MINERAL RESOURCES BRANCH

Guide to Accompany the Geological Resource Atlas of Nova Scotia (Open File Maps ME 2010-1, -2, -3 and -4)

Open File Report ME 2010-2

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Cover photo: Aerial photograph of the East Milford gypsum mine in central Nova Scotia, operated by National Gypsum (Canada) Ltd. The mine reportedly has the largest gypsum production in the world and has been operating continuously since the 1950s.

Acknowledgments: In addition to the authors on the front cover, the entire management and staff of the Mineral Resources Branch provided information and analysis necessary to compile the Geological Resource Atlas. Regional Geologists and Integrated Resource Management staff of the department's Regional Services Branch were also important contributors to the project.

Revision of the Geological Resource Atlas: The atlas and all its components are active documents that will be periodically revised as new data are added to the many databases that constitute the atlas. No document that is part of this atlas should be considered final.

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Introduction

The Geological Services Division (GSD) of the Nova Scotia Department of Natural Resources (DNR) conducted a project from 2007-2010 to develop a Geological Resource Atlas for Nova Scotia as a way to provide geological input for future land-use decisions. The project employed the collective scientific experience, data and knowledge of division staff past and present. The initial phase of the project focused specifically on mineral resource information, resulting in the preparation of a Mineral Resource Potential map product for the entire province. The following report provides context for the information used in preparing this phase of the Geological Resource Atlas. Future plans are to prepare additional data layers, including information on energy, dimension stone and geochemistry, which can be incorporated into the mineral potential model.

Mining has been an important part of the Nova Scotia economy for more than 300 years. A study of the impact of the mining industry on the Nova Scotia economy conducted in 2008 revealed that the industry employed more than 6300 people, mostly in rural parts of the province, with the highest average salaries of any resource-based industry (approximately $1000 per week). Mining contributed approximately $490 million to the Gross Domestic Product (GDP) for the province in 2006, and mineral resource development is considered to be one of the major 'natural capitals' in the current provincial economic growth strategy. Nearly 50% of the employment and GDP contribution from the mining sector is from secondary manufacturing and processing of Nova Scotia's minerals, including the production of cement products, brick, refined salt products and dimension stone (marble, slate, sandstone, granite).

Mineral commodities produced in 2008, in decreasing order of total value of production, include gypsum, crushed stone, salt, coal, sand and gravel, limestone, anhydrite, peat, metals (lead, zinc) and minor amounts of other commodities including clay, barite, silica sand, dimension stone and limestone for cement. Nova Scotia has the potential to produce, and has produced other commodities in the past, including gold, tin, iron, silver, copper, celestite, antimony, arsenic, diatomite, fireclay, fluorite, graphite, magnesium, manganese, molybdenum, oil shale, talc and tungsten.

Unlike forests and other natural resources, mineral resources are mostly hidden and require remote techniques to evaluate their economic significance. The Geological Resource Atlas was designed to use available information to produce a Mineral Resource Potential map that illustrates the current relative potential of the various regions of the province to host economically significant mineral deposits. Like most models, it can be modified at any time by a new discovery or new scientific evidence that indicates a previously unrecognized mineral potential.

There have been several recent developments in Nova Scotia that have prompted the Geological Services Division of Natural Resources to initiate a project to evaluate the mineral resource potential of the province. These include the proclamation of the Environmental Goals and Sustainable Prosperity Act (http://nslegislature.ca/legc/bills/60th_1st/3rd_read/b146.htm) in March 2007 that set a target of 'legal protection' of 12% of the total land mass of the province by 2015. In addition, a bilateral initiative involving major forestry companies and nongovernmental organizations (NGOs) to identify possible lands for consideration for protection was initiated in late

2004. This process, termed the Colin Stewart Forest Forum, will make numerous recommendations to government on areas that should be considered for protection, based on ecology and major forest company values.

The Geological Services Division initiated a project to evaluate the mineral resource potential of the entire province in 2007. This guide is intended to explain the many polygons identified on the maps and how they were derived. Wherever possible, clients are encouraged to contact the Geological Services Division to request assistance in interpreting the mineral potential map products. Interested clients can contact Liaison Geologist Diane Webber by phone at 902-424-3053, or e-mail webberde@gov.ns.ca.

Since the early 1990s, the Mineral Resources Branch has been developing its Geographic Information System (GIS) capacity and it was decided that a GIS-based approach for this project was timely and appropriate. Nova Scotia has one of the best geoscience databases of any global jurisdiction, and arguably the most comprehensive of any jurisdiction in Canada. These data give Nova Scotia an enviable starting point for developing a Geological Resource Atlas. Considerable resources have been dedicated to the digitization of analogue geoscience data, which provided the basis for the preparation of the atlas and the development of associated GIS-based models for resource assessment.

The first step in the production of the atlas was the collection of mineral-related information. For the purpose of the analysis the claim-staking map grid used by the department's Registry of Mineral and Petroleum Titles was used as a base. Each of the 360,562 individual claims was assessed for mineral-related values including: (1) the number of times each claim was staked since map-staking was introduced in 1940; (2) whether the claim was over a mineral lease, special lease, or nonmineral registration or mining permit area; (3) whether the claim contained an exploration drillhole, abandoned mine opening, current or past-producing mine, large pit or large quarry; (4) whether the claim was underlain by the Windsor Group, which is deemed to have high mineral potential based on historic mineral production statistics for gypsum, limestone, shale, salt, base metals and silver; (5) the presence of peat deposits; (6) the presence of an industrial mineral, metallic mineral or coal occurrence; (7) the presence of a mineral 'domain' with demonstrated mineral potential; or (8) suitable bedrock types, or surficial sand and gravel deposits, for aggregate development.

These data were grouped into broad themes and presented in three sets of open file maps: Exploration and Mining Activity, Open File Map ME 2010-1; Mineral Occurrences and Deposits, Open File Map ME 2010-2; and Aggregate Resources, Open File Map ME 2010-3. The Mineral Resource Potential Map, Open File Map ME 2010-4, is a derivative of values applied to the data layers. Each map layer was divided into four overlapping 1:250 000 scale sheets for plotting.

Exploration and Mining Activity - Open File Map ME 2010-1

This series of maps consists of noninterpretative historical records and, therefore, is factual. A brief description of the various components of this layer follows.

Mineral Rights Staking 1940-2009

Nova Scotia was one of the first global jurisdictions to establish a map-based system for staking mineral claims, having changed from traditional land-based claim-staking methods in 1940. Nova Scotia was the first Canadian jurisdiction to initiate map staking, but several other provinces and territories have developed, or are in the process of developing, map-staking procedures. The Registry of Mineral and Petroleum Titles has maintained a complete record of all registered mineral claims from 1940 to the present. This database provided a powerful tool to illustrate historical interest by the mining industry in the various regions of the province. Since this information was collected over the past 69 years, it spans numerous commodity cycles (e.g. gold, silver, base metals, etc.) and exploration 'booms' that resulted from the discovery of major mineral deposits in the province, such as deposits at Moose River (gold), Stirling (base metal), Walton (barite and base metals), Gays River (lead-zinc), East Kemptville (tin) and Chaswood (kaolin). Nova Scotia is the only jurisdiction in Canada with this comprehensive record of historical claim-staking information.

Commencing in 2007, staff of the Geological Services Division and contractors entered the historical claim-staking information, from 1940 to present, into an ArcGIS® geodatabase. These data were used to portray the number of years that each of the approximately 360,000 individual mineral claims (400 m x 400 m) was held under exploration licence. The data were then grouped into six class intervals corresponding to the number of years each claim was staked (i.e. 1-2, 3-5, 6-10, 11-15, 16-34, 35-84).

The intensity of red shading on this layer corresponds to the number of times each mineral claim was staked. In several cases throughout the province, individual claims were held for general claims staking and other mineral rights, such as special exploration licences; thus, the maximum cumulative number of times a claim could have been held was 84.

Mineral Leases, Special Leases, Nonmineral Registrations, Underground Storage and Mining Permits

All active or pending mining operations in Nova Scotia require a mineral lease from the Nova Scotia Department of Natural Resources. A mineral lease allows a mining company the rights to extract minerals from a defined deposit. The area for each mineral lease is established using the mineral claim grid and is designed to allow the company sufficient area to accommodate proposed mining activities. All current mineral leases are plotted on the Exploration and Mining Activity maps. In addition, 'leases' include inactive leases and mining permits and permits for operations where mining activity has ceased, as well as nonmineral registrations (e.g. for operations related to gypsum and limestone extraction).

Current and Past-producing Mines

The location of all current mining operations, including coal, industrial minerals (e.g. gypsum, salt) and metallic minerals, is shown with a crossed hammer symbol on the Exploration and Mining Activity maps. All major crushed stone and sand-gravel aggregate operations with annual production >20 000 t are also indicated with a larger crossed hammer symbol.

The locations of former mining operations (coal, industrial minerals, metallic minerals) with significant mineral production were identified from DNR historical records and are depicted with a crossed hammer symbol within a circle. These include mines such as Walton (barite and base metal), Stirling (base- and precious-metals), Yava (lead-zinc), East Kemptville (tin), coal mining regions (e.g. Springhill, Stellarton, Inverness, Sydney, Glace Bay), gold mining districts (e.g. Goldenville, Waverley, Montague, Tangier, Moose River, Beaver Dam) and gypsum mining regions (e.g. Windsor-Walton area, Little Narrows, River Denys).

Exploration Drilling

Mineral exploration companies routinely use drilling techniques to test the size and grade of mineral deposits, and to evaluate their economic viability. Companies may use either diamond drilling or percussion/reverse-circulation drilling techniques to explore the subsurface. Diamond drilling refers to the use of diamond-impregnated drill bits to extract a continuous cylinder of rock core from bedrock. Percussion and reverse-circulation drilling techniques result in the recovery of small rock chips.

Exploration companies are required to submit a notice of drilling to DNR prior to commencing any drill projects. Drilling activity is monitored by DNR staff. At the time this report was prepared, there are approximately 17,000 diamond-drill and percussion/reverse-circulation holes in the DNR database and an additional 9000 holes from the National Coal database.

Abandoned Mine Openings

Past mining and exploration activities throughout the province have resulted in the excavation of 8478 reported abandoned mine openings (AMO), with most being located in the historical mining districts from the late 1800s and early 1900s. All reported AMO from both DNR and the National Coal database have been plotted on the Exploration and Mining Activity maps.

Closures

Areas that are currently closed to mineral exploration and development are indicated by dark and light green outlines with diagonal lines (federal and provincial, respectively). A complete list and description of the closure areas are beyond the scope of this report, but the areas include wilderness areas, protected beaches, Indian reserves, federal parks, national historic parks, special places and mineral closure areas.

Ecodistricts

To facilitate the decision-making process, a comprehensive land classification scheme, based on ecological and physiographic features, has been established for the province. This ecological land classification (ELC) has divided the province, at a scale of 1:250 000, into 39 ecodistricts based on distinctive assemblages of relief, geology, landform, soils and vegetation (Neily *et al*., 2003).

Many land-use decisions, including the establishment of a protected areas network, are somewhat predicated on the need to have representation of protected areas within each of the 39 ecodistricts throughout the province. In light of the importance of this, the boundaries for all ecodistricts have been plotted on the Exploration and Mining Activity map layer.

Series 2: Mineral Occurrences and Deposits - Open File Map ME 2010-2

The mineral exploration and development activities outlined in Open File Map ME 2010-1 have resulted in the discovery of numerous economic mineral deposits that were mined in the past or are currently being mined, and many mineral occurrences with varying mineral potential. The Mineral Occurrences and Deposits maps contain information on current and past-producing mines, mineral occurrences, mineral domains and rock units with high mineral potential.

Mineral Occurrences

The Mineral Resources Branch of DNR maintains an inventory of the mineral occurrences in the province. This Mineral Occurrence Database is a computer-based inventory of metallic and industrial mineral occurrences (http://www.gov.ns.ca/natr/meb/download/dp002.asp). A mineral occurrence is defined as any location where there is a naturally occurring concentration of a mineral(s), rock or surficial material above the norm, such that it may be of interest. The department includes any locations that are deemed of interest to the mineral exploration industry or other client groups, including geotechnical professionals, national coal database, mineral and rock collectors, naturalists, the construction industry and the general public.

As of July 1, 2009, the Mineral Occurrence Database contained information for 2911 metallic and industrial mineral occurrences, and an additional 860 from the National Coal Database, but it should be stressed that these numbers do not represent all of the known mineral occurrences in the province. The databases are continually being revised with the addition of new mineral occurrence entries, as well as information that is added to existing entries.

For the purpose of the Mineral Occurrence Database, mineral occurrences include:
(1) mineral occurrences *sensu stricto* (i.e. ranging from small concentrations of a mineral up to well-defined and mineable mineral deposits);

(2) locations of a seemingly noneconomic mineral commodity that may be an indication of the presence of another commodity of economic interest (e.g. a location of well developed clay alteration features suggesting the nearby presence of other commodities of greater economic value);
(3) subsurface mineral enrichment intersected by diamond drilling; and
(4) occurrences of mineralized boulders, glacial till, soil or other surficial material with mineral enrichment.

Mineral Domains

Mineral domains on the Mineral Occurrences and Deposits maps were proposed, reviewed and ultimately refined on the basis of published data and expertise by geoscientists in the Geological Services Division during 2008 and 2009. Mineral domains are based on the physical and chemical features of mineral deposits and occurrences, and on the composition, structure and geological history of the host rocks. Mineral domains are somewhat subjective and represent geological, mineralogical and metallogenic interpretations based on the cumulative knowledge and scientific input of past and current staff.

Seventeen (17) mineral domains are presented on the Mineral Occurrences and Deposits maps. Mineral domains can be grouped into three main categories:
(1) those that are host to current or past-producing mines, may have associated mineral occurrences, and are considered to have high mineral potential;
(2) those with no history of mining, but that have significant mineral occurrences or deposits and are considered to have moderate to high mineral potential; and
(3) those with multiple mineral occurrences with similar geological characteristics that are considered to have only low to moderate mineral potential, at least at current global commodity prices.
The 17 mineral domains have been plotted individually (though more than one may be shown on each figure) and included as Figures 1-14 in Appendix 1 in this guide for the user to view more easily.

Windsor Group

No other sequence of rocks has contributed more, on a consistent basis, to the economy of Nova Scotia than the Lower Carboniferous (340-320 Ma) Windsor Group. This series of marine limestone, dolostone, gypsum, anhydrite, salt, potash and siltstone hosts numerous industrial mineral, energy, base metal and precious metal resources. In 2010 there were 20 mining operations in Nova Scotia, of which 14 were producing gypsum, salt and limestone from the Windsor Group (Nova Scotia Department of Natural Resources, 2010). As a result, areas underlain by Windsor Group rocks are denoted on the Mineral Occurrences and Deposits maps with a solid blue colour.

Early Cretaceous Unit (Includes Kaolin and Silica Sand)

Early Cretaceous sedimentary deposits are known to occur in small areas throughout mainland Nova Scotia and Cape Breton Island, most notably in the Shubenacadie-Musquodoboit Valley region. These deposits include mottled red and white kaolinitic clay ('kaolin'), grey to very light grey, massive kaolin, light grey to coloured kaolinitic silica sand, and black, organic-rich kaolinitic clay containing lignite to subbituminous grade wood fragments (Stea *et al*., 1996). Silica sand has been mined for several decades from an Early Cretaceous deposit in the Hardwood Lands area west of Shubenacadie.

Geoscience research focusing on the Early Cretaceous sediments in the Musquodoboit Valley by DNR geoscientists in the mid-1990s revealed extensive kaolin and silica sand deposits (Stea *et al*., 1996). Massive kaolin beds were noted to be up to 15 m in thickness and overall thickness of some Cretaceous deposits was in excess of 200 m. Analytical work revealed the kaolin deposits were suitable for many industrial filler applications, including use in the manufacture of coaters, fillers, ceramics and geotechnical liners and sealers. Following this work there was considerable mineral exploration by private-sector companies, which resulted in the discovery of a thick (>200 m) interbedded sequence of silica sand and kaolin in the Sibley Road area near Chaswood, Halifax County.

Early Cretaceous sedimentary deposits throughout the mainland and Cape Breton Island are considered to have very high mineral potential for the discovery of additional economic deposits of kaolin and silica sand.

Peat Resources

In the 1980s the Nova Scotia Department of Mines and Energy conducted a province-wide peat inventory project (Anderson and Broughm, 1988). Peat is not classified as a mineral under the Mineral Resources Act, so this resource is owned by the landowner.

Peat deposits are identified and outlined on the Mineral Occurrences and Deposits maps. Moss grade peat has been produced from at least one operation, and sometimes as many as three operations, in central and southern Nova Scotia over the past few decades.

Anderson and Broughm (1988) identified 30 deposits with good potential for commercial moss peat development, and noted that there are numerous other deposits that had not been inventoried. They concluded that there were more than 8000 ha of harvestable moss-grade peat containing approximately 137 M m^3 of peat moss.

Aggregate Resources - Open File Map ME 2010-3

Nova Scotia is fortunate to have ample supplies of aggregate materials that are suitable for a wide range of domestic construction applications, and for export. Annual domestic production of aggregate in Nova Scotia is approximately 7.5 million tonnes (Mt), including approximately 5 Mt of crushed stone and 2.5 Mt of sand and gravel. Approximately 4 Mt of crushed granite

are produced for export at the Aulds Cove Quarry, owned and operated by Martin Marietta Materials Canada Ltd. This operation is the 5th largest crushed stone quarry in Canada and ships its material along the eastern seaboard of the United States, the Gulf Coast and to several Caribbean countries.

Aggregate resources are grouped into two basic types: (1) bedrock aggregate, and (2) surficial aggregate.

Bedrock Aggregate

There are numerous rock units throughout Nova Scotia that have suitable physical and chemical attributes befitting their use as crushed stone for construction aggregate purposes. These bedrock units have been grouped together into broad rock types and are identified on the Aggregate Resources maps of the Geological Resource Atlas. The major rock categories include granitic rocks, basalt ('traprock'), greywacke, high-grade metamorphic rocks and sandstone. Brief descriptions and pertinent facts for each rock type are given in following sections.

Granitic Rocks

Granites in southern Nova Scotia have wide-ranging textures and grain sizes, with some units containing individual feldspar crystals up to 10 cm in length. As a general rule, coarse-grained granitic rock units have only moderate potential for use as aggregate, due mostly to the presence of microfractures within large crystals. Conversely, fine-grained granites have much less microfracturing and have good potential for crushed stone aggregate applications. Accordingly, these granites meet most of the stringent aggregate requirements, both in Nova Scotia and in many other Canadian, US and Caribbean jurisdictions.

Granitic rock units in northern Nova Scotia are mostly fine- to medium-grained and lack the very coarse-grained feldspar crystals of many southern granites. In general, the granitic units in northern Nova Scotia and Cape Breton Island have physical and chemical characteristics that yield moderate to good potential for aggregate use, as indicated on the Aggregate Resources maps.

Basalt and Mixed Volcanic Rocks

There are several regions of the province that are underlain by basalt or other mixed volcanic rocks. The largest deposits of basalt are found along the Bay of Fundy, including the North Mountain from Brier Island to Cape Split, and at Five Islands and Cape d'Or. Areas underlain by mixed volcanic rocks are situated in the Cobequid and Antigonish highlands in the northern mainland, and in Cape Breton Island in several of the highland areas and the Gabarus-Forchu area.

The characteristics important in the assessment process for high-quality volcanic aggregate include: (1) the presence of thick volcanic units and, within these units, an absence of less durable sedimentary interbeds, (2) the absence of metamorphic fabrics (foliation) that impart

weakness to the rock, and (3) a minimum of soft alteration minerals (e.g. chlorite) that would make the aggregate susceptible to weathering and other mechanical stresses.

Mixed volcanic rocks in the northern part of the province tend to be highly variable in both composition and physical characteristics, so any location would need to be evaluated individually to assess its potential for aggregate applications.

Greywacke

Large areas of southern and eastern mainland Nova Scotia, extending from Yarmouth to Canso, are underlain by greywacke of the Goldenville Group. Greywacke is generally a dark grey or greenish, firmly indurated, metamorphosed sandstone that consists of poorly sorted, angular to subangular quartz and feldspar grains embedded in a compact clay matrix. Greywacke has been used extensively throughout southeastern parts of the province, including the Halifax Regional Municipality where annual production for domestic use exceeds 3 Mt. All three of the currently operating greywacke quarries in the Halifax-Dartmouth-Bedford-Sackville area are experiencing urban encroachment issues and alternate sources for aggregate may soon be required.

The chemical characteristics of greywacke present problems when it is used in the production of concrete. Specifically, quartz minerals are broken down in the highly alkaline environment present during the concrete-making process, such that gels form and expand, causing cracking and a reduction in the strength and competency of the concrete. This process, termed alkali reactivity, can be mitigated by certain additives in concrete, although the susceptibility of Goldenville Group greywacke to alkali reactivity makes it difficult to market this rock type in many export aggregate markets.

High-grade Metamorphic Rocks

High-grade metamorphic rocks are located in highland areas of the northern mainland and Cape Breton Island. These areas contain a wide range of rock types, including gneiss, schist, quartzite and marble. With the exception of schist, all of the aforementioned rock types have potential for use as aggregate. A metamorphic fabric in the schist imparts a plane of weakness that reduces stone durability and makes it susceptible to water entry and weathering associated with freeze-thaw cycles.

Several large deposits of marble, collectively referred to as carbonate deposits, are situated in highland areas of Cape Breton Island. The largest carbonate deposits are at Glencoe and Kewstoke, near Whycocomagh, where deposits in excess of 500 Mt have been delineated by previous advanced mineral exploration activities. In addition, several large areas of limestone and dolomite are known in the North Mountain, Glendale and central Cape Breton Highlands areas of Cape Breton Island. These carbonate deposits also have potential for use in production of cement, lime and high-cost mineral fillers for industrial applications.

Sandstone

Deposits of sandstone are distributed throughout the lowland areas of northern Nova Scotia and Cape Breton Island, often associated with coal deposits. In general, these unmetamorphosed sandstone deposits are soft and poorly indurated, thus not well suited for aggregate use. There are areas of sandstone within several highland areas, however, that have some potential as an aggregate source because of good stone durability. These areas are outlined on the Aggregate Resources maps. Specific areas of interest would be the thick units of sandstone that contain minimal interbeds of less competent shale.

Surficial Aggregate Materials

An important component of the aggregate resource is the sand and gravel deposits that are found throughout Nova Scotia. Most of the province is blanketed by unconsolidated surficial materials that cover more than 90% of the underlying bedrock. Prime (1992) presented an overview of the origin, composition and aggregate potential of surficial deposits in Cumberland and Colchester counties and interested readers are referred to this report.

During warming periods when the large ice sheets were receding from the province about 12,000 years ago, large volumes of water were generated and these often resulted in the deposition of well-sorted deposits of sand and gravel. These deposits include glaciomarine deposits, which as the name implies were deposited in ocean waters, as well as glaciofluvial deposits such as outwash fans, deltas, valley train deposits, kame fields and esker systems. Large areas of these glaciofluvial deposits (undivided) are denoted with a dot pattern on the Aggregate Resources maps.

Glaciomarine deposits consist of sand and gravel produced in a marine environment during, or immediately following, the melting of ice sheets. Glaciomarine deposits include: (1) deltaic deposits that were deposited where water and sediment from melting ice sheets met standing water bodies, such as a marine basin; and (2) raised beach deposits, which are now situated above current sea level, contain evidence of marine deposition (such as shells), but were formed along former coastlines during periods of elevated sea level.

Outwash fans, deltas, and valley train deposits comprise flat-lying gravel landforms that were deposited at the front of glaciers, where melt-water streams came in contact with lowland areas. Kames are individual mounds or hummocky terrain deposited in meltwater channels that were formed in depressions in former ice sheets. Eskers are long sinuous ridges of sand and gravel that were deposited by meltwaters in tunnels or crevasses at the base of stationary or retreating ice sheets. Eskers may form as individual ridges or as a series of linear ridges or hills.

Kames and outwash plains have varying degrees of value as sources for sand and gravel. Characteristics such as composition of the rock materials, the degree of sorting, grain size distribution of the deposits and their proximity to the market determine their importance to the aggregate industry. These deposits are denoted with individual symbols on the Aggregate Resources maps.

Potential Crushed Stone Aggregate for Export Markets

Nova Scotia's strategic location near United States and Caribbean markets for crushed stone aggregate is advantageous. This is demonstrated by the continued success of the Martin Marietta Materials Canada Ltd. granite quarry at Aulds Cove. Transportation of crushed stone aggregate by ship is, by far, the most efficient and cheapest method of transport and the only option available for many areas that do not have access to local supplies of stone.

Coastal areas of the province that are underlain by bedrock units with moderate potential for aggregate export are shown in blue, and areas with high potential are indicated with a red outline. A maximum distance of 5 km from the coastline was chosen because there are several global examples of aggregate export operations that are located within this distance to port facilities.

The controlling factors for the viability of any bedrock unit as a source of aggregate are: (1) chemical and physical characteristics of the rock, (2) proximity of the deposit(s) to shoreline, (3) deep-water port facilities or potential to develop them, (4) protected anchorage (from storm events), and (5) remote location.

Mineral Resource Potential - Open File Map ME 2010-4

Perhaps the most significant challenge in assembling a Geological Resource Atlas is the evaluation and weighting of the importance of the various data layers, and ultimately the generation of a Mineral Resource Potential map for the province. Recent advances in Geographic Information System (GIS) technologies provide powerful computer-based tools to approach this challenge. After considerable research and discussion of various options, it was decided that a Mineral Resource Potential map would be generated using the mineral claim grid as a base. Staff of the GIS section of the Geological Services Division developed an ArcGIS® model to process and evaluate the data layers outlined in this report. The following section describes the salient aspects of the ArcGIS® model and presents the scoring methodology (Table 1).

Exploration and Mining Activity - Open File Map ME 2010-1

Claim-staking Data

The number of years that each of the approximately 360,000 claims in the province were held under exploration licence between 1940 and 2009 were determined and entered into a database. The entire data set was statistically evaluated and divided into 10 percentile groups. A number from 1-10 was then assigned to each claim based on its percentile score.

Mineral Leases, Special Leases, Nonmineral Registrations and Mining Permits

Areas around existing and historical mines are considered to have excellent potential for discovering additional economic mineral deposits. Lease areas under the Mineral Resources Act

Table 1. Summary of the scoring methodology used to generate the Mineral Resource Potential maps.

Mineral Value	Explanation	Area of Influence*	Score or Range of Scores**	Source***
Exploration and Mining Activity - Open File Map ME 2010-1				
Claim-staking Data	Number of years claims have been held under exploration licence since 1940. Results were divided into 10 percentile groups and assigned a score of 1 to 10 based on number of years held.	Each claim measures 400 m x 400 m (N = 360,000 for province)	1-10	8,10
Mineral Leases, Special Leases, Nonmineral Registrations, Mining Permits	All active and pending mining operations	Specific area of lease, registration or permit	3	8,10
Current and Past-producing Mines	All current and past-producing mines (coal, industrial minerals, base- and precious-metals)	1 km radius from mine location	3	17
Exploration Drilling	Represents advanced exploration activity. Presence of one or more drillholes on claim (from 26,000 drillholes for the province)	100 m radius from drillhole(s)	1	6, 12
Abandoned Mine Openings (AMO)	Represents activities, including advanced exploration and small-scale extraction from 1800s and early 1900s. Presence of one or more AMO on claim (from of 8478 AMO for the province)	100 m radius from AMO	1	7, 12

Table 1. (continued)

Mineral Value	Explanation	Area of Influence*	Score or Range of Scores**	Source***
Mineral Occurrences and Deposits - Open File Map ME 2010-2				
Mineral Occurrences	Presence of one or more mineral occurrences on mineral claim. Information from DNR and National Coal databases with 3771 mineral occurrences	100 m radius from mineral occurrence	1	12, 24
Mineral Domains	Areas having mineral deposits and occurrences with similar physical and geochemical features, and host rocks with similar composition, structure and geological history (domains include coal, industrial minerals, and base- and precious-metal commodities)	Domain areas divided into 3 groupings: High (score = 3) - contain current or significant past-producing mines; Medium (score = 2) - no mines, but moderate to high mineral potential; Low (score = 1) - multiple mineral occurrences with low to moderate mineral potential	1-3	15, 20, staff
High-potential Rock Units (potential for several commodities)	Two rock units have long mining history, and moderate to very high potential for future economic mineral development. They are: Carboniferous Windsor Group (salt, gypsum, anhydrite, base metals, celestite, barite), and Cretaceous Chaswood Formation (silica sand and kaolin clay)	Areas underlain by high potential rock units (Windsor Group and Chaswood Formation)	3	15, 20, 42-46
Peat Resources	Approximately 160 000 ha of peat resources throughout the province, with highest density in southwestern Nova Scotia (information from Anderson and Broughm, 1988)	Areas underlain by peatland resources	1	1, 11

Table 1. (continued)

Mineral Value	Explanation	Area of Influence*	Score or Range of Scores**	Source***
Aggregate Resources - Open File Map ME 2010-3				
Bedrock Aggregate Materials	Suitable bedrock units for use as crushed stone aggregate for many uses, including residential and commercial construction, road-building and export. Rock units include: granite, basalt and mixed volcanic rocks, greywacke (clay-rich sandstone), high-grade metamorphic rocks and some sedimentary units (mostly sandstone)	Areas underlain by suitable rock units for domestic consumption. Units divided into Low (score = 1) and High potential (score = 3); Areas near coastline with deep water and protected harbour that are underlain by suitable rock units for export markets. Units divided into Low (score = 1) and High potential (score = 5)	Domestic (1, 3) Export (1, 5)	15, 20, staff
Surficial Aggregate Materials	Areas with surficial deposits of sand and gravel, mostly interpreted as well-sorted deposits from late-glacial period meltwater processes (e.g. kames, eskers, etc.)	Areas underlain by sand and gravel deposits	1	5, 9, 13, 14, 18, 25-38, 42, 47-49
Active or Past-producing pit or quarry	Claims containing an active or past-producing pit or quarry	Mineral claims with an active or former pit or quarry	1	9, 13, 14, 18, 25-38, 40 47-49
Large aggregate operations	Areas with an active, major aggregate producer	1 km radius from location	3	16

* Point data for mineral values have been assigned an area of influence to allow values to be assigned to adjoining claims when individual point data, such as drillholes, are located near claim boundaries (see text for further discussion).
** Scores assigned using ArcGIS® data model developed in GIS Section of the Geological Services Division (see text for description).
******* See numbered sources in Selected Bibliography, p. 18-22.

often exceed the immediate area of the proposed mining operation and may encompass up to several square kilometres. All lease areas were, therefore, given a score of 3 in the ArcGIS® model. 'Lease' areas, which include active leases, inactive leases and permits, nonmineral registrations (e.g. gypsum and limestone), active special licences for geothermal energy and underground hydrocarbon storage licences, were given a score of 3 in the ArcGIS® model.

Current and Past-producing Mines

Current and past-producing mine sites represent areas with very high mineral potential. There are many examples in most global mining districts where additional economic mineral deposits have been discovered very close to former mine sites. Accordingly, all mineral claims containing current and former mine sites, with a 1 km buffer, were assigned a score of 3 in the ArcGIS® model.

Exploration Drilling

Exploration drilling represents a significant commitment by mineral exploration companies. Depending on the characteristics of the mineral target, companies may have drilled numerous holes over very limited areas. To accommodate for the importance of drillholes on adjoining mineral claims, each drillhole was assigned a 'buffer zone' with a 100 m radius from the hole location. Buffers were assigned to all of the 26,000 records in the drillholes databases to allow for individual holes to yield a score in adjoining mineral claims, where appropriate. Any mineral claim with one or more drillholes was given a score of 1 in the ArcGIS® data model.

Abandoned Mine Openings

The density of abandoned mine openings (AMO) in any given area is a reflection of the exploration and mining activities in that area, but does not necessarily reflect the mineral potential. Accordingly, a similar approach was adopted as noted above for drillholes, with each of the 8478 AMO receiving a buffer with a 100 m radius, and any mineral claim encompassing one or more AMO was given score of 1 in the ArcGIS® data model.

Mineral Occurrences and Deposits - Open File Map ME 2010-2

Mineral Occurrences

Each of the 2911 metallic and industrial mineral occurrences and 860 coal occurrences were provided with a 100 m buffer. Regardless of the number of occurrences reported within an individual claim the maximum score was 1.

Mineral Domains

As noted previously, all mineral domains in the province have been assigned to one of three categories:
(1) those that are host to current or past-producing mines, may have associated mineral occurrences, and are considered to have high mineral potential - these were given a score of 3 in

the ArcGIS® model;
(2) those with no history of mining, but with significant mineral occurrences or deposits and are considered to have moderate to high mineral potential - these were given a score of 2 in the ArcGIS® model; and
(3) those with multiple mineral occurrences with similar geological characteristics that are considered to have only low to moderate mineral potential, at least at current global commodity prices - these were given a score of 1 in the ArcGIS® model.

High-potential Rock Units

Mineral claims that are underlain by rocks of the Windsor Group are considered to have very high mineral potential as noted above. These claims were assigned a score of 3 in the ArcGIS® model. Mineral claims that are underlain by Early Cretaceous kaolin- and silica sand-bearing strata were given a score of 3 in the ArcGIS® model.

Peat Resources

Mineral claims that are underlain by peat deposits were assigned a score of 1 in the ArcGIS® model.

Aggregate Resources - Open File Map ME 2010-3

Bedrock Aggregate Materials

Areas of the province with moderate and high potential for domestic aggregate production were outlined on the Aggregate Resources maps and described in the previous section of this report. Mineral claims overlying areas with low to moderate bedrock aggregate potential for domestic markets were given a score of 1, and areas with high potential for domestic markets were assigned a score of 3 in the ArcGIS® model.

Areas within 3 km of the coastline (export markets) that are underlain by rocks with moderate crushed stone aggregate potential were assigned a score of 1, and areas underlain by rocks with high potential were given a score of 5 in the ArcGIS® model.

Surficial Aggregate Materials

Mineral claims overlying areas with glaciomarine or glaciofluvial deposits, including eskers, kames, outwash plains and deltas, with good potential for use as sand and gravel aggregate for domestic markets, were given a score of 1 in the ArcGIS® model. Mineral claims with identified surficial deposits including eskers (with 100 m buffer), kames, and undivided glaciofluvial and glaciomarine deposits were given a score of 1 in the ArcGIS® model.

Active or Past-producing Pit or Quarry

All mineral claims containing an active or past-producing pit or quarry were given a 100 m buffer and assigned a score of 1 in the ArcGIS® model.

Large Aggregate Operations

All areas with an active major aggregate producer were given a 1 km radius from the quarry and assigned a score of 3 in the ArcGIS® model.

Results

More than 400,000 mineral claims in the province were evaluated using the aforementioned ArcGIS® model and assigned cumulative scores for each mineral value. All of the resulting scores were then statistically analyzed and divided into 10 equal percentile groups, representing lowest to highest mineral resource potential, and plotted on the Mineral Resource Potential maps.

An evaluation of the Mineral Resource Potential maps reveals a broad range of mineral potential. Moderate to high mineral potential areas mostly cluster where past mining activities occurred, for example the gold districts, near Walton (barite and base metals), over historical coal mining areas, over Windsor Group rocks, and over the southwestern Nova Scotia tin domain, to name a few. In fact, all of the historical mining districts are shown as having moderate to high mineral potential, which represents an independent corroboration of the ArcGIS® model that was employed in this analysis.

Some areas with strategic mineral occurrences may only have a moderate score, but may have a strategic importance. An example of a strategic mineral resource is the Lake Enon celestite (a strontium-bearing sulphate mineral) deposit near Loch Lomond, Cape Breton Island, which represents the largest deposit of celestite in North America, with reported reserves of approximately 1 Mt of $SrSO_4$. Celestite was mined from this area in the 1970s, but no mining has taken place since then. The area around the deposit has moderate to high mineral potential (i.e. scores 7-10). There are numerous other areas in the province with mineral potential values similar to the Enon area that do not contain known mineral deposits, such as parts of the granites of southern Nova Scotia that are prospects for several mineral commodities (e.g. tin, tungsten) and have received considerable past exploration work. The Enon area might be considered to be more strategic in terms of future mineral development than other areas of the province with similar mineral potential scores.

Recommendations

The Geological Resource Atlas, including the 1:250 000 scale Mineral Resource Potential maps, provides an exhaustive science-based estimate of the mineral potential for the entire province. This evaluation provides a sound starting point for future discussions of land-use in Nova Scotia. It is strongly recommended, in light of the complexity of the background geological information, that users of the Geological Resource Atlas consult with staff of the Geological Services Division prior to making any land-use decisions based on the mineral resource potential scores.

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Appendix 1. Mineral Domains in Nova Scotia

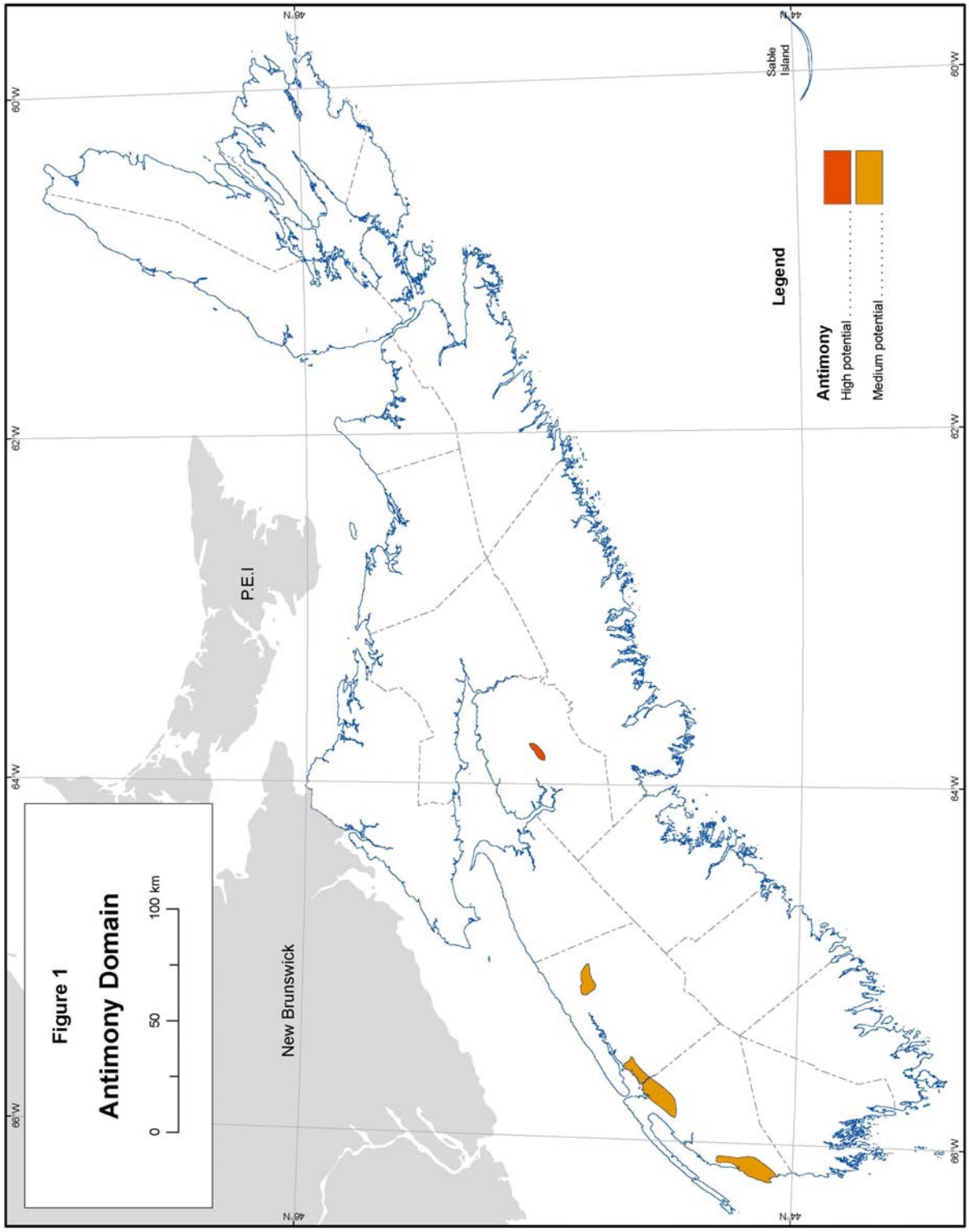


Figure 1
Antimony Domain
0
50
100 km
New Brunswick
P.E.I
Sable Island
Legend
Antimony
High potential
Medium potential
66°W
64°W
62°W
60°W
46°N
44°N

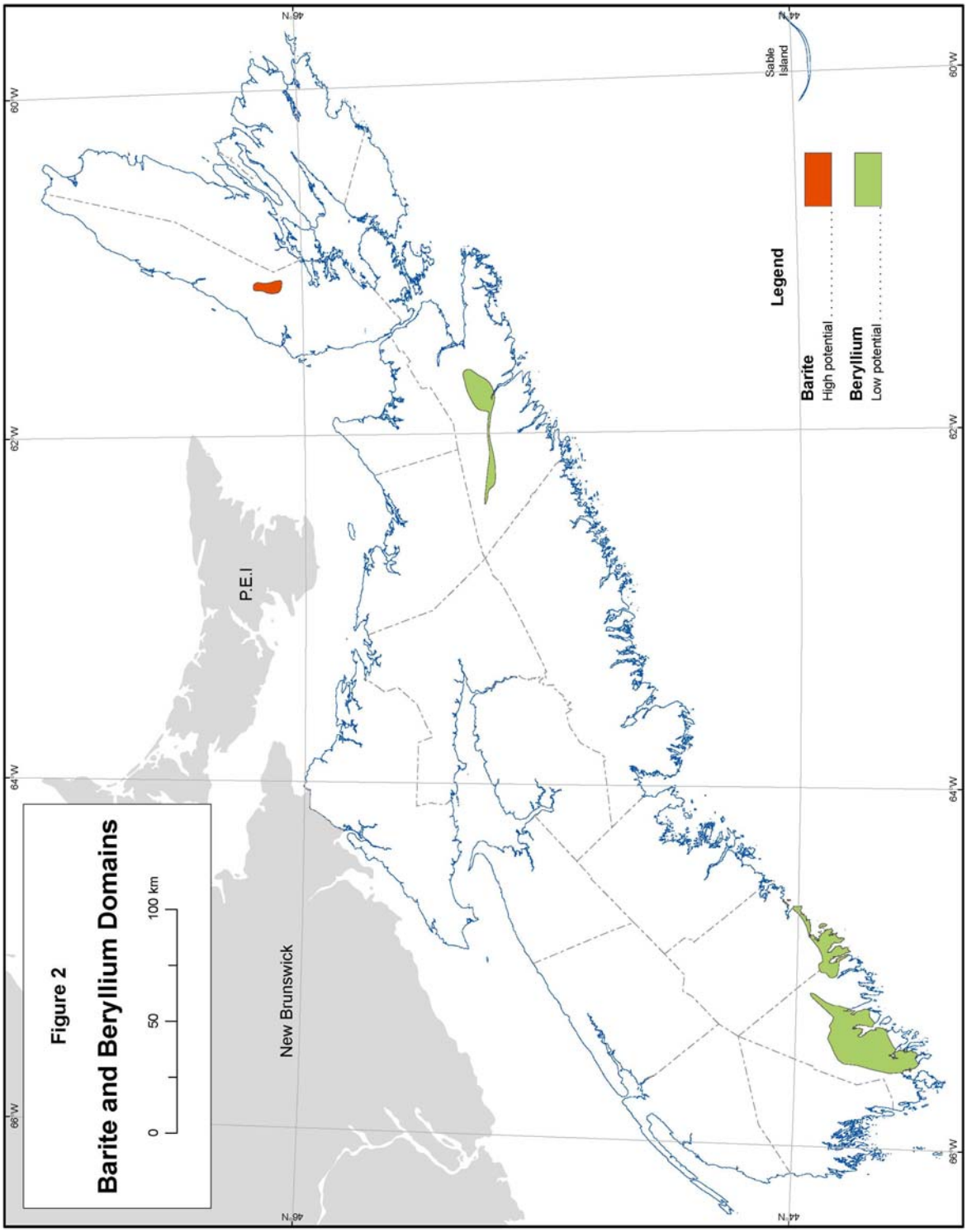
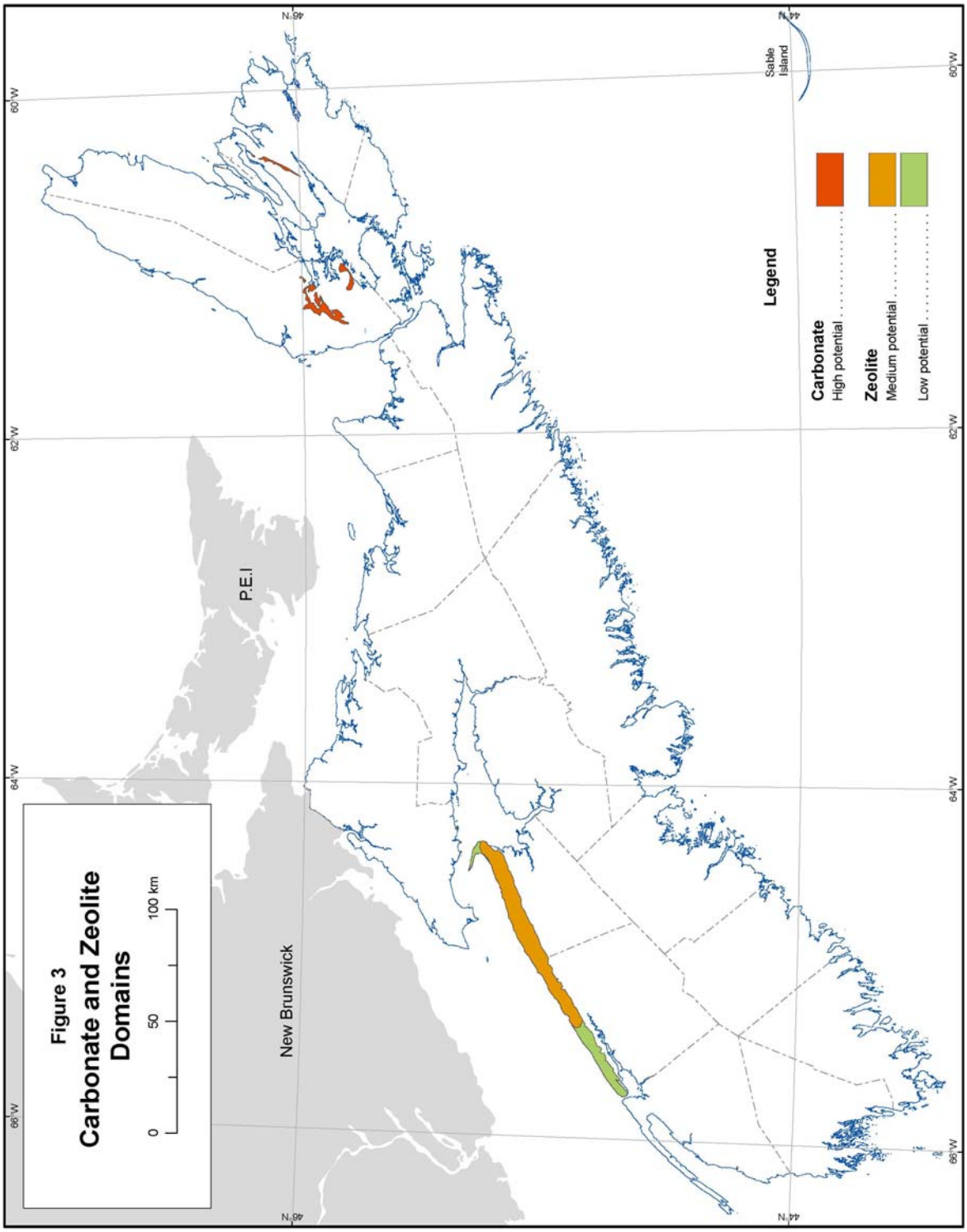


Figure 2
Barite and Beryllium Domains
0
50
100 km
New Brunswick
P.E.I
Sable Island
Legend
Barite
High potential
Beryllium
Low potential
66°W
64°W
62°W
60°W
46°N
44°N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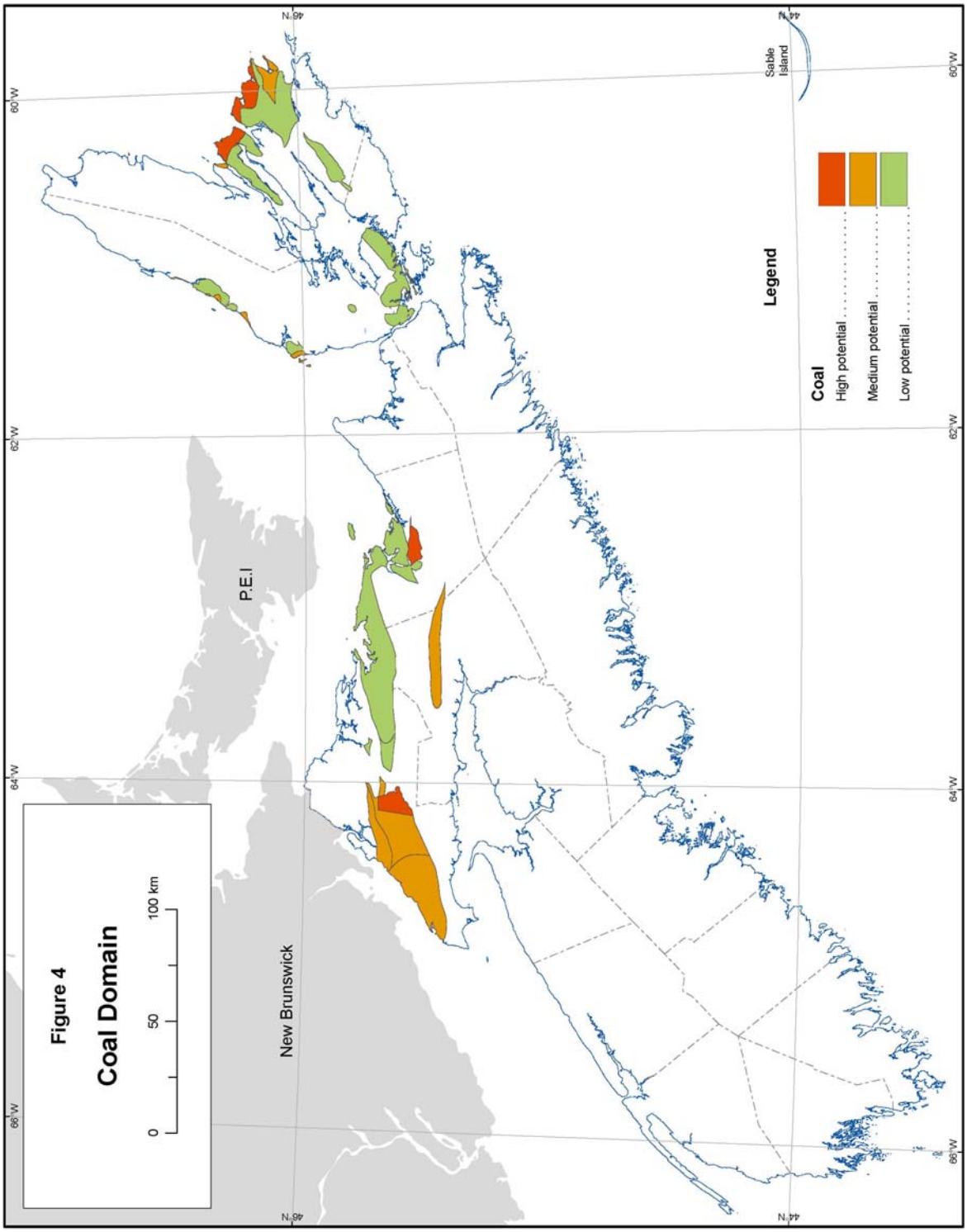
Carbonate and Zeolite Domains
0
50
100 km
New Brunswick
P.E.I
Sable Island
Legend
Carbonate
High potential
Zeolite
Medium potential
Low potential
66°W
64°W
62°W
60°W
46°N
44°N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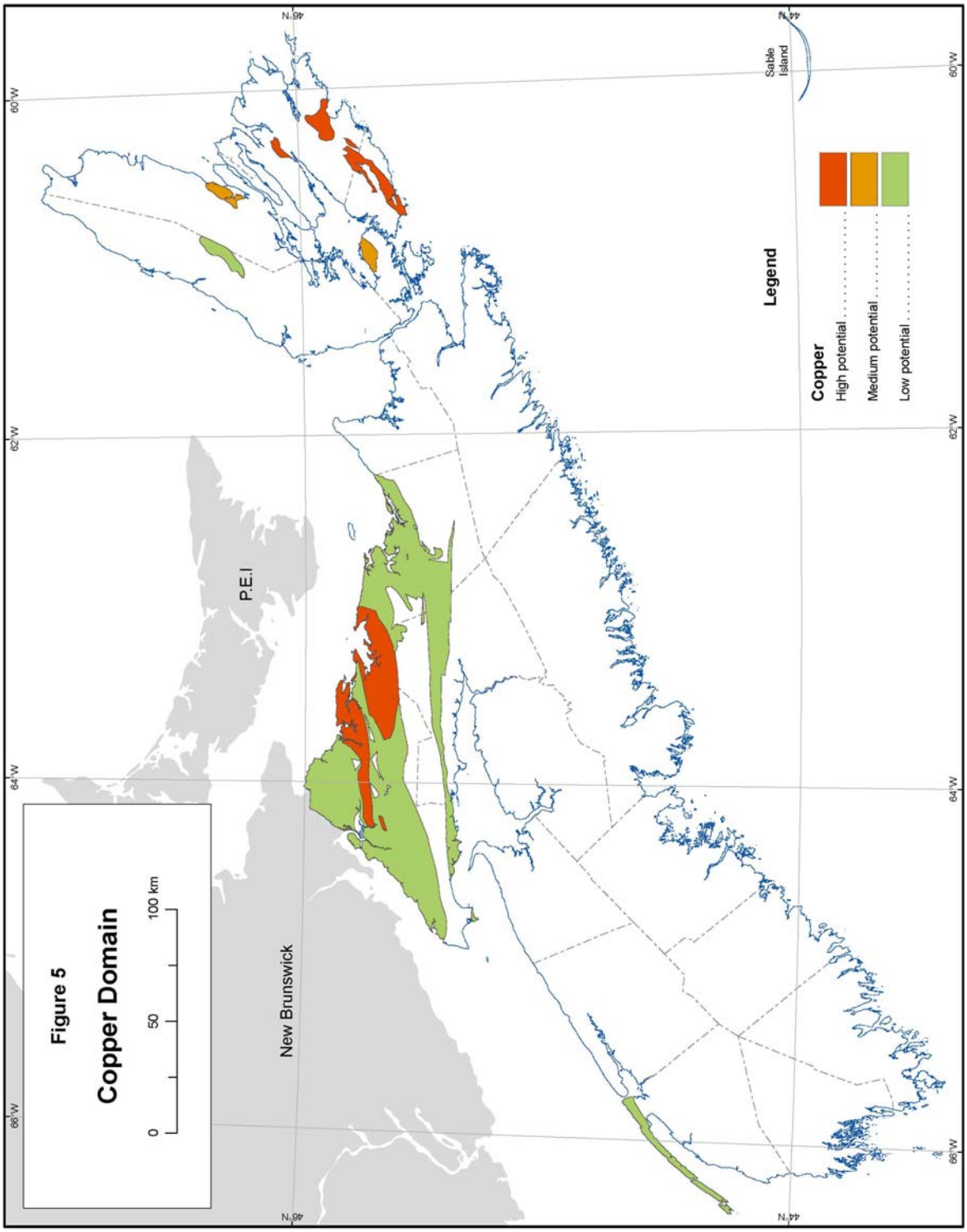
Coal Domain
0
50
100 km
New Brunswick
P.E.I
Sable Island
Legend
Coal
High potential
Medium potential
Low potential
66°W
64°W
62°W
60°W
46°N
44°N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Copper Domain
0
50
100 km
New Brunswick
P.E.I
Sable Island
Legend
Copper
High potential
Medium potential
Low potential
66°W
64°W
62°W
60°W
46°N
44°N

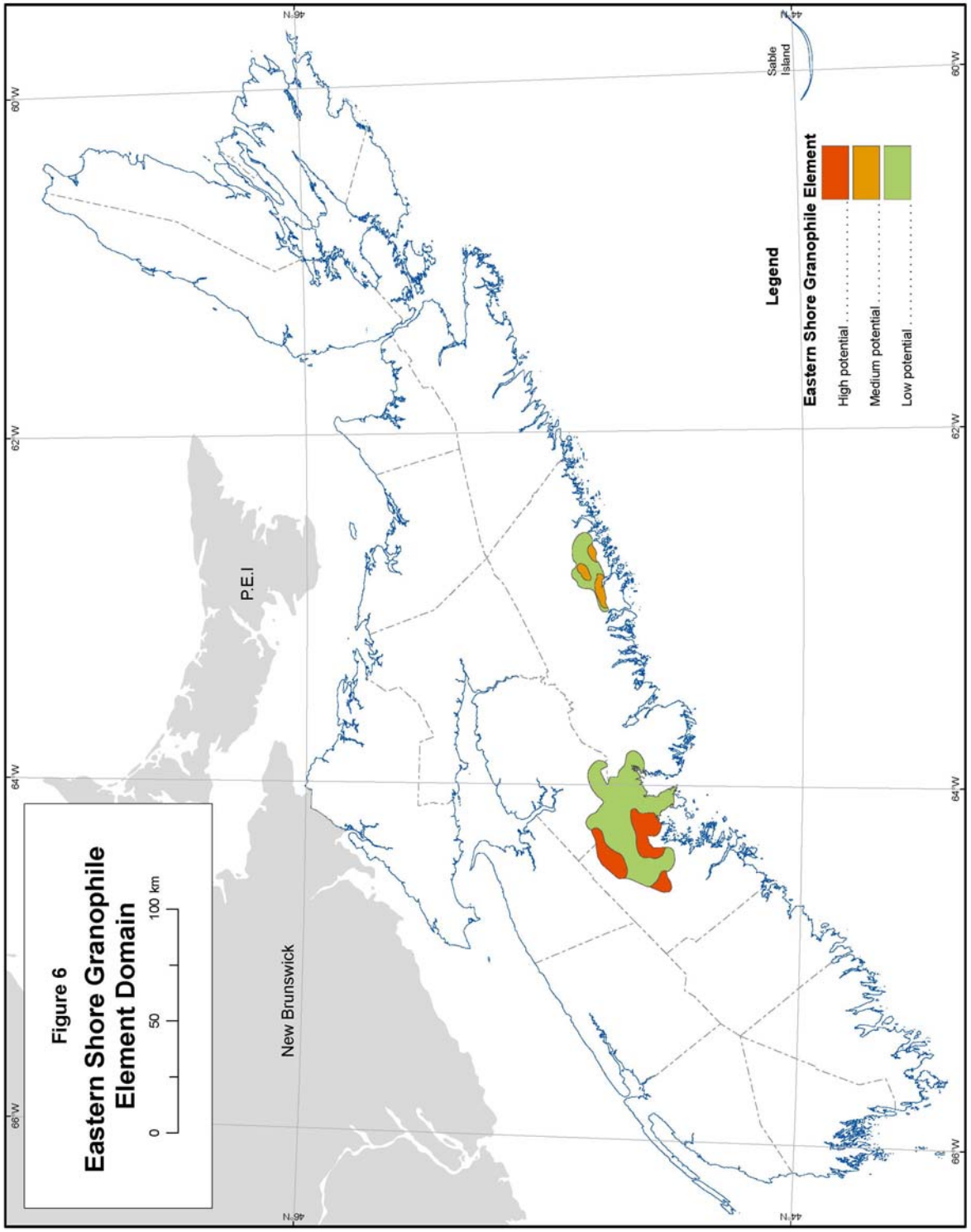
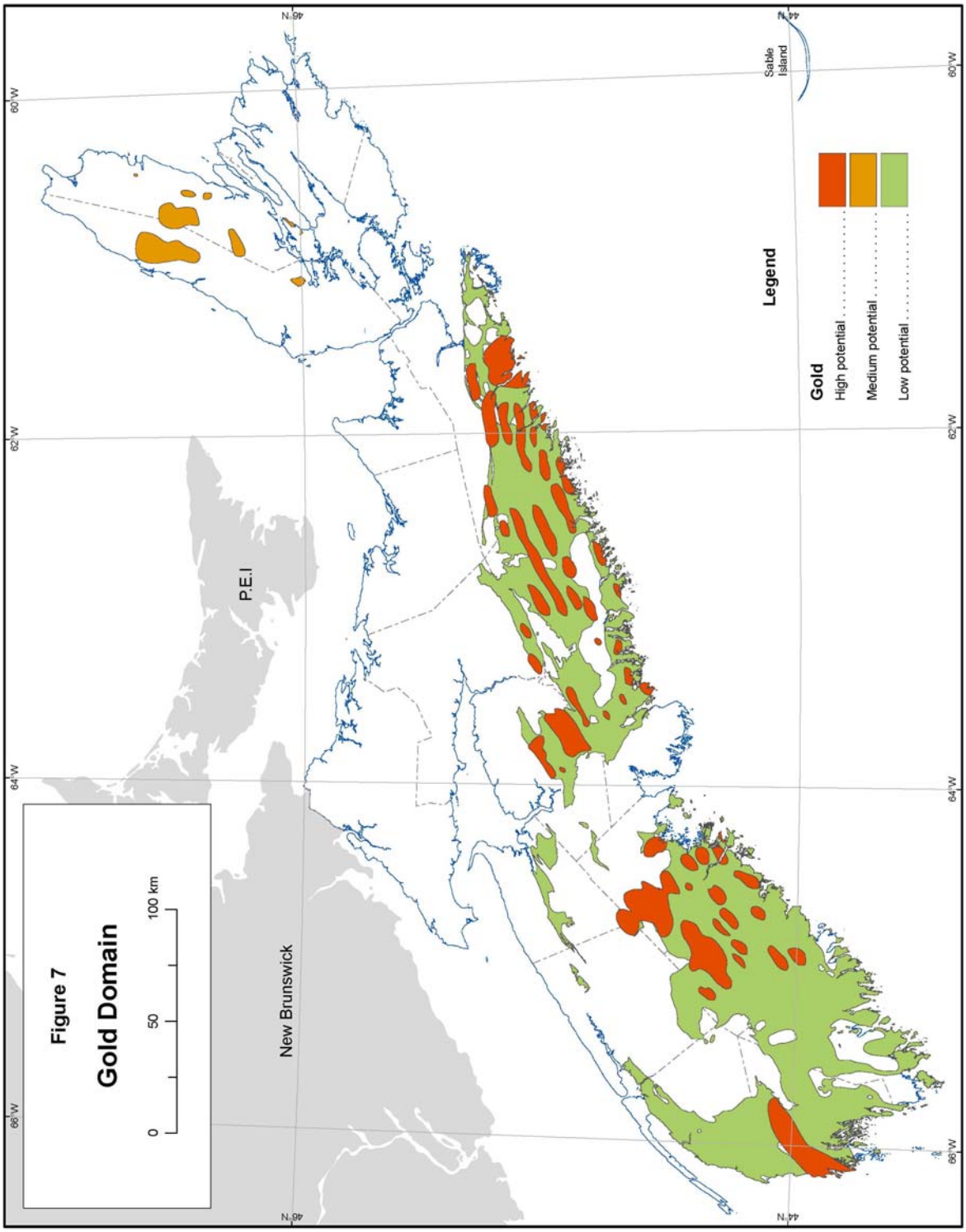


Figure 6
Eastern Shore Granophile Element Domain
0
50
100 km
New Brunswick
P.E.I
Sable Island
Legend
Eastern Shore Granophile Element
High potential
Medium potential
Low potential
66°W
64°W
62°W
60°W
46°N
44°N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Gold Domain
0
50
100 km
New Brunswick
P.E.I
Sable Island
Legend
Gold
High potential
Medium potential
Low potential
66°W
64°W
62°W
60°W
46°N
44°N

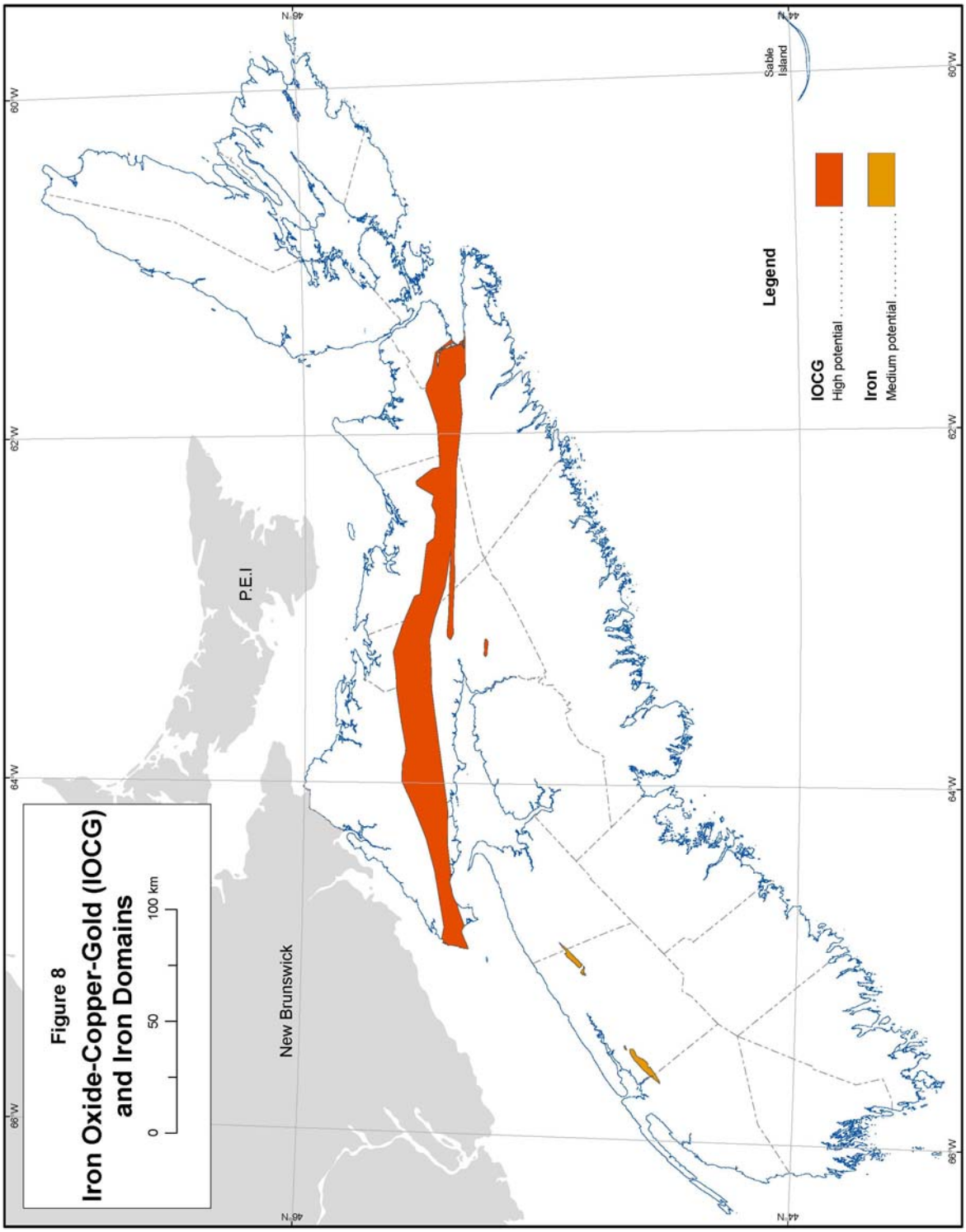
Figure 8
Iron Oxide-Copper-Gold (IOCG) and Iron Domains
0
50
100 km
New Brunswick
P.E.I
Sable Island
Legend
IOCG
High potential
Iron
Medium potential
66°W
64°W
62°W
60°W
46°N
44°N

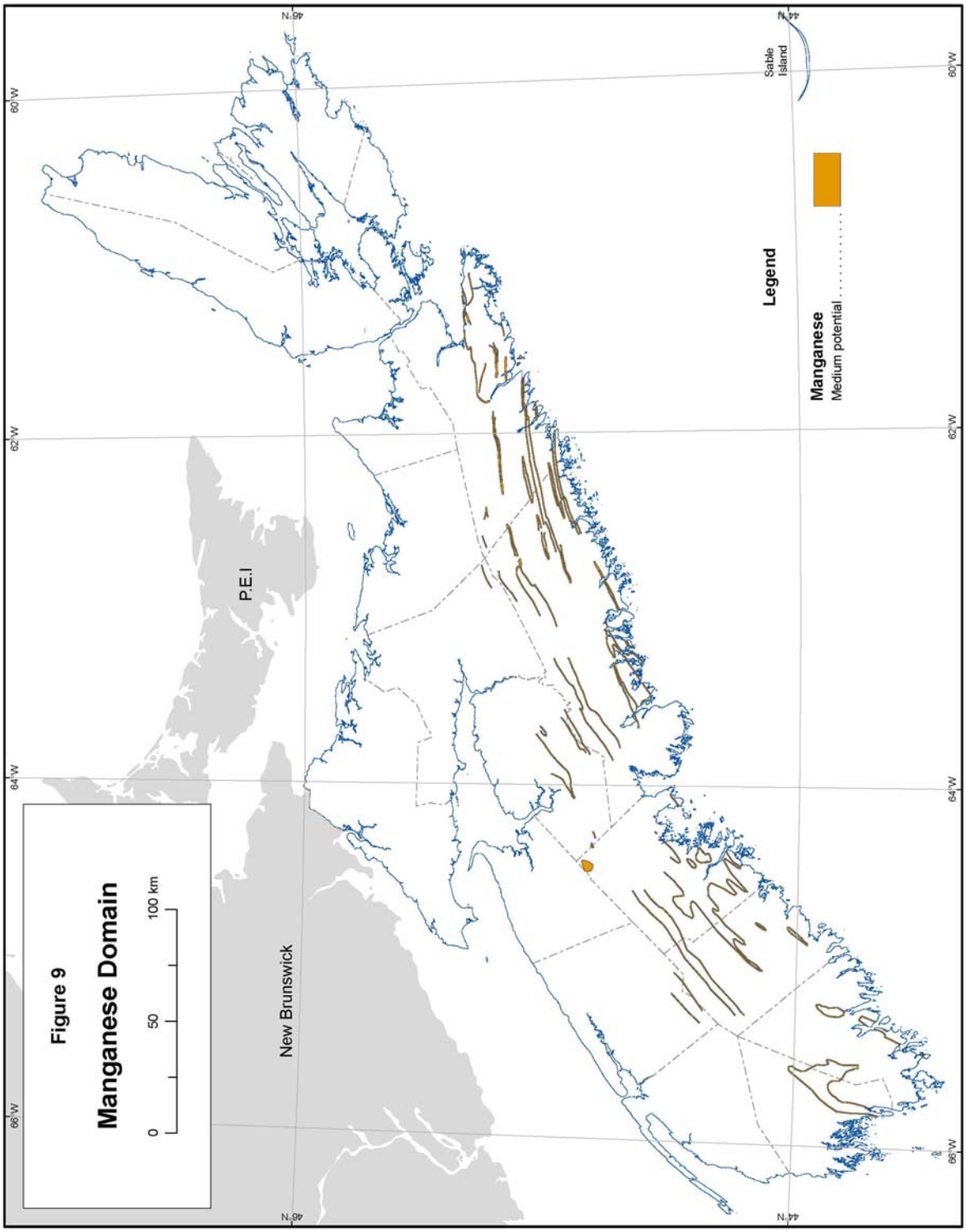
Figure 9
Manganese Domain
0
50
100 km
New Brunswick
P.E.I
Sable Island
Legend
Manganese
Medium potential
66°W
64°W
62°W
60°W
46°N
44°N

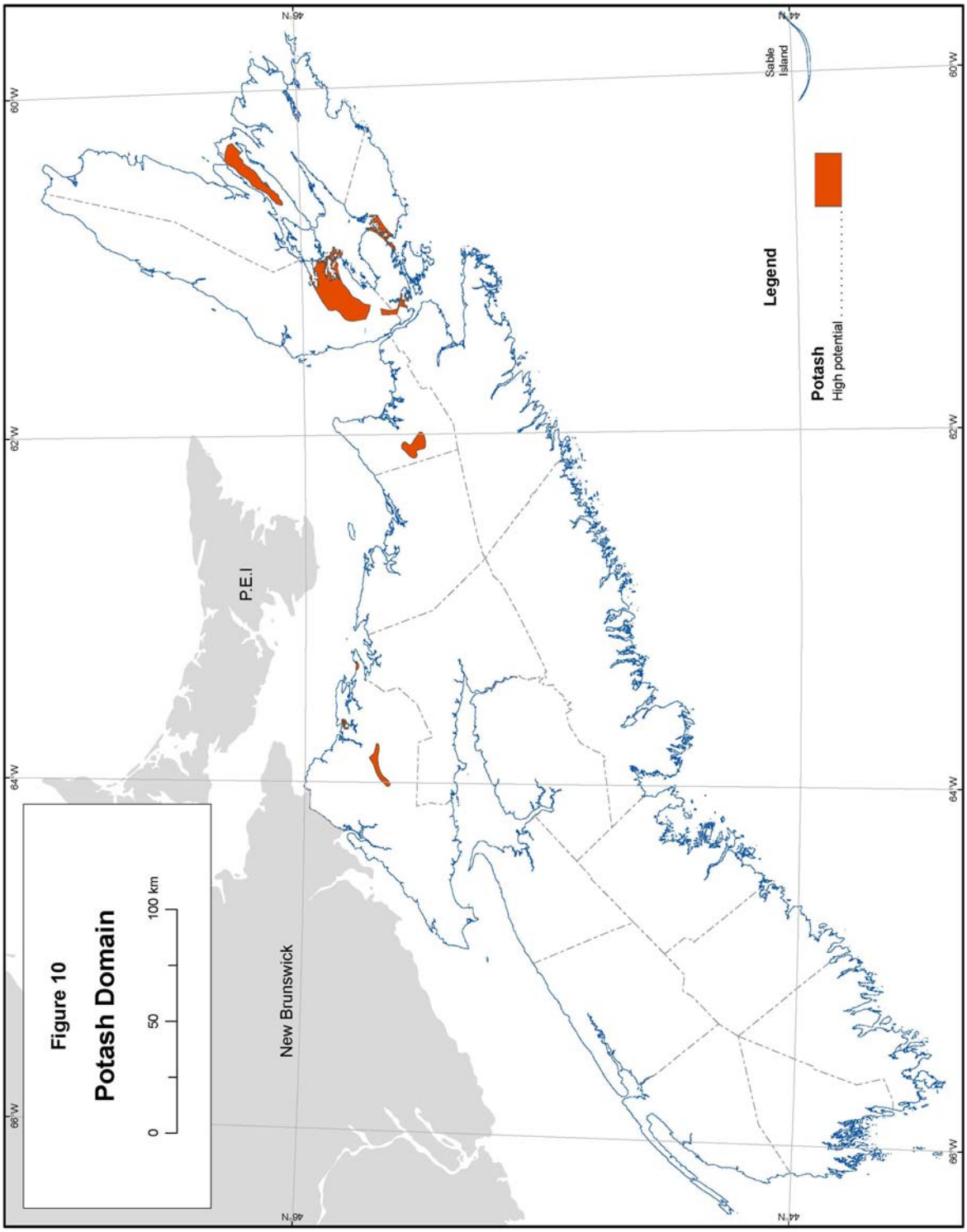
Figure 10
Potash Domain
0
50
100 km
New Brunswick
P.E.I
Sable Island
Legend
Potash
High potential
66°W
64°W
62°W
60°W
46°N
44°N

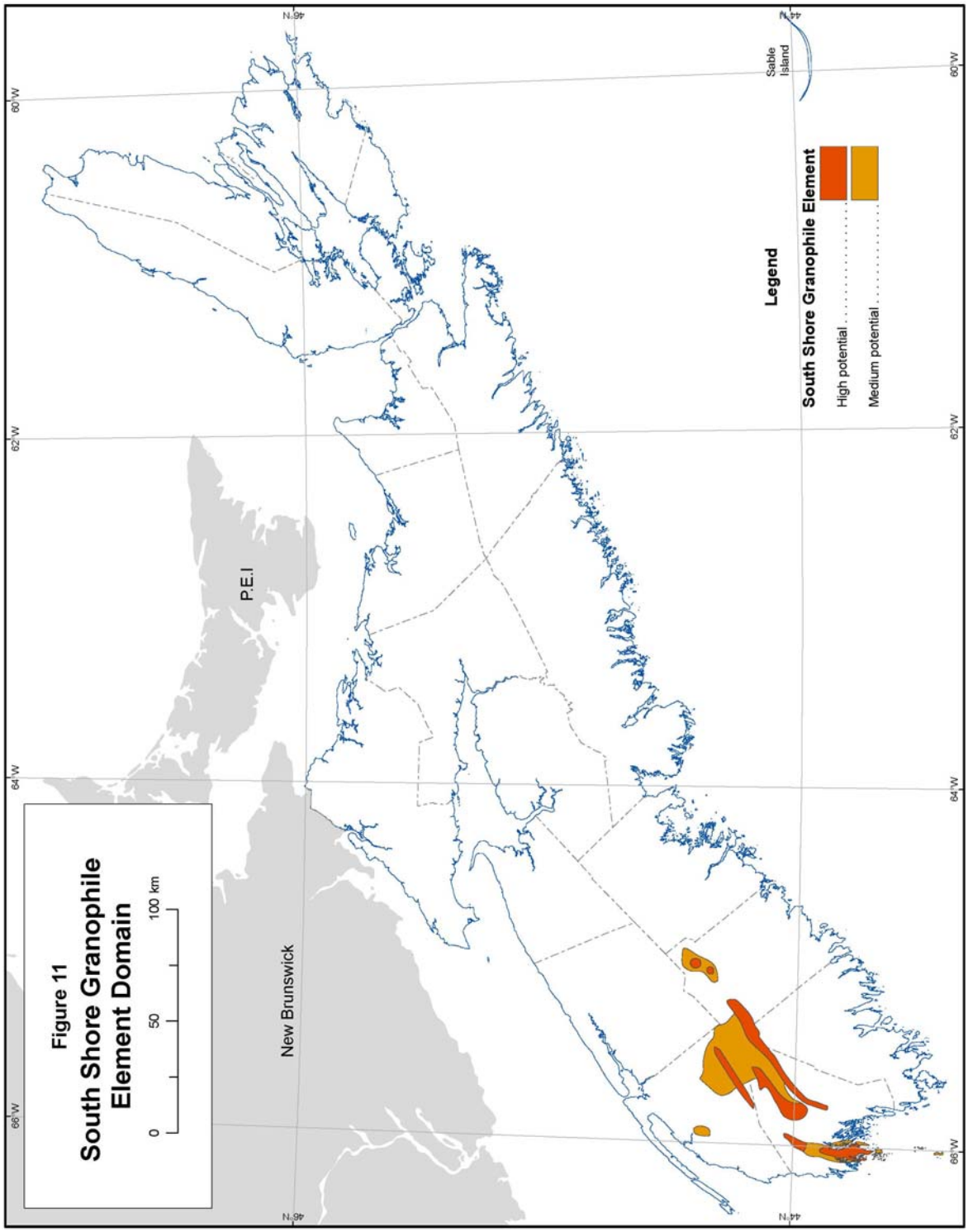
Figure 11
South Shore Granophile
Element Domain
0
50
100 km
New Brunswick
P.E.I
Sable
Island
Legend
South Shore Granophile Element
High potential
Medium potential
66°W
64°W
62°W
60°W
46°N
44°N

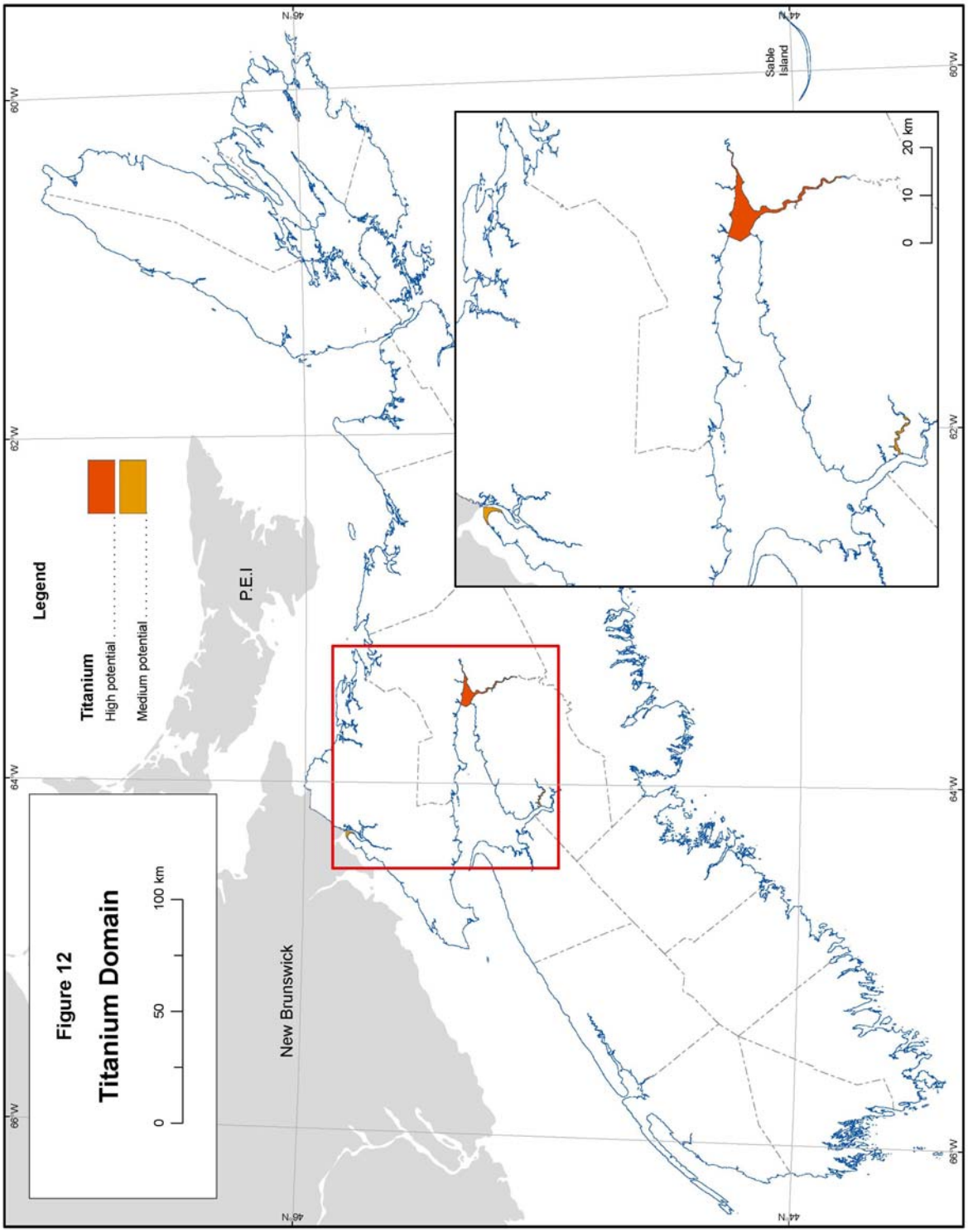

Figure 12
Titanium Domain

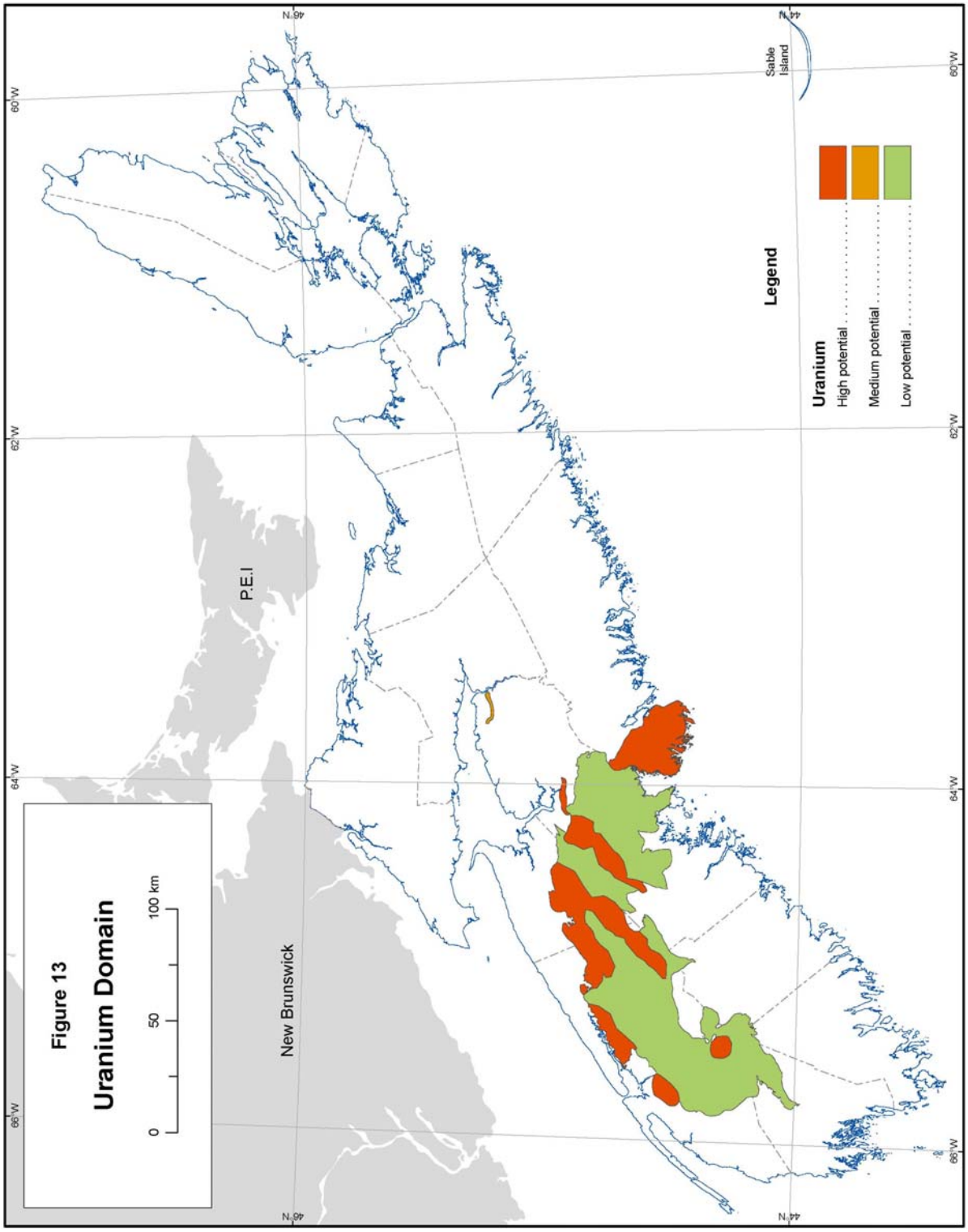
Figure 13
Uranium Domain
0
50
100 km
New Brunswick
P.E.I
Sable Island
Legend
Uranium
High potential
Medium potential
Low potential
66°W
64°W
62°W
60°W
46°N
44°N

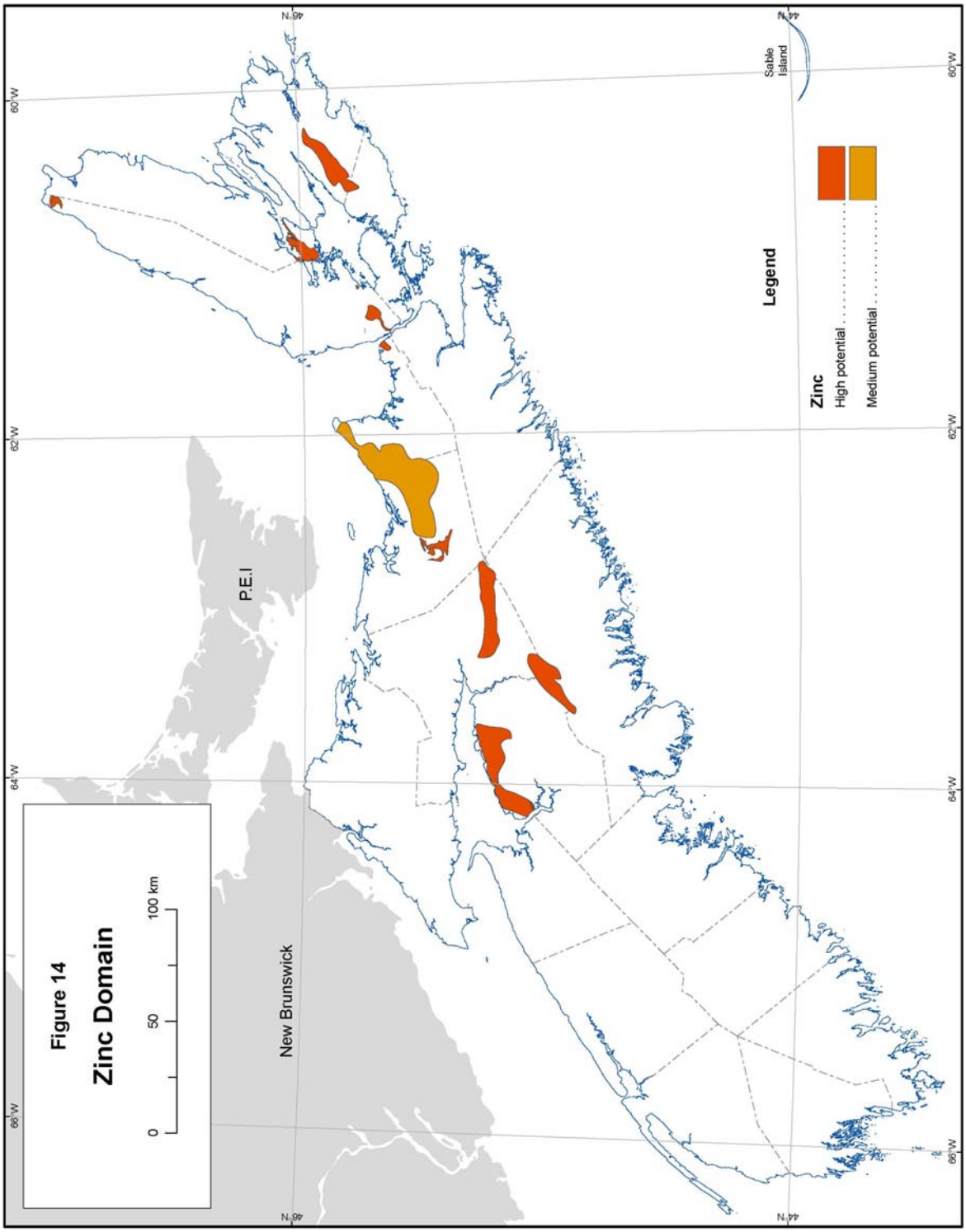
Figure 14
Zinc Domain
0
50
100 km
New Brunswick
P.E.I
Sable Island
Legend
Zinc
High potential
Medium potential
66°W
64°W
62°W
60°W
46°N
44°N