## Geological resources of the Last Ice Area - Summary

With climate change and global warming a reality, Arctic sea ice is receding, and the area of remaining ice is getting smaller. The remaining ice area, including Canada's Arctic Islands and Northern Greenland, is projected to retain its summer sea ice longer than any other area in the entire Arctic. This is the core of the Last Ice Area (LIA), the area where critical Arctic summer sea ice is predicted to be most resilient.

As it assumed the chair of the Arctic Council in 2013, Canada stated its top priorities for Arctic development as: responsible Arctic georesource development; safe Arctic shipping; and sustainable circumpolar communities. These are common themes for all Arctic states. Development of this nature is increasingly discussed because the retreat of Arctic summer sea ice is making development on the fringes of the Arctic Ocean more feasible. By the same logic, the area where summer sea ice is projected to persist the longest, the Last Ice Area (LIA), is where development is likely least feasible. As part of its research to frame potential management options for this ecologically valuable area, WWF has commissioned an independent report on the geological resources of the area, and the likelihood of their development. This is a summary of the report, and the conclusions are those of the author, not WWF.

Large known and predicted hydrocarbons occur in the LIA although there is no current exploration or production. Most of the past exploration has been in the Paleozoic and Mesozoic strata in the central Sverdrup Basin, which have substantial proven reserves. Future exploration may test the southern rim of the basin and the Arctic Fold Belt where there is significant hydrocarbon potential. In the Greenland part of the LIA hydrocarbon potential occurs in major offshore Phanerozoic sedimentary basins, notably the large basins offshore west Greenland and east Greenland. To date no fields have been discovered and no commercial development occurs on the Greenland continental margin. Assessment studies indicate that there is significant potential for large resources in the offshore basins. Seismic studies are underway, but all of the work is south of the Greenland LIA.

The geological setting of the LIA naturally favours hydrocarbon resources over mineral resources. The latest known period of widespread mineralization in the area predates the Paleozoic sedimentary rocks, therefore rocks of this age or younger may be discounted as sources of metals. All of the mineral exploration activities occur in Archean rocks in the southern part of the LIA particularly on Baffin Island where the geology is more conducive for mineralization. A number of zinc-lead deposits and occurrences have been delineated in the Greenland part of the LIA with the Citronen Fjord deposit being in an advanced stage of exploration.

Given the long lead times necessary to meet regulatory requirements, a lack of strategic infrastructure, economic factors and insufficient scientific data, large scale production of resources in the LIA is unlikely to occur soon. New large discoveries in more temperate environments are more prospective for industry investment. There are many technical and environmental obstacles which will complicate global Arctic and LIA development. Technical challenges arise from extreme climatic conditions that necessitate specific requirements for equipment, materials and construction operations. Environmental concerns are particularly associated with accidents and pollution that may damage delicate Arctic ecosystems and local people's livelihoods. The main obstacle, however, is the lack of sufficient infrastructure to confirm viability, economy and safety of LIA operations.

## Canada

### Hydrocarbon Resources

The Arctic Islands contain one of Canada's largest hydrocarbon basins in the most northerly of Canada's exploration regions. Large, offshore sedimentary basins in the LIA form prospective oil and gas frontier plays. There are many unproven plays most of which would be promising exploration targets if they were located in more accessible areas.

Currently there are no commercial hydrocarbon exploration activities in the LIA and given the long lead time of 10 to 20 years required to bring a field to production status it is unlikely that there will be any production in the region before 2030 to 2040. For example, in Atlantic Canada it took 18 years to move the Hibernia field from discovery to production status and it will have taken 33 years from the discovery of the Hebron field to production.

The severe conditions of the LIA impose distinct technological and environmental challenges on operators hoping to exploit the northern resources. Given the current economic situation, it is unlikely that petroleum companies will be interested in starting large-scale LIA projects when there are other options available in less demanding regions. This suggests that in the near- to mid-term LIA energy operations are unlikely to increase. However, this does not mean that hydrocarbon exploration will not restart in the future when increased demand for energy and advances in technology and environmental control may lead to renewed interest in the LIA.

### Coal Resources

The main potential coal resources in the LIA are on Ellesmere and Axel Heiberg islands with discovered resources calculated at 43.8 billion tonnes. Recent advances in coal mining, processing and transportation technology may encourage future exploitation of coal potential if sizable resources are determined. Coal resources located in the remote areas of the LIA are not currently economically viable. In December 2013 Canada Coal Inc. announced that it has withdrawn all project applications submitted to the Nunavut Impact Review Board and will delay exploration activities on Ellesmere Island for at least one year.

### Mineral Exploration

There are currently no operating mines in the Arctic Islands; however, the Mary River iron ore project on Baffin Island is anticipated to begin production in 2013 or 2014 with plans to extract 3.5 million tonnes of iron ore. The resource is one of the largest iron ore deposits in the world. Other prospective economic mineral projects in various stages of development include lead-zinc, gold and diamonds. All of the mineral activities occur on the mainland or in the southern part of the Arctic Islands, and particularly on Baffin Island, where the geology is favourable for mineralization. An important result of mineral exploration in the Arctic Islands has been the development of new communities that support georesource projects. Exploration activities employ many Inuit workers providing valuable income and training for northern communities.

## Greenland

### Greenland Georesources

Geological surveys in Greenland have documented zinc and iron ore mineralization in the LIA as well as possible petroleum fields onshore and offshore in the Franklinian Basin, and offshore in the Greenland-East Canada and East Greenland Provinces.

### Greenland Mineral Resources
The geology of northern Greenland is a continuation of the Rae Domain from the Canadian Arctic Islands which has mineralization on the mainland to the south. Other mineral prospecting and exploration activities are taking place within the Greenland LIA although none is mature enough to result in production in the short to medium term. The region does host mineral occurrences, particularly lead-zinc mineralization, that could be developed into resources over a 10-20 year time frame.

### Greenland Hydrocarbon Resources
No significant oil or gas fields have yet to be discovered either onshore or offshore the LIA in Greenland. Currently, there is little interest in the area and investors focus on more accessible plays to the south. The prospective plays of the North Greenland Sheared Margin, which borders the LIA to the north, are relatively small and the severe operational challenges make exploration investment prohibitive at this time. Extensive development of oil and gas resources within the northern core of Greenland's LIA is unlikely by 2030 to 2040. Future georesource discoveries in Greenland will need to demonstrate large to giant accumulations of recoverable reserves to justify the capital required for production.

## Development Factors

### Resource Drilling Costs
Drilling in the Arctic Islands is a high-risk high-cost proposition due to the almost total lack of infrastructure. Industry is developing a number of technologies that will significantly lower drilling costs, but with all the new oil and gas shale plays in southern Canada and the US and vast potential in Brazil and other new fields in less severe environments it is unlikely that companies will risk the enormous costs of exploration in the LIA any time soon. Most of the discovered resources will remain "orphaned" until economic and technical factors become more favourable.

### Oil and Gas Price Forecasting
The Energy Futures report of Canada's National Energy Board predicts that energy supply will continue to grow to record new heights over the projection period up to 2035. The petroleum industry is making an effort to reduce energy requirements and increase production rates by employing new technologies for both conventional and unconventional production. The overall result will be an increase of oil and gas prices in real terms which could lead to consideration of renewed hydrocarbon exploration in the LIA.

### Infrastructure
To become an economically viable venture in the Arctic the georesource industry must have access to transportation and development infrastructure. Geological resource exploration and development will require expansion of air, marine, and land transportation systems. To advance economic development in the LIA a massive investment in infrastructure would be required, and when coupled with the extremely high costs of drilling further exploration in the LIA may be prohibitive in the near future. The severe climate, long distances and lack of infrastructure require new logistics systems and solutions to access and exploit onshore and offshore petroleum and mineral deposits in the LIA. To construct efficient, secure, environmentally sensitive infrastructure systems to facilitate georesource and local community development would require a cooperative, domestic and international governance effort.

### Transportation and Navigation
A significant rise in Arctic shipping is expected by 2020, due to an increase of ecotourism cruises and the possible development of several large scale georesource projects. By 2050,

Arctic shipping in Canadian waters could increase by a factor of six, if hydrocarbon production occurs. An Arctic Gateway is critical for an emerging long-term development strategy for northern Canada. The opening of the Arctic to transportation and construction will have both positive and negative outcomes for the LIA by increasing access to the north and its treasures but also opening it to potentially disastrous environmental challenges. Overall, the lack of infrastructure will frustrate development in the Arctic as long as there are other frontier areas that can link to existing infrastructure in a more cost-effective strategy.

**Climate Change in the Arctic**

Future challenges for resource development and infrastructure design in the LIA are closely linked with the Arctic climate. There are a number of potential Arctic feedback mechanisms and critical tipping points that affect the earth system. Short term impacts from ground disturbance and construction will be immediately apparent while global climate effects such as sea level rise and large-scale sea ice melting become more evident over longer time periods.

Access to remote areas will improve due to the retreat of the ice cap and melting of sea ice associated with warming of the environment, though as noted, sea ice loss is expected to be lower in the LIA than in other places. Operational challenges such as higher mobility of sea ice, more frequent calving from glaciers, and extreme weather will increase the likelihood of accidents in the LIA. Pipelines would be affected by changes in ground thermal regime, drainage and terrain stability, due to warming over the lifetime of a georesource project. Melting of permafrost can lead to a loss of structural strength and an increase of settlement and instability of buildings and other structures. Ground disturbances such as the loss of insulating vegetation will increase the rate of warming and subsequent thawing of permafrost.

**Environmental Impact**

For georesource plans in the LIA to progress, discussion with businesses, governments and northern communities on impact, adaptation and mitigation would be needed to assess and respond to environmental impacts and vulnerabilities. Resource exploration programs require costly infrastructure construction and an increase of workers to service the projects. Predicted decreases in sea-ice cover may result in intensified exploration activity in the Arctic Islands due to easier access to remote areas in the LIA. Exploration activities must remain flexible in order to mitigate the changing conditions in an unpredictable environment. The tangible effects of environmental factors may be far removed from the source, for example contamination of watercourses, or changes in land-use, as a result of construction of transportation routes. It is crucial to consider immediate, short-term impacts as well as long-term, indirect and cumulative impacts from separate, but linked operations.

**Hydrocarbon Spills**

Large scale pollution is the primary environmental concern for georesource activity in the LIA. In Arctic environments pollution both onshore and offshore will persist longer than anywhere else. Responder’s time and efforts will be hampered by harsh environmental conditions, a near total lack of infrastructure and long distances. The environmental and ecological impact of Arctic contamination would depend on its timing and location relative to patterns of breeding, spawning and species migration. Sea birds, marine mammals, and fish larvae are particularly vulnerable to larger oil slicks and other industrial contaminants.

Arctic conditions impose significant environmental and logistical challenges. Responders need techniques to collect pollution in both heavy-ice conditions and open-sea conditions. Arctic pollution contingency plans emphasize multiple countermeasure options to manage a variety of contamination situations. Proven techniques include in situ burning in ice and fire-resistant booms in open waters as well as mechanical recovery with modern containment and recovery equipment. The current technologies and infrastructure for recovery of pollution from the surface perform poorly in high waves and rough weather conditions, and strong ocean currents in the LIA will spread the pollutants over extensive areas. In the Arctic, low temperatures and scarce sunlight over much of the year will slow evaporation rates as well as the physical, chemical and biological breakdown of pollutants. Ice in its various forms can make it more difficult to detect oil, and to encounter, contain and recover oil slicks with booms, skimmers, and other countermeasures Thus, hazardous compounds released during an emergency may remain in Arctic ecosystems for long periods of time, aggravating the risk of bioaccumulation.

Oil spill cleanup in an Arctic environment will never be a simple operation, however, some characteristics of the natural ice environment, if properly understood, can aid an offshore cleanup. Due to the cold temperatures and reduced wave energies in ice fields, spilled oil will weather more slowly, which may extend the window-of-opportunity for some countermeasures. Solid ice naturally contains and immobilizes oil for up to 230 days per year giving response crews some time to design and implement a plan for managing discharges.

Reports from both industry and government groups in the polar states have addressed strategies and techniques for handling pollutants in a variety of ice conditions. With very little infrastructure in the LIA from which to stage an effective recovery program it becomes obvious that Canada and Greenland are poorly equipped to handle such catastrophes. The rich and unspoiled ecosystems of the LIA will always be at risk from industrial activity. A comprehensive, international policy on clean-up response techniques, mitigation policies and liability recommendations is required.

## Conclusions

The LIA is a frontier region for petroleum and mineral exploration. Given the long lead times necessary to meet regulatory requirements, a lack of strategic infrastructure, economic factors and insufficient scientific data large scale production of resources in the LIA is unlikely to occur within the next 20 to 30 years.

The most probable targets for future georesource development in the LIA are:

1. Hydrocarbons – Development of West Greenland-East Canada Province is possible in 20 to 25 years if current seismic surveys delineate large-scale offshore structures. All the recent work is south of the LIA. The Greenland continental margin may be more prospective than the Sverdrup Basin due to infrastructure factors.
2. Zinc – Citronen Greenland mine site production is possible in 10 to 15 years if current activity demonstrates significant reserves.
3. Iron ore – Limited production at Mary River may begin in 2014 but large scale mining is probably 15 to 20 years away.

These estimates are best judgments by the author based on the content of this report and other readings, approximation of resource development costs, long project lead times in the Arctic and the current and likely future price of a georesource based on global supply and demand. As more data becomes available the estimates may become more refined.

Natural resource development, economic growth, ecosystem protection, and impact of climate change in the Arctic and the LIA all have one thing in common - a pressing need for science. Except for a few areas, LIA land masses, oceans, ecosystems and climate have received little attention or funding. There is a crucial requirement for scientific observations, including long-term monitoring and mapping programs, modern computer modeling, and development of technologies ranging from simple field sampling to sophisticated satellite monitoring systems to enable informed decision making by both public and private sectors in the LIA. This will require innovative, cooperative solutions to overcome the challenges of economic resource development in the LIA region.