, with the need to cover all eventualities. Though it cannot be eliminated entirely, an effort is made to limit inherent bias during data collection toward pre-conceived deposit types. This sampling bias limits the possibility of detecting evidence for an entirely new deposit type, for which no indicators are present in existing data.

The highest priority for the work plan is to ensure that knowledge of the bedrock and surficial geology is current and comprehensive. Due to the current limits on government resources and the logistical challenges of nondestructive fieldwork in these pristine remote areas, geological mapping is usually thematic and targeted. The broad geological framework is determined from existing maps, and parts of typical geological domains are remapped in detail so as to better understand their history and mineral potential. Typical mineral occurrences are compiled and representative sites are mapped and sampled in detail to verify the deposit type and prospective elements. Potential hydrocarbon-bearing structures are mapped, and existing or on-going exploration plays are documented. Results from these detailed areas and typical mineral or hydrocarbon occurrences are then extrapolated subjectively over the entire study area.

A standard way of reducing bias in data collection is to obtain regionally consistent geochemical samples from whatever media (e.g. sediments from streams, lakes, soils, tills, marine environments / biogeochemistry) are most appropriate for the terrain in the study area. Such samples may be analysed for as many elements as possible, thereby providing for the possibility of objective analysis that could discover a deposit type not previously considered in the area. Multiparameter geophysical data, especially including gamma ray data, may provide another form of objective regionally consistent geoscience coverage. In each case, however, the costs must be balanced against the expected value of the data collected and the resources available to do the Phase II study. The Canadian government experience is that geochemistry is generally affordable, with data density tailored to the resources available and area that must be covered. Geophysical data are generally not affordable and have resulted in elimination of Phase II work when insisted as part of a project (e.g. South Moresby examples above). Whatever the combination of work proposed, if the geoscientist preparing the work plan insists on too expensive a proposal, the risk increases that no fieldwork at all will be done.

As with any large project, partnerships frequently enhance resources and build enthusiasm to provide a better field component to Phase II MERA. This has been the case with most GSC MERA projects. Internal GSC partnerships are developed whereby staff and data from other research priorities are coordinated with MERA work to significantly enhance the quality and confidence of the MERA results and vice versa. External partnerships with other geoscience agencies and universities (students) further enhance the results. Since 1978, the GSC (now part of ESS = Earth Science Sector) has delivered the geological MERA projects, and worked in partnership with Minerals and Metals Sector (MMS) and Energy Sector (ES) of NRCan who supply the federal economic and strategic context (L.-A. Lapalme, pers. comm., 2003).

Once data are collected as budgets permit, the scientists use available geospatial and geostatistical tools to normalize analytical results over the study area, systematically go through their checklist of deposit types and their essential characteristics, and subjectively determine the potential of each deposit type for each resource assessment domain according to Table 2. Before the report goes out for peer review, or as part of the peer review, the MERA coordinator will provide the draft report and prognostications to recognized experts on each deposit type for their critical comments. If there are ten deposit types, then usually ten experts are sought. In addition, experts on regional metallogeny and hydrocarbon resources of the area are consulted to review whether or not anything has been forgotten. Having a critical mass of hydrocarbon and mineral deposit experts in one institution aids the GSC in administering and delivering this task since it is a corporate priority. External partnerships with other geoscience agencies (e.g. Territorial government geoscience directorates, Indian and Northern Affairs Canada's Northern Oil and Gas Directorate, and university professors and students) further enhance the results, and provide unbiased peers for critical reviews.

## 4. MERA CASE STUDIES

### 4.1 Tuktusiuqvialuk (Proposed National Park) – An Example of Compromise Acceptable to Both Conservation and Mining Interests on Northern Bathhurst Island

A study of the feasibility of a national park on northern Bathurst Island was initiated in 1995 with an agreement between the Inuit of Resolute Bay and Parks Canada. Lands were reserved under the Territorial Land Act in 1996 to provide interim protection until the necessary consultations, studies and negotiations could be completed.

The proposed area represents the typical characteristics of Natural Region 38, in particular the long cold winters, expanses of exposed bedrock, sparse vegetation and soil, and scarce wildlife, which includes muskox and the Peary Caribou. The proposed area contains an important calving ground for the Peary Caribou, which are recognized as an endangered species

At the request of the Senior MERA committee, the GSC conducted a MERA of the proposed area between 1994 and 1999. The extended time was a result of the large amount of data that needed to be collected and the short field seasons.

The published results indicated a very high potential for carbonate-hosted zinc-lead deposits (Mississippi Valley Type) as well as oil and gas plays in the eastern portion of the study area.

The published MERA results were discussed at a public workshop in Resolute, Nunavut.

In 1996, the northern Bathurst Island area of interest for park purposes was withdrawn from mineral and energy development for three years. Subsequently, this interim withdrawal was renewed for a further three years, such that the current land withdrawal order will expire in October 2004, thereby allowing time for all stakeholders to discuss various options.

It was agreed that the position of the Government of Canada was to prohibit any activity that would destroy critical habitat in the caribou calving grounds.

In 2001, the Mining Association of Canada, in cooperation with the Canadian Nature Federation and other stakeholders, offered a compromise boundary option for the proposed national park. In essence, the compromise would make the eastern portion of the proposed park accessible for energy and mineral resource exploration and development, in exchange for additional lands in the western part of the proposed park. Furthermore, a moratorium on exploration and development would be put in place until the Peary Caribou recover. Upon lifting of the moratorium, exploration and development would be subject to special management measures to account for the sensitivity of the caribou and their habitat.

The success of the MERA process in this case is a result of a transparent process that involves all the stakeholders, including the public, in discussions on the technical reports and the boundary delimitation. This allowed diverse groups such as an industry association and an environmental non-governmental organization to work together to develop a compromise acceptable to both conservation and mining interests.

The next step to complete the park creation process is to begin formal negotiations between Parks Canada and Inuit regarding terms and conditions of park establishment.

## 4.2 South Nahanni River MERA – An Example of Responding to New Knowledge

The South Nahanni River study (area 14 on Fig. 1) is an excellent example of significant change in knowledge and context over time, an important consideration when making decisions on permanent uses of our land. The original South Nahanni River National Park Reserve (NNPR) was established in 1972, well before the MERA process. NNPR is a long narrow corridor along the South Nahanni River and its major tributary valleys. This MERA study began in 1983 and focused on three proposed additions to NNPR that were thought to have significant heritage value. In 1990 this MERA was put on hold pending resolution of the Deh Cho native land claim process. It was finally reactivated, along with the Deh Cho process, in 2001 and completed in 2003 with publication of GSC Open File 1686 (Jefferson and Spirito, 2003).

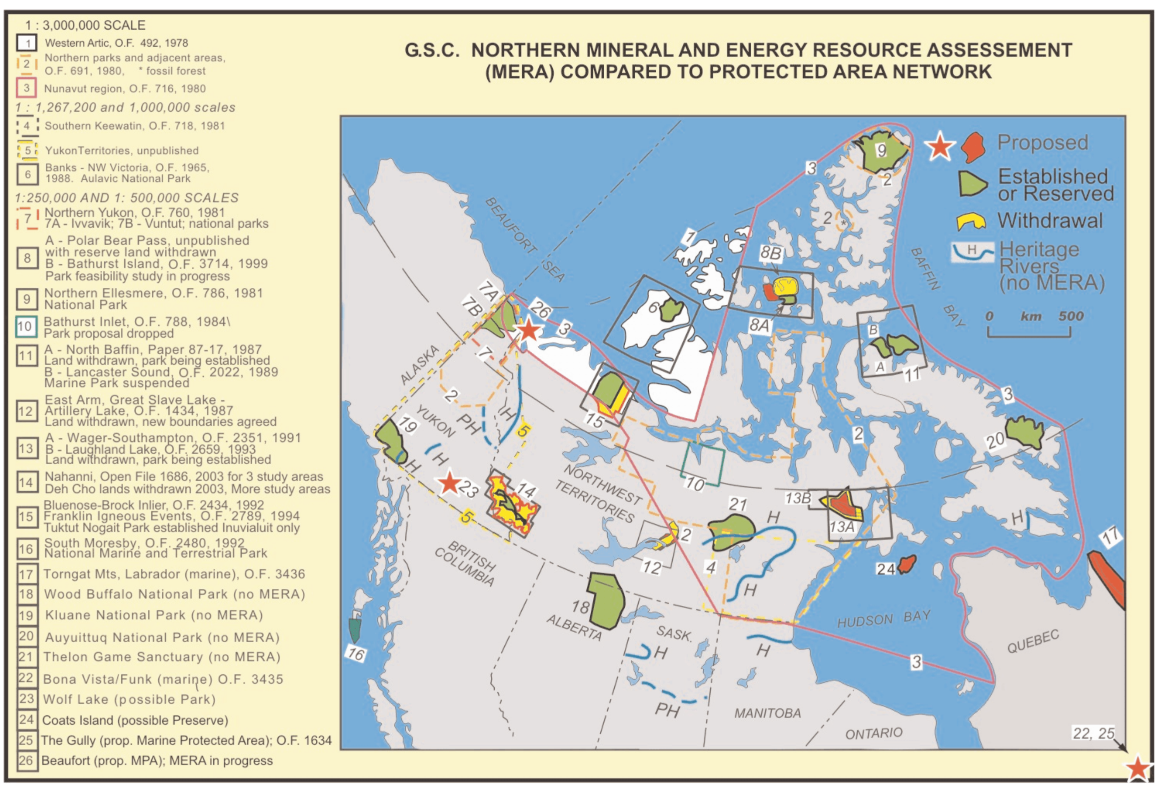


**Figure 1.** Northern mineral and energy resource assessments in Canada, compared to national parks at various stages of establishment, and Canadian Heritage Rivers. (Courtesy of Parks Canada) O.F. = Open File report.

In 1983, microdiamonds had been found in the Mountain diatreme close to the study area, but no diamonds had been discovered north of Yellowknife and gemstones were given little consideration. The MERA study had discovered anomalous amounts of gold near Nahanni Butte and determined that it was significant. The Liard gas play was also being investigated but was not progressing partly due to the lack of support from the Canada Oil and Gas Lands Administration (a now defunct regulatory body), which recognized it as having low potential. The Cantung mine, one of Canada's major tungsten producers, was being shut down due to low tungsten prices.

Presently, the Liard is a strong natural gas play and the area is considered to hold 4% of Canada's potential reserves, with significant revenues and employment benefiting Fort Liard. The gold finds are believed to be placer gold transported from the Canadian Shield along with indicator minerals from the diamondiferous kimberlites north of Yellowknife, which were found after the initial MERA was started in 1983, and are thus no longer significant. Although neither significant kimberlites nor kimberlite indicators were found in the South Nahanni River area, there are now world-class diamond mines north of Yellowknife and there is significant potential for diamonds in the East Arm area of the Great Slave Lake area. Emeralds and other precious stones are now an exciting exploration prospect associated with Cretaceous granites, and Cantung is back in production with secure continental tungsten buyers. Finally, the original pre-MERA park concept was to preserve the South Nahanni River watercourse and no MERA was performed. The next stage was to expand the park into three special areas, thus triggering MERA studies. The present park concept is to preserve the entire South Nahanni River ecosystem, now requiring a new MERA to cover a huge new area. Such elements of change have been experienced in every MERA project conducted by the GSC, and thus every published report includes caveats noting that the assessment is based on the best information available at the time, and that changes in one or more assessments are to be expected.

### 4.3 Tuktut Nogait National Park – An Example of Responding to Changing Information

In the case of the Tuktut Nogait National Park (area 15 in Fig. 1), reviews of the first published MERA report (Jones et al., 1992) were generally positive, and most criticisms could be defended by data presented in the report. However, peers within the GSC together with industry representatives raised questions about the low rating for platinum group elements, nickel, and copper that could not be answered with confidence using data from the Phase II work in the study area. These questions could only be resolved by a regional assessment of the Franklin magmatic province, part of which extends into the Tuktut Nogait area of interest. Fortunately, a partnership involving additional MERA funding, a federal regional development program, and two GSC scientists with specialized expertise in the deposit type and host region was able to address the problem. The ensuing second MERA publication (Jefferson et al., 1994) confirmed the previous assessment of low Ni-Cu-PGE potential with more convincing data in the Tuktut Nogait area. It also pointed explorationists to the focus of the Franklin magmatic event, located on northern Victoria Island, 600 to 800 km northeast of Tuktut Nogait.

GSC Open File 2789 (Jefferson et al., 1994) is unlike all other MERA reports in that it focuses on only one deposit type – Ni-Cu-PGE in ultramafic rocks. Wide-ranging field mapping, systematic regional sampling of the entire sill and dyke complex and its host strata, sophisticated geochemical analyses, and re-processing of a gravity survey over a huge anomaly under Darnley Bay (immediately west of Tuktut Nogait) were some of the work incorporated in this Open File report. At the time it was produced, some might have questioned whether so much effort on one deposit type was valid. However the Ni-Cu-PGE question was raised again later by other explorationists who convinced local communities to protest the park based on high Ni-Cu-PGE potential, leading to special hearings in the Canadian House of Commons and Senate. The high quality of the GSC's geoscience data proved to be crucial in once again allaying these fears of foregone mineral development in the Tutkut Nogait area. At the same time, intense mineral exploration has been stimulated and is ongoing at the apex of the Franklin magmatic province, as encouraged by the same report.

## 5. GEOSCIENCE TOOLS AS PART OF THE MERA PROCESS

Canada's large area and correspondingly large data bases of earth science data make the development and use of effective tools for collecting, managing and analysing the data essential and are an integral part of the data collection and analysis component of the MERA process.

### 5.1 Remote Sensing Technology

Canada's far north is a difficult terrain for carrying out mineral and energy exploration programs due to its ruggedness, cold climate, access problems, short field seasons and the associated high costs. Canada's development and use of remote sensing technologies are proving to be viable and cost effective approaches to geoscience applications, especially in the far north. In particular, Canada's RADARSAT-1 and -2 satellites, the airborne hyperspectral system Imaging Spectrometer Data Analysis System (ISDAS) and applications of Landsat TM data have been applied to bedrock mapping in the north.

### 5.2 Near-Surface Geophysics

Canada has, over several decades, been involved in the development of instrumentation and techniques applying geophysics to near-surface problems. The GSC and provincial agencies have been systematically conducting geophysical surveys of the Canadian landmass that measure magnetic, conductive, resistive, gravity, and radiometric parameters. High-resolution seismic profiling techniques and borehole equipment designs and techniques have proven to be valuable tools for identifying geophysical characteristics of deposit types. For the most part, such technologies have been deemed to be too expensive for MERA projects, although existing data setas may be incorporated.

### 5.3 Geochemistry

Deposit models often include distinctive geochemical signatures that are important for exploration and resource assessment processes. Laboratories at the GSC are equipped with state-of-the-art analytical instrumentation, including leading-edge inductively coupled plasma mass spectrometry, laser ablation and electrothermal vaporization sample introduction for ICP-MS. These techniques can quantitatively determine most elements of the periodic table as well as determine isotope ratios of these elements with absolute limits of detection in the femtogram (10-15 g) range. Sample sizes down to milligrams can be handled.

National surveys of stream and lake sediment geochemistry, which use established methods and specifications for collection, preparation and commercial analysis, provide a systematic database that is nationally standardized. Such cost-effective regional surveys have been incorporated into the GSC's recent MERA projects, as have specialized studies such as spring water geochemistry, where appropriate.

### 5.4 Geographic Information Systems

Geographic Information Systems (GIS) are computer tools designed specifically for digital data capture, input, manipulation, transformation visualization, combination, query, analysis, modeling and output. They have become essential tools for processing the data involved in the MERA process.

### 5.5 Integration Methods

Though the MERA process uses essentially a qualitative conceptual model dependent on a manual process of integrating the geological characteristics of a deposit type to access its potential, there have been recent developments that use more quantitative automated methods implemented in a GIS study. The GSC has been a world leader in the development and application of methods for modeling mineral potential that include both knowledge and data driven techniques (e.g. Bonham-Carter, 1994). These methods have the advantage of reducing bias, measuring uncertainty and coping with the large amount of data involved.

## 6. MANAGING MARINE CONSERVATION AND PROTECTED AREAS

The Canada National Marine Conservation Areas Act, passed in 2002, provides the legislative framework to establish and manage a National Marine Conservation Areas (NMCA) system. Canada's three oceans and fresh water lakes have been divided into 29 distinct marine regions. The long-term goal of the policy is to establish a national marine conservation area within each region. Selecting a NMCA involves consideration of:

- quality of regional representation
- relative importance for maintaining biodiversity
- protecting critical habitats of endangered species
- exceptional natural and cultural features
- existing or planned marine protected areas
- minimizing conflict with resource users
- threats to the sustainability of marine ecosystems
- implications of Aboriginal claims and treaties
- potential for education and enjoyment
- value for ecological research and monitoring

Canada's Oceans Act (1996) provides for the establishment of Marine Protected Areas (MPA) - areas of the sea that can be designated for special protection for one or more of the following reasons:

a) the conservation and protection of commercial and on-commercial fishery resources, including marine mammals, and their habitats;
b) the conservation and protection of endangered or threatened marine species, and their habitats;
c) the conservation and protection of unique habitats;
d) the conservation and protection of marine areas of high biodiversity or biological productivity; and
e) the conservation and protection of any other marine resource or habitat as is necessary to fulfill the mandate of the Minister (of Fisheries and Oceans).

Canada's Oceans Act (1996) also recognizes that the oceans and their resources offer significant opportunities for economic diversification and the generation of wealth for the benefit of all Canadians. Thus the process and steps in identifying and evaluating an area of interest proposed as a MPA involve ecological, technical and socio-economic assessments, including nonrenewable resource assessments. Nonrenewable resource assessments inform on how a MPA might affect human activities and on how the socio-economic benefits can be enhanced or the cons reduced, before proceeding to development of the regulations for managing the MPA.

Federal resource assessments must be carried out where the area of interest is under federal jurisdiction. Resource assessments of marine areas are, and will continue to be a challenge for the GSC, due to low resolution and incomplete data for marine areas and the high cost of collecting new data.

## 7. LIMITATIONS ON RESOURCE ASSESSMENTS

The quality of mineral or energy potential for a given area is based on the current knowledge of mineral deposit models and the availability of geoscience data. Therefore, the resource assessments are a snapshot in time based on existing, incomplete knowledge. An initial assessment of low potential can result in permanently alienating land from exploration and exploitation. Understanding of deposit genesis, new extractive technologies for minerals and metals, availability of data and methods of analysis are constantly changing. Though it cannot be done due to time constraints, ideally, it would be best to re-evaluate each area at regular intervals to reflect these changes. An example within the MERA process where a re-evaluation was conducted to reflect new information on Ni-Cu-PGE deposits is the Tuktut Nogait National Park (area 15 on Fig. 1), which is discussed in the above case histories.

The GSC's geological MERA reports do not assign an economic value to an area. The economic and strategic values are assigned by policy analysts in the Minerals and Metals Sector of NRCan, and other MERA partners (*see* Step 11 of the MERA Administrative Framework, listed near the beginning of this paper). For land use planning purposes, a comparative evaluation must be made based on all types of resources in the area, including park values. Measuring a quantitative value for surface land attributes such as game harvesting, timber or forest products, recreational use or water resources is in some cases more direct and in other cases more intangible than unseen or even unknown mineral or energy resources. For this reason, the economic and strategic values are not published, but communicated among the responsible government agencies and presented to stakeholders informally at public meetings and workshops, so that all can understand the likelihood and uncertainties involved, without publishing estimates that cannot be substantiated.

## 8. CONCLUSIONS

Canada recognizes the importance of setting aside land and marine natural areas to conserve and protect ecosystems and their biodiversity. It has supported this effectively through policies and legislation that have made positive contributions to federal and global conservation goals. At the same time, the exploration for and the exploitation of nonrenewable resources are essential to Canada's social and economic well-being. The Mineral and Energy Resource Assessment (MERA) process helps to ensure that the economic and strategic significance of mineral and energy resource potential are duly considered in the national park establishment process in the Yukon, Northwest Territories and Nunavut.

The MERA process is transparent, has well defined steps and is governed by senior government officials who ensure that technical assessments of mineral and energy resource potential are taken into account in stakeholder consultations and ultimate decisions regarding proposed national parks. Government geoscientists play a critical role by bringing a wide range of geoscience expertise and unbiased information to the decision-making process for. For virtually every national park established in northern Canada since 1983, stakeholders have worked together and compromises have been made to allow various areas of high mineral potential to remain open to nonrenewable resource development.

MERA reports have contributed to decisions on boundaries of protected areas that allow access to areas of high mineral and energy potential, without compromising park conservation aspects. Identification of variations in mineral potential of geological domains that transect national parks has increased exploration activity outside of the parks while confirming lower potential within the final park boundaries. Improved geological knowledge increases confidence that the parks can be established without seriously compromising future nonrenewable resource development.

The MERA process is limited by what we know of mineral and energy deposit models and the availability of data. Government geoscientists play an important role in closing this gap in knowledge as they develop tools and applications in the areas of remote sensing, ground level geophysics, geochemial analysis, field techniques and spatial data integration techniques.

Overall, the MERA process has been an effective tool for sustainable development, by encouraging balance, coordination and partnerships involving Canada's mineral and energy industry, those creating protected areas for environmental objectives, and those representing various stakeholder groups, especially the residents of these lands.

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