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OFFSHORE MINERALS MANAGEMENT OPTIONS: MINERAL POTENTIAL AND MANAGEMENT OPTIONS

A Report to Mines Ministers

by

A Task Force Appointed by
The Intergovernmental Working Group on the Mineral Industry

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I. INTRODUCTION

Federal and provincial geological surveys, as well as the minerals industry, are aware of the significant mineral potential that exists in Canada's offshore. Placer deposits that contain either proven (e.g., gold) or potential (e.g., titanium) commodities exist at technologically exploitable depths, as do large reserves of aggregate (sand and gravel). Although the brief resource evaluation included with this report focuses on the Atlantic offshore area, offshore minerals also present real development possibilities in both the Arctic and Pacific oceans (e.g., massive sulphides occurring in "black smokers" along the Juan de Fuca ridge, offshore British Columbia). It is understandable, therefore, that the provinces and territories contiguous to Canada's marine areas are eager to work with the federal government to develop a management regime for these offshore resources.

The most pressing question at this point, before a concerted effort can be made to seriously evaluate offshore-minerals development possibilities and related issues, is for the federal, provincial and territorial governments to agree on a management regime. Regime options are: federal management; provincial management; and federal-provincial joint management. Once a management regime is in place, it will be easier to champion site-specific systematic analysis of prospective minerals and the environmental issues related to their development.

II. DEVELOPMENT ISSUES

a. Management Options

The four options outlined below will serve as a basis for further discussions and are put forward without projection to the views and position of the federal, provincial and territorial government agency involvement in the preparation of this report to MMC '98.

1) The status quo (no action)

   This option would not foster development of offshore non-fuel resources.

2) Federal Management Regime

   NRCan would directly regulate offshore activities through new federal legislation and regulations. This option would require new resources from NRCan to develop and administer the legislation.

3) Provincially Administrated Management Regime

The federal government would delegate administration of offshore minerals management to the provinces. The underlying legal regime would, however, be based on federal legislation and regulations.

The federal government would have two options for establishing the underlying legal regime:

a) Pass federal legislation that would be mirrored in the provinces; and
b) Pass federal legislation allowing incorporation by reference of provincial statutes.

4) Federal-Provincial Joint Management Regime

NRCan and appropriate provincial agencies would jointly administer offshore activities through management boards that might be a smaller versions of the offshore pretroleum boards set up with Newfoundland and Nova Scotia. The federal government and the provinces would enact mirror legislation to set up the boards and establish framework for issues, such as as tenure and issuance of claims.

Another possibility might be to extend the mandates of the present offshore petroleum boards in Nova Scotia and Newfoundland to cover offshore non-fuel minerals by amending existing legislation. Although administrative functions could be combined with these boards' existing responsibilities, new land and royalty regimes for minerals would be needed.

b. Environmental Issues

Much work has been done internationally in various jurisdictions (including Canada) to demonstrate that offshore mining, if properly managed, can be conducted in an environmentally sound manner with no significant impact on:

- commercial fisheries;
- fish habitat;
- other offshore interests (e.g. pipelines, shipping, oil and gas production); or
- the shoreline.

In some cases, offshore deposits present an alternative that is economically, environmentally and socially preferable to sources on land.

However, the public case for environmentally safe offshore mining may be difficult because of negative images that are conjured up in many peoples' minds. The primary voices of concern have been, and would likely continue to be, environmental groups and fishermen.

It is emphasized that all projects would have to go through the federal (and likely provincial) environmental assessment process and that they would be carefully monitored.

c. Fisheries Impact

The only materials put into the water from the mining process are those that exist naturally in the marine environment. The most common environmental and fisheries concerns relate to:

- coastal erosion;
- disturbance of fish spawning grounds and lobster habitat;
- the introduction of fine-grained material into the water column; and
- interference with the commercial fishery.

These concerns can be resolved by operational and technological measures.

Past efforts to address environmental and fisheries concerns have been successful. In the late 1980s all responsible regional officials from Fisheries and Oceans and Environment Canada, as well as key east coast fisheries associations, recognized that offshore mining could be done without significant environmental impact.

Some important work continues as a project undertaken by Memorial University's Centre for Cold Ocean Resources Engineering (Canada-CORE). During the course of their fieldwork, researchers located a placer gold deposit off the north shore of Newfoundland and started an environmental test mining operation with the support of local fishermen.

III. MINERAL POTENTIAL OF OFFSHORE ATLANTIC CANADA

a. Summary

The federal government and provincial geological surveys in Atlantic Canada have been systematically mapping the Eastern Canadian continental shelf in order to inventory reserves of industrial minerals. The mineral industry has led the search for gold and other placers in the offshore. Geological mapping in search of these commodities has been recently enhanced with the advent of multibeam imaging technology. When multibeam bathymetry is combined with more traditional side-scan sonar and sub-bottom profiling methods, a three-dimensional view of the seabed is produced, providing new and exciting insights into seabed processes and geological history.

Gold placers have been discovered off Nova Scotia and Newfoundland and preliminary assessments have been promising, but no detailed follow-up assessment has been attempted. The proven economics of modern beach placers, such as the Ovens in Nova Scotia, and the potential for many lode and placer deposits in relict shorelines offshore, make further exploration attractive. Vast areas of the continental shelf remain under-explored, and may yet prove to contain significant reserves. Titanium and chromium placers have been discovered and the geological potential exists for tin and tungsten as well.

Perhaps the most promising target for offshore investigation is sand and gravel extraction. Both the Scotian Shelf and the Grand Banks contain large reserves of sand, sand and gravel, and high-purity silica sand. Testing has shown that much of the aggregate meets the minimum requirements for concrete and asphalt grades, but more rigorous analysis is required to determine if the sediments can be competitive with onshore deposits. It may be possible to combine both placer and aggregate mining in areas such as the Atlantic Coast of Nova Scotia and the north coast of Newfoundland where there is a strong potential for such deposits, thereby greatly enhancing the economic return per ton of extracted material.

Virtually all of the economically viable deposits of the continental shelves occur within the offshore zone that was once dry land after the last ice age, defined at its lowest limit by a relict lowstand shoreline. Aggregate and placer deposits formed as waves, currents and tides mechanically sorted glacial deposits within the zone of drowned former shorelines. The maximum depth of the lowstand shoreline over much of Atlantic Canada roughly corresponds to the maximum range of dredging operations (less than 80 m) that could be used to exploit these resources. Further geological research, using new multibeam mapping techniques, is warranted to find, delineate and evaluate these mineral resources.

b. Introduction

This report summarizes the mineral potential of offshore Atlantic Canada. It has been prepared for the Mines Ministers Conference of 1998 and the federal and provincial natural resource departments in Atlantic Canada. Included in this report is a description and classification of the main offshore mineral commodities, a selected reference list for offshore mineral resources, a summary of their mode of origin and a brief assessment of development potential. Much of this information has been gleaned from reports by Hale and McLaren (1984) and Hale (1987), updated to include the results from recent mapping programs conducted by the Geological Survey of Canada (Atlantic; Fader and Miller, 1994). These programs focused on areas of the continental shelf with potential for aggregate and placer resources. Continued geological research is needed to further delineate and evaluate these resources.

c. Exploration Techniques

Mapping and mineral assessment of Atlantic Canada's continental shelf began in the 1960s, funded by federal government agencies including the Geological Survey of Canada. Recently, mapping programs that targeted mineral resources were funded through federal-provincial Mineral Development Agreements (Fader *et al.*, 1991a, 1991b, 1993). Initial mapping programs were based on the collection of many small samples of seabed sediments combined with echosounder profiles and low resolution seismic reflection profiles to provide information on subsurface stratigraphy. These surveys presented a two-dimensional view of the seabed with limited detail about surface sediment thicknesses and properties. These pioneering surveys were supplanted by more advanced mapping in the 1980s using higher resolution seismic systems and new sampling techniques. The Huntec deep-towed boomer (seismic) system provided 0.25 m vertical resolution and up to 40 m penetration. Side-scan sonars provided 0.25 m planar resolution. Robust sediment samplers included the IKU grab which had the ability to penetrate surface gravel and collect up to a cubic metre of sediment sample. Vibrocores penetrated up to 3 m into the seabed to provide a continuous record of samples. These new methods have revealed a complex distribution of sediments and bedforms, reflecting a variety of geological processes, including continental glaciation and the rise and fall of global sea level.

During the course of these federal-provincial mapping programs, a new and revolutionary technique called multibeam imaging was developed in Atlantic Canada. This system relies on an array of echo-sounders, enhanced digitally, to provide a detailed three-dimensional view of the seabed with less than 2 m resolution. Multibeam imaging data also provide clues to the sediment types as well as seabed topography. The combination of multibeam imaging, side-scan sonar, high-resolution seismic reflection systems, and seabed samples, provides new and exciting insights into seabed processes and geological history and allows a more detailed assessment of potential mineral commodities.

d. Description and Classification of Offshore Mineral Commodities

The following is a list of commodities found in Atlantic Canada's offshore marine environments. An inventory of source areas is also provided, based on the current state of knowledge. It must be emphasized that potential reserves are estimated on the basis of limited data, and large parts of the continental shelf of eastern Canada remain to be mapped in detail and evaluated for economic potential.

1. Industrial Minerals

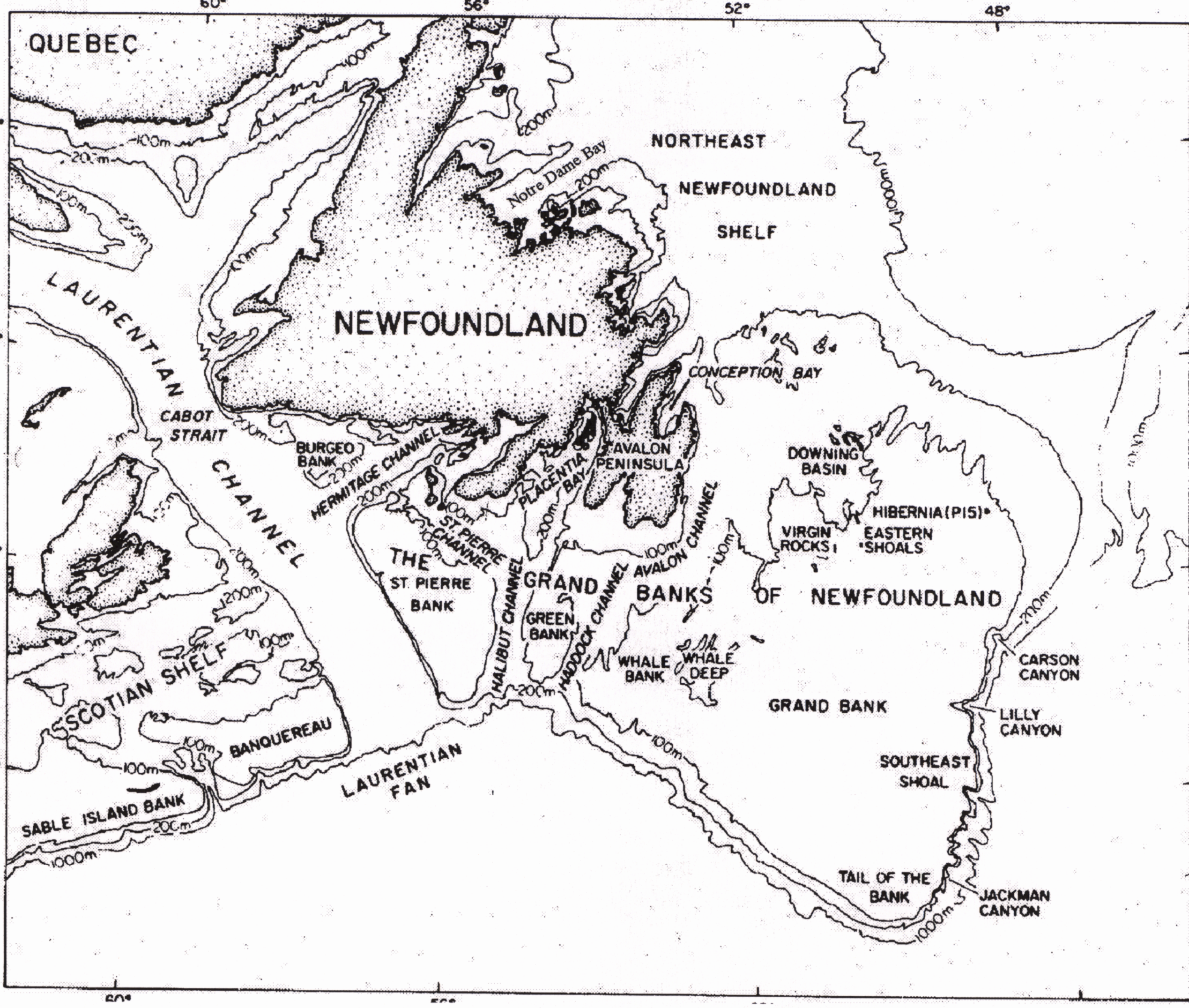
Industrial minerals may be sub-divided into texturally dependent (e.g., sand and gravel) and mineralogically dependent (e.g., silica sand, calcium carbonate) commodities.

Sand and gravel are the least valuable marine commodities by volume, but are required in enormous tonnages to supplement onshore resources in many parts of the world. Offshore exploitation commonly results from a lack or regulatory exclusion of onshore resources. Sand and gravel are used in either the construction industry or in beach replenishment programs. Canada's main experience in offshore aggregates has been dredging in the Beaufort Sea to produce artificial islands for placement of oil wells. Volumes in excess of 20 million cubic metres have been extracted for this purpose. Other dredging programs have been undertaken in Prince Rupert, B. C. (about 175,000 cubic metres dredged annually for local consumption), and Vancouver Harbour.

The continental margin of eastern Canada contains vast reserves of sand and gravel. The outer banks of the Scotian Shelf, such as Brown's Bank, Middle Bank, Misaine Bank and Banquereau (Fig. 1), are known to have thick sand and gravel deposits. Many of these have been tested for aggregate properties recently (Maritime Testing, 1996). George's Bank and Sable Island Bank have environmental restrictions related to fisheries and the fragility of Sable Island itself. The Grand Banks of Newfoundland are also a vast reserve of sand and gravel, but aggregate testing or evaluation has not been done. The inner shelf areas of the Maritime Provinces are closer to potential local markets and can also provide sources of aggregate. On the inner continental shelf of the Maritime Provinces and Newfoundland, above the depth of the lowstand of sea level, sand and gravel extraction is possible. Beyond that, in deeper water, clay and till deposits predominate. The quality of sand and gravel depends in large measure on the hardness and durability of the minerals inherent in the underlying source rocks. Testing has shown that the Scotian Shelf and Bay of Fundy offshore aggregates could be utilized for road sub-base, railway ballast, abrasives, and filter sands. Testing for concrete and asphalt uses has shown that the Nova Scotian source areas comply with national standard (CSA) for concrete aggregates, but the deleterious effects of grain rounding and salt-coating on concrete durability have yet to be evaluated.

High-purity silica sand is in demand for use in the concrete and glass industries. Some offshore exploitation of this commodity occurs in Finland and New Zealand, in both cases for use in the glass industry. Onshore reserves of silica sand in Newfoundland are limited to several small deposits which are mined for use in cement. Nova Scotia has mineable deposits of Cretaceous silica sand in the Shubenacadie and Musquodoboit valleys. High-purity silica sand is commonly derived from the weathering of coarse-grained granite, siliceous sandstone and quartzite. On the Grand Banks and Scotian Shelf, Cretaceous and Tertiary sandstones, naturally rich in quartz, can be further concentrated by mechanical abrasion and sorting in marine environments. Deposits of high-purity silica sand have been identified on the Magdalen Shelf in the Gulf of St. Lawrence, on the Bradelle Bank northeast of Prince Edward Island, on Banquereau Bank and the Scotian Shelf of Nova Scotia, and on the northern Grand Banks of Newfoundland.

A



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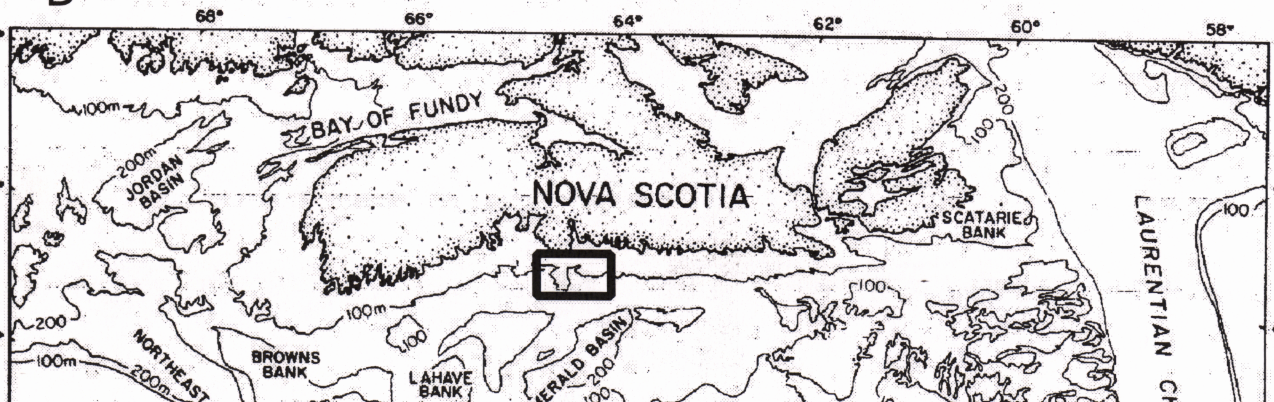

Figure 1. The Atlantic Provinces and continental shelf (A and B). Location of multibeam image off Halifax (B).

Calcium carbonate sand from offshore is used widely in the cement, glass making, agricultural lime and industrial filler markets. Countries currently engaged in mining calcium carbonate sands (aragonite, coral, marl and shells) include the United States, Bahamas, Fiji, France, Iceland and the United Kingdom. These deposits are either derived from chemical precipitation or from biochemical processes. Several deposits of calcium carbonate sand have been identified in Atlantic Canada, mostly consisting of shell material, although it is uncertain whether these are dead shell fragments or live colonies. Identified sources include southern and southwestern Nova Scotia, Strait of Belle Isle, and the southern shore of the Magdalen Islands (detrital limestone).

2. Placer Minerals

Placer deposits are common worldwide in the offshore environment. They have been produced by mechanical or chemical weathering, transported by glacial, glaciofluvial or pre-glacial fluvial systems, and later concentrated by tides and currents during the fall and rise in sea level following the last ice age. Placer deposits are relict (i.e., they formed under different conditions than exist at present) or modern (i.e., they are in equilibrium with modern marine conditions). Exploration for offshore marine placers, particularly in eastern Canada, has typically concentrated on areas associated with an onshore source or favourable bedrock geology.

Marine gold placers are currently mined in the Philippines, the United States and Fiji. In North America, gold placers have been successfully mined on the Alaskan continental shelf promoting speculation about the economic viability of placer mining in Canadian waters. Newfoundland has active gold mines, as well as several areas currently under mineral exploration. Nearshore and offshore coastal areas associated with onshore resources have been explored as part of federal-provincial mineral development agreements. These efforts focused on the north coast of Newfoundland, from the Baie Verte Peninsula to Bonavista Bay (Emory-Moore *et al.*, 1993; Emery-Moore and Solomon, 1990; McConnell, 1997; Shaw *et al.*, 1997). Although some placer deposits were identified, they commonly contained too little volume to be economically viable. In Nova Scotia, beach gold placers were mined from the Ovens District near Lunenburg in the early part of the century. Gold has been mined from 66 districts on land in Nova Scotia from the turn of the century to the present. It has been estimated that the Atlantic Ocean off Nova Scotia covers at least 50 more such gold districts in the same bedrock unit (Fowler and Miller, 1985: Miller and Fowler, 1987). Offshore placer deposits were identified off Country Harbour (Coughlan *et al.*, 1980) and Tangier (Stea *et al.*, 1993), with the "dome" deposit off Country Harbour estimated to contain from 3-9 million cubic metres of auriferous sediment ranging in grades from 0.03 to 0.5 grams/ton (Hopkins, 1985). Exploration for placer gold was curtailed because of a moratorium for evaluation of pipeline route.

Tin (cassiterite) is an important offshore resource, with about 7% of the global tin production coming from offshore sources. Thailand, Russia and Indonesia are major cassiterite producers. Tin (cassiterite) and tungsten (scheelite) deposits have been discovered in the granite batholiths of southern Nova Scotia. These discoveries culminated in the opening of North America's first tin mine at East Kemptville in the 1980s. Similar rocks in the offshore regions of Nova Scotia could host economic deposits of tin and tungsten, and fragments eroded from these bedrock deposits may be concentrated informer beaches that are now less than 65 m below sea level. However, no economic evaluation of placer tin or tungsten has been undertaken.

Diamonds are commonly mined from beaches and nearshore environments in South Africa. Geological potential exists for diamond host rocks in the Canadian Shield of Labrador, but as yet no diamonds have been discovered. Chromite (chromium) is used as a durable coating for corrosion protection in metals, and in the health sector. Onshore mining occurs in South Africa and Zimbabwe, from which 80% of the worlds chromium output is produced. Exploration for placer chromite in coastal areas is associated with onshore ultramafic rocks. In western Newfoundland, chromite-bearing placers were identified at the mouth of Fox Island River, although not in economic concentrations (Emory-Moore *et al.*, 1988; Solomon *et al.*, 1990; Dimmell, 1992). Titanium is found in ilmenite, rutile and other ores. It is used extensively in the aerospace industry, and as a filler in paints and plastics. Exploration for onshore titanium placers in coastal Labrador has resulted in the delineation of reserves of iron-titanium sands on the beach at Porcupine Strand (Emory-Moore and Meyer, 1992). Although grades are promising (4.6% TiO_2 overall), reserves are too low for economic development of the site. In Nova Scotia, titanium sands were reported by Glooscap Minerals in 1972, on the Shubenacadie River near the Bay of Fundy, with grades reported as high as 40%.

Other minerals mined as offshore placers include monazite (Australia, India, Sri Lanka), platinum (United States), zircon (Sri Lanka), iron sands (Brazil and Japan), and phosphate. Of these, only phosphate is known to occur on the eastern Canadian continental shelf, on the Grand Banks of Newfoundland.

e. Origin of Offshore Mineral Deposits

Virtually all of the economically viable deposits on the continental shelves occur within the zone that was once dry land during or after the last ice age. The fall in sea level resulted from less water reaching the oceans because more was freezing into glaciers, and from isostatic rebound after a kilometre or more of ice was removed. Bedrock sources of aggregate and mineral deposits were scraped by glaciers, the resulting sediment was deposited as till or glaciofluvial deposits, then reworked by waves, currents and tides as the sea rose, drowning the former land extensions of the Atlantic Provinces.

The lowstand of this former sea level represents the maximum present-day water depth to which sea level fell, and is represented in many areas of the Atlantic Canada offshore as a well-developed submerged shoreline. The lowstand shoreline features barrier bars, spits and enclosed lagoons, similar to the present day shoreline, that are visible from multibeam imaging of the seabed (Stea *et al.*, 1994; Fig. 2). This shoreline usually defines the limit of economic deposits. Although sand and gravel can be found below the lowstand, these deposits are commonly mixed with varying amounts of clay. The clay-free sand and gravel deposits above the lowstand have been mapped throughout Atlantic Canada and are called the Sable Island Sand and Gravel, whereas the less well-sorted sandy deposits below the lowstand are termed the Sambro Sand (King, 1970; King and Fader, 1986).

The maximum depth of the post-glacial sea level varies throughout Atlantic Canada. The depth is generally less towards the north and northwest, where glaciers were thickest during the last ice age. On the outer banks off Nova Scotia, where the glaciers once stood, sea level dropped to more than 80 m below present. Off the Atlantic coast of Nova Scotia, the lowstand shoreline is only 70 m below present sea level. The maximum lowstand depths over much of Atlantic Canada roughly correspond to the maximum range of dredging operations (less than 80 m) that could be used to exploit these resources. In general, the greater the lowstand depth the more shelf area that is available for economic exploitation. In most areas of Atlantic Canada sea level has been rising since lowstand shorelines were formed between 16 and 10 thousand years ago. Higher submerged shorelines formed whenever low rates of sea-level rise and sediment supply favoured the preservation of these features. Using the new multibeam imaging systems and high resolution sub-bottom profiling systems, economically favourable, relict shorelines can be found within the zone of transgression.

Modern hydrodynamic processes including tidal and current activity, especially within the Bay of Fundy and the bays and fjords of the Newfoundland coastline, result in the production of large bedforms which can be utilized as economic sources of aggregate. Tidal currents within the Bay of Fundy produce enormous sand waves, which contain over 35 million cubic metres of sand (Fader and Miller, in press). These active waves are being fed by sediment transported from the southwest, and may be a renewable resource, if the rate of sediment supply equals or exceeds extraction.

f. Development Potential

The continental margins of Atlantic Canada have been the focus of active exploration for placer and industrial minerals. Grades of placer minerals have been variable, and although there has been some industry activity, it has been fragmentary and incomplete. The proven economics of modern beach placers, such as the Ovens, and the potential for many lode and placer deposits in relict shorelines make further offshore exploration attractive.

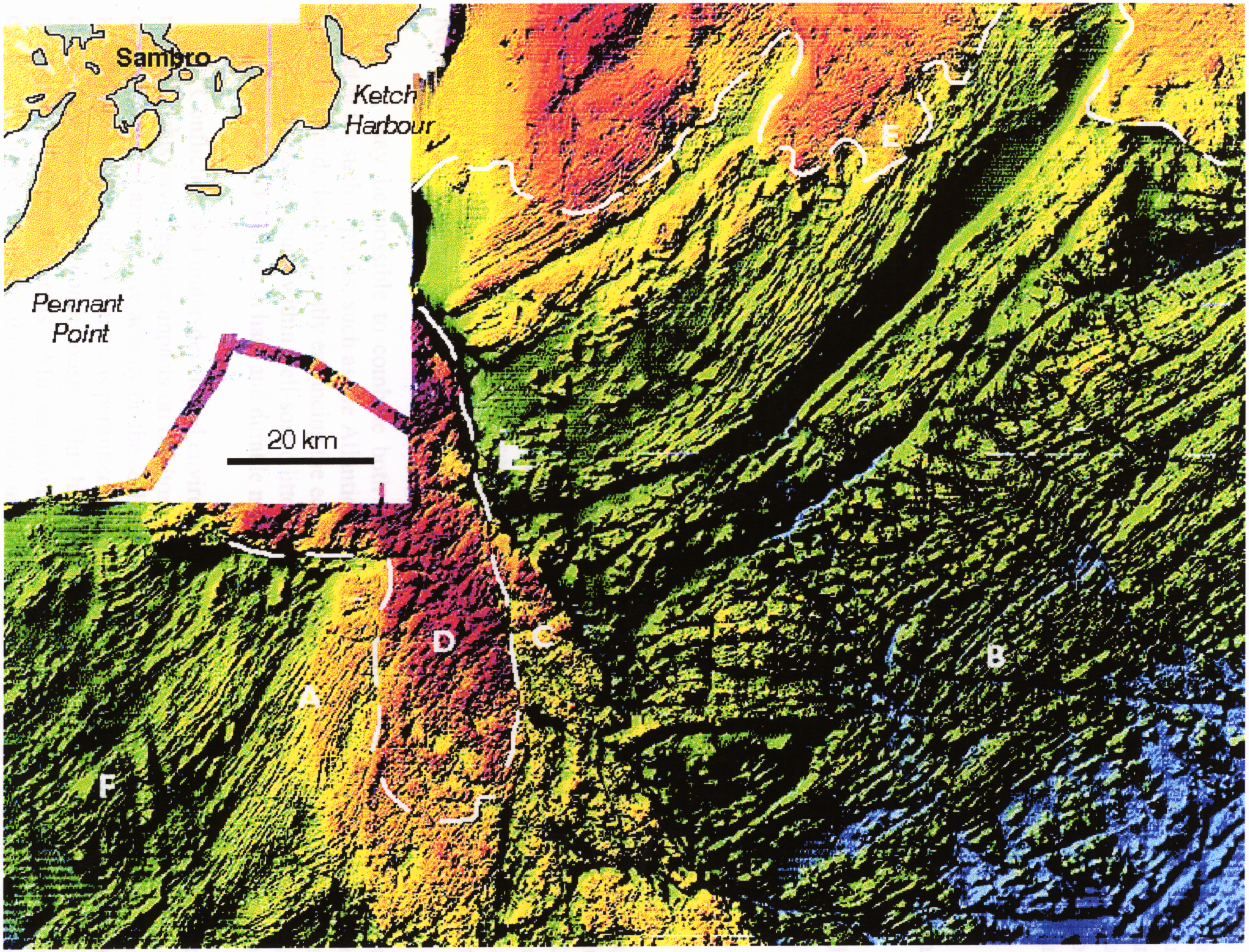

Figure 2. Multibeam bathymetric image of the inner continental shelf off Halifax, Nova Scotia. A and B - Meguma Group metamorphic bedrock below lowstand. C and D - Granite bedrock. White dashed line follows the lowstand shoreline at 70 m water depth. Note the muted topography above the lowstand.

Vast areas of the continental shelf remain under-explored, and may yet prove to contain significant reserves. Perhaps the most promising target for offshore investigations is sand and gravel. Both the Scotian Shelf and the Grand Banks contain large reserves of sand, sand and gravel, and high-purity silica sand. Reserves may be estimated from state-of-the-art multibeam imaging technology as well as more traditional sidescan sonar and sub-bottom profiling methods. Testing has shown that much of the aggregate meets the minimum requirements for concrete and asphalt grades, but more rigorous testing is required to determine if the sediments can be competitive with the onshore supply.

In order to satisfy local aggregate markets, prices must be competitive. Factors that would affect price include:

1. Environmental conditions (ice-wind-waves) inhibiting the extraction and transport of the aggregate.

2. Steaming distance to off-loading ports from the resource site.

3. Size and storage capacity of the vessels.

Although initial geological results have been promising, it is clear that mining, transportation and market feasibility studies are necessary to establish the economic viability of potential aggregate resources. Supplying the lucrative New England market may be possible with larger vessels (barges), which would compensate for long transport distances with larger storage capacity. At present some southern U. S. ports are being supplied with crushed stone aggregates from Mulgrave, Nova Scotia, and from Lower Cove, western Newfoundland.

It may be possible to combine both placer and aggregate mining in areas with potential for such deposits, such as the Atlantic coast of Nova Scotia and the north coast of Newfoundland, thereby greatly enhancing the economic return per ton of extracted material. Placer deposits are found within well-sorted littoral zone sediments and tend to be associated with their bedrock source, in hard and durable metamorphic rocks best suited for aggregates.

Conflicting and under-developed environmental policies and regulatory regimes for mineral rights have negative impacts on offshore exploration and mining. Marine mining is often considered an invasive activity on the seabed, detrimental to various fisheries. In most jurisdictions where marine mining is permitted, environmental assessments are mandated and monitoring takes place continuously. This has resulted in guidelines to allow both seabed mining and fishing to coexist. Mining activities can also be carried out in phase with the cycle of marine organisms that seasonally use the seabed for habitat so as not to be in competition. A general philosophy in marine mining is an approach not to change the grain size of the sediment on the seabed, but only to remove the upper few metres of section. This provides continued access to similar habitat for marine organisms. The mining of near shore minerals and aggregates in the coastal zone presents additional problems concerning the stability of nearby beaches and potential for increased coastal erosion. In some settings the removal of nearshore sand bars, which normally dissipate wave energy offshore, can increase wave energy on the beach resulting in higher erosional rates. In eastern Canada many of the potential aggregate resources are found on offshore banks completely isolated from the coast by glacial troughs. Removal of material from these banks would in no way affect the coast. Fine-grained plumes of sediment generated from seabed mining can be a problem as these sediments may smother critical habitats when they settle at distances from the mining activity. If, however, the material to be mined is already well sorted and free of fine-grained components, the threat is minimal.

IV. CONCLUSIONS

Significant mineral potential and known deposits exist in the offshore of Canada's three ocean areas. Environmental concerns are a critical factor in the exploitation of these resources. However, as alluded to in both sections of this report, it is possible to resolve or mitigate these concerns by operational and technological measures. Therefore, a sound management regime is an essential prerequisite to realizing the benefits from the development of offshore minerals.

Questions related to the ownership of and jurisdiction over offshore mineral resources has been an issue between the Provinces and the Government of Canada for some time. Private companies have expressed an interest in exploring for minerals and aggregates in Canada's offshore regions; however, they will not do so until they can be sure that they have the rights to the minerals they discover. Currently, neither jurisdiction can give industry the satisfaction they require with respect to the mineral rights and the regulatory regime that will exist. Although serious multilateral discussions took place between the Government of Canada and some of the provinces several years ago, no final agreements were negotiated. Therefore, to resolve all outstanding issues surrounding the matter, it is recommended that the federal government conduct timely consultations with the coastal provinces and territories, and other interested stakeholders, with the precise goal of establishing a management regime that permits mineral-resource exploitation in a timely manner consistent with sustainable development.

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VI. REFERENCES

Coughlan, T. D., Chafer, C. and Dawe, J. E. M. 1980: Report on the Country Harbour offshore placer deposit; Nova Scotia Department of Natural Resources, Assessment Report 11F/04/a 21-6-61.

Dimmell, P. 1992: Third year assessment report on the Fox Island River Property (Lucero option), western Newfoundland; International Corona Corporation, Open File 12B (347).

Emory-Moore, M. 1991:. Gold placer potential of the northern Newfoundland shelf; Contract report for Atlantic Geoscience Centre, C-Core contract number 91-C7; Geological Survey of Canada, Open File 2417.

Emory-Moore, M. and Meyer, J. 1992: Geology of the Porcupine Strand beach placers, eastern Newfoundland; Current Research, Newfoundland Department of Mines and Energy, Report 92-1, p. 221-230.

Emory-Moore, M. and Solomon, S. 1989: Placer gold potential offshore Newfoundland: A preliminary assessment; Current Research, Newfoundland Department of Mines and Energy, Report 89-1, p. 229-236.

Fader, G. B. J., Miller, R. O. and Pecore, S. S. 1991a: The marine geology of Halifax Harbour and adjacent areas (v. 1 and 2); Geological Survey of Canada, Open File Report no. 2384, 23 p.

Fader, G. B. J. and Miller R. O. 1991b: The Scots Bay sand wave field, Bay of Fundy: an example of potential environmental enhancement by extraction; Geological Association of Canada, Annual Meeting with Abstracts, Toronto.

Fader, G. B. J. and Miller R. O. 1984: A preliminary assessment of the aggregate potential of the Scotian Shelf and adjacent areas; Coastal Zone Canada '94, Conference Proceedings, Coastal Zone Canada Association; Bedford Institute of Oceanography, Dartmouth, Nova Scotia, v. 1, p. 230-2.

Fader, G. B. J. and Miller R. O. in press: A preliminary assessment of the aggregate potential of the Scotian Shelf and adjacent areas; Geological Survey of Canada, Open File Report.

Fader, G. B. J., Miller, R. O., Stea, R. R. and Pecore, S. S. 1993: Cruise Report 91-018, C.S.S. Dawson: operations on the inner Scotian Shelf; Geological Survey of Canada, Open File Report no. 2633.

Fowler, J. H. and Miller, C. K. 1985: The development potential of Nova Scotia's offshore aggregate and placer resources; Nova Scotia Department of Mines and Energy, Open File Report 656, 37 p.

King, L. H. 1970: Surficial geology of the Halifax-Sable Island map area; Marine Sciences, Paper 1, Energy Mines and Resources Canada, 16 p.

King, L. H. and Fader, G. B. J. 1986: Wisconsinan glaciation of the continental shelf-southeast Atlantic Canada; Geological Survey of Canada, Bulletin 363, Ottawa, 72 p.

Hale, P. B. 1987: Canada's offshore non-fuel mineral resources - opportunities for development; Marine Mining, v. 6, p. 89-108.

Hale, P. B. and McLaren, P. 1984: A preliminary assessment of unconsolidated mineral resources in the Canadian offshore; Canadian Mining and Metallurgical Bulletin, v. 77, no. 869, p. 51-61.

Hopkins, R. 1985: Placer gold potential, Country Harbour, Nova Scotia; Canadian Oil and Gas Lands Administration, Special Report, 89 p.

Maritime Testing Ltd. 1996: Testing of marine seabed sampled from the Scotian Shelf, Bay of Fundy and adjacent areas for aggregate characteristics; CSS Hudson Cruise 95-030.

McConnell, J. 1997: A re-evaluation of the gold content of a glaciofluvial deltaic deposit near Birchy Bay, Newfoundland (NTS 2E/7); *in* Report of Activities, 1997; Newfoundland Department of Mines and Energy, p. 32-34.

Miller, C. K. and Fowler, J. H. 1987: Development potential for offshore placer and aggregate resources of Nova Scotia, Canada; Marine Mining, v. 6, p. 121-139.

Solomon, S., Swinden, S., Emory-Moore, M. and Proudfoot, D. 1990: Spatial analysis in marine placer exploration: Preliminary results from St. Georges and Port au Port Bays, Newfoundland; Current Research, Newfoundland Department of Mines and Energy, Report 90-1, p. 77-83.

Stea, R. R., Pecore, S. S. and Fader, G. B. J. 1993: Quaternary stratigraphy and placer gold potential of the inner Scotian Shelf; Nova Scotia Department of Natural Resources, Mines and Energy Branches Paper 93-2, 62 p.

Stea, R. R., Boyd, R., Fader, G. B. J., Courtney, R. A., Scott, D. B. and Pecore, S. S. 1994: Morphology and seismic stratigraphy of the inner continental shelf off Nova Scotia: evidence for a -65 m lowstand between 11,650 and 11,250 yr. B.P.; Marine Geology, Volume 1994.