FUEL CYCLE WASTES - THE CANADIAN PROGRAM

by

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INTRODUCTION

The Canadian program for management of fuel cycle wastes was discussed at the meeting of this group last year(1). That paper was concerned exclusively with the storage of CANDU fuel in interim facilities. Our use of interim storage facilities will be dealt with in this paper. In addition, during the past year we have made some progress in defining and outlining a program to develop techniques for ultimate storage, or disposal. That program will also be covered.

When interim storage is discussed, the reference material is spent fuel. The projected arisings curve is shown in Figure 1. However, ultimate storage techniques and reprocessing are both expected to reach maturity in Canada by the year 2000, so when geologic storage is discussed the reference material is solidified high level waste from a reprocessing plant. The alternatives are not excluded, of course. Fuel could be buried in deep mines, or wastes could be held for some time in interim storage, but that is not the plan.

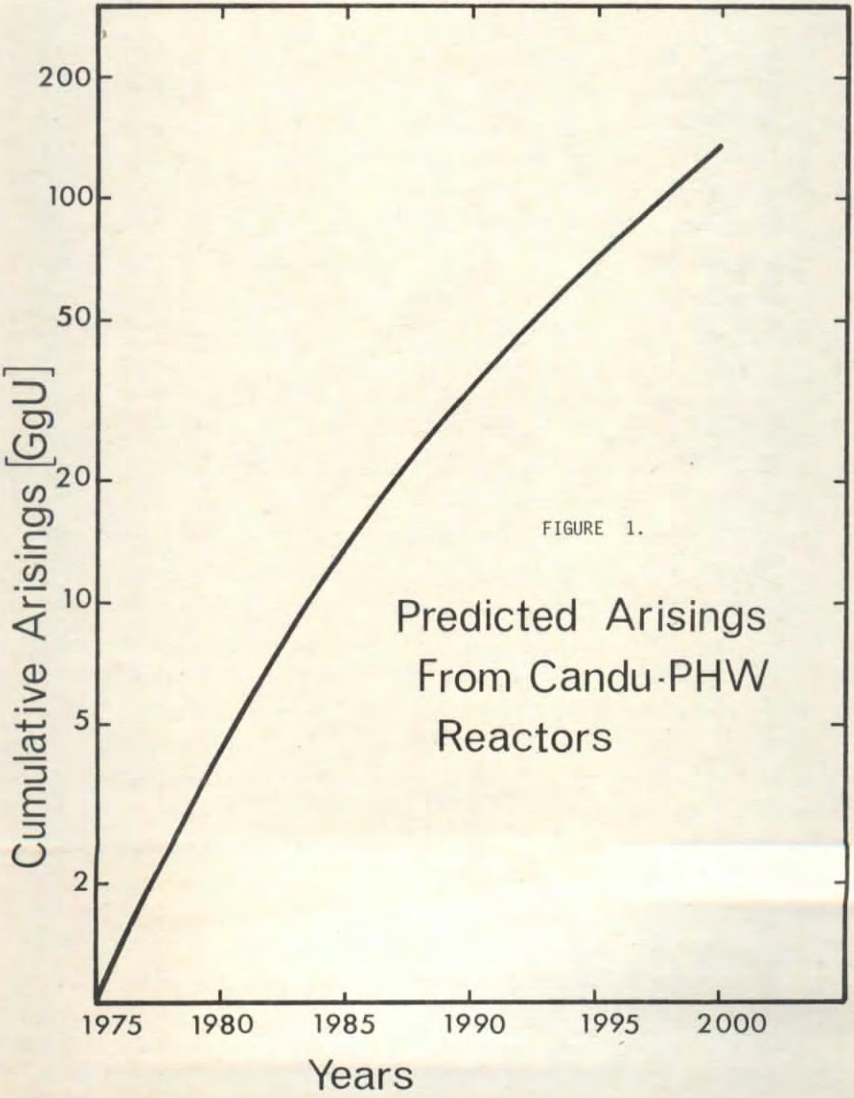


FIGURE 1.

Predicted Arisings From Candu-PHW Reactors

INTERIM STORAGE

The immediate problem is interim storage of spent fuel. There are two generally accepted methods - wet storage and dry storage. Wet storage techniques are well developed in Canada. All our reactors are built with facilities for storing the fuel arisings for 5 to 10 years, in water-filled pools. We have been storing fuel in pools for 25 years now, without difficulty. Since the quantity to be stored is becoming significant, the major nuclear utility in Canada, Ontario Hydro, is planning to develop a large, centrally located facility rather than expand the on-site pools(2). They expect this facility to be in operation by 1985.

However, pools are not ideal in that they require maintenance and produce secondary wastes. AECL has, therefore, undertaken the development of a dry storage system which eliminates these two problems. The first objective of the program is to demonstrate the feasibility of dry storage. As a reference concept, the concrete flask-type structure, which we call the canister, has been selected. A cutaway of a typical canister is shown in Figure 2.

Canadian and U.S. studies of dry storage techniques were carried out almost simultaneously, but quite independently(3,4). The fact that both concluded that a shielded cask has merit, and arrived at designs which are remarkably similar, suggests that this technique may be useful. The Canadian canister is cylindrical, about 5 m high, 2.5 m in diameter, with an internal cavity approximately 0.8 m in diameter and 3 m high. It is designed to hold 4.5 tonnes of spent fuel. Cooling air does not enter the structure. Heat transfer is by radiation and convection from fuel to basket, by conduction through the steel can, the lead shot, and the concrete wall, and then by natural convection from the outside surface of the canister. There are three barriers to release of activity from the fuel, not including the concrete - the fuel sheath, the seal-welded inner basket, and the seal-welded outer can. The primary function of the concrete is, therefore, shielding and isolation - not containment.

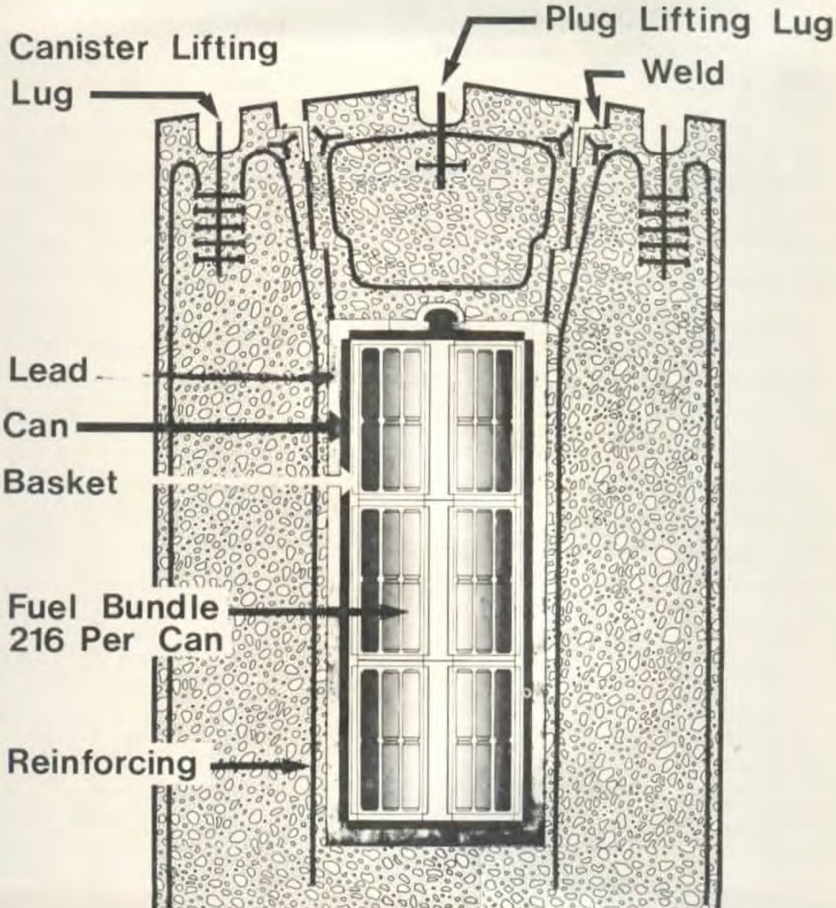


FIGURE 2. **CONCRETE CANISTER**

The canister appears to be a simple, straightforward device. However, there are several potential problems which must be investigated.

a) CONCRETE TEMPERATURE DIFFERENTIAL

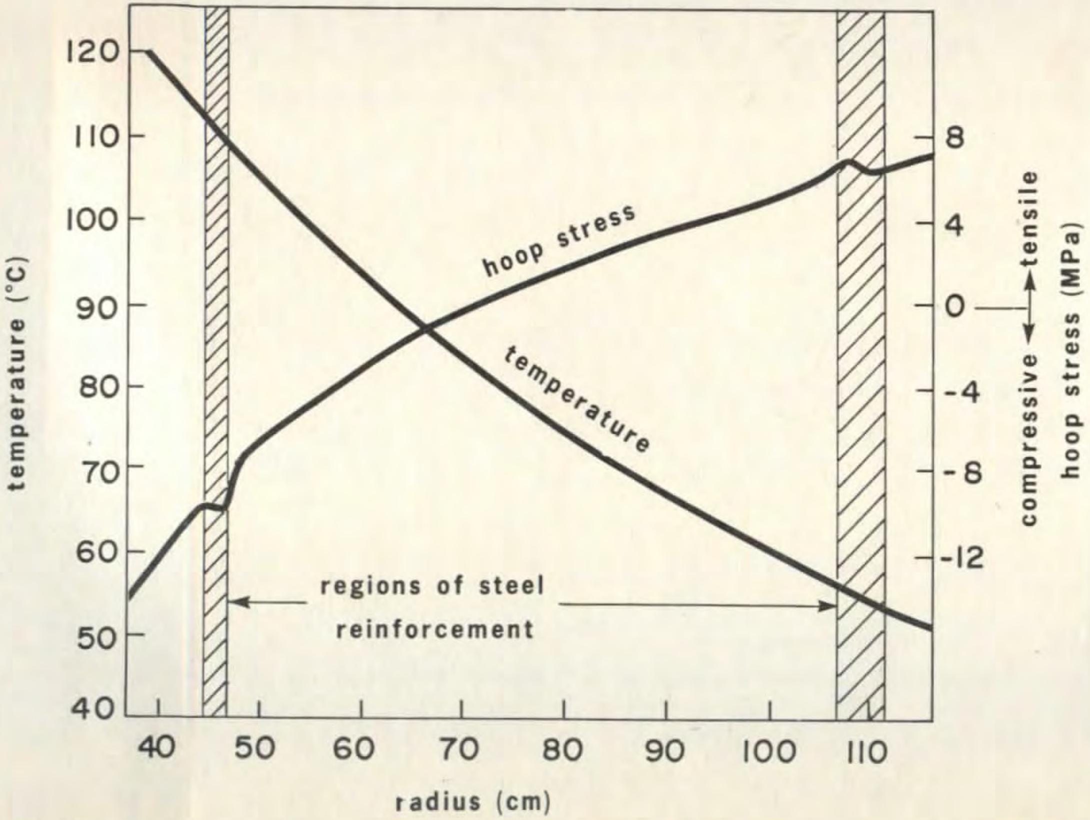
Each canister was designed to hold fuel producing, when initially emplaced, 2 kW. The calculated stress and temperature distributions for this load are shown in Figure 3. The temperature drop across the concrete is approximately 65 degrees C. The stress levels appear to be acceptable. The concrete should crack in the outer regions, but the reinforcing steel will prevent the cracks from growing to any significant width. Provided these calculations are shown to be correct or conservative, cracking will not present a problem. On the contrary - it may be possible to increase the initial heat load by shortening the cooling period before emplacement, or by increasing the fuel loading per canister.

b) BEHAVIOUR OF DEFECTED FUEL

Fuel which is known to be defected will be canned before installation in the canister basket. However, we must expect that incipient or undetected defects will be emplaced in some canisters. In air, at canister centerline temperatures, UO_2 gradually oxidizes to U_3O_8. Since U_3O_8 is less dense than UO_2, any defect will progressively worsen - the fuel will expand, the sheath will split, more UO_2 will be exposed, and so on. If the oxygen supply were unlimited, all the UO_2 in such defected elements would eventually be converted to U_3O_8 powder. Since the oxygen supply is sufficient to convert $< 0.1\%$ of the fuel in a canister, and two barriers to fission product release would remain intact, this would not cause any serious difficulties. However, with a view to eventual recovery of this fuel for reprocessing, we would prefer to prevent such deterioration. A simple solution seems to be to make the inner basket inert with an atmosphere of helium, argon, or nitrogen. This solution will be tested.

FIGURE 3.

TEMPERATURE AND STRESS DISTRIBUTIONS (2 kW)

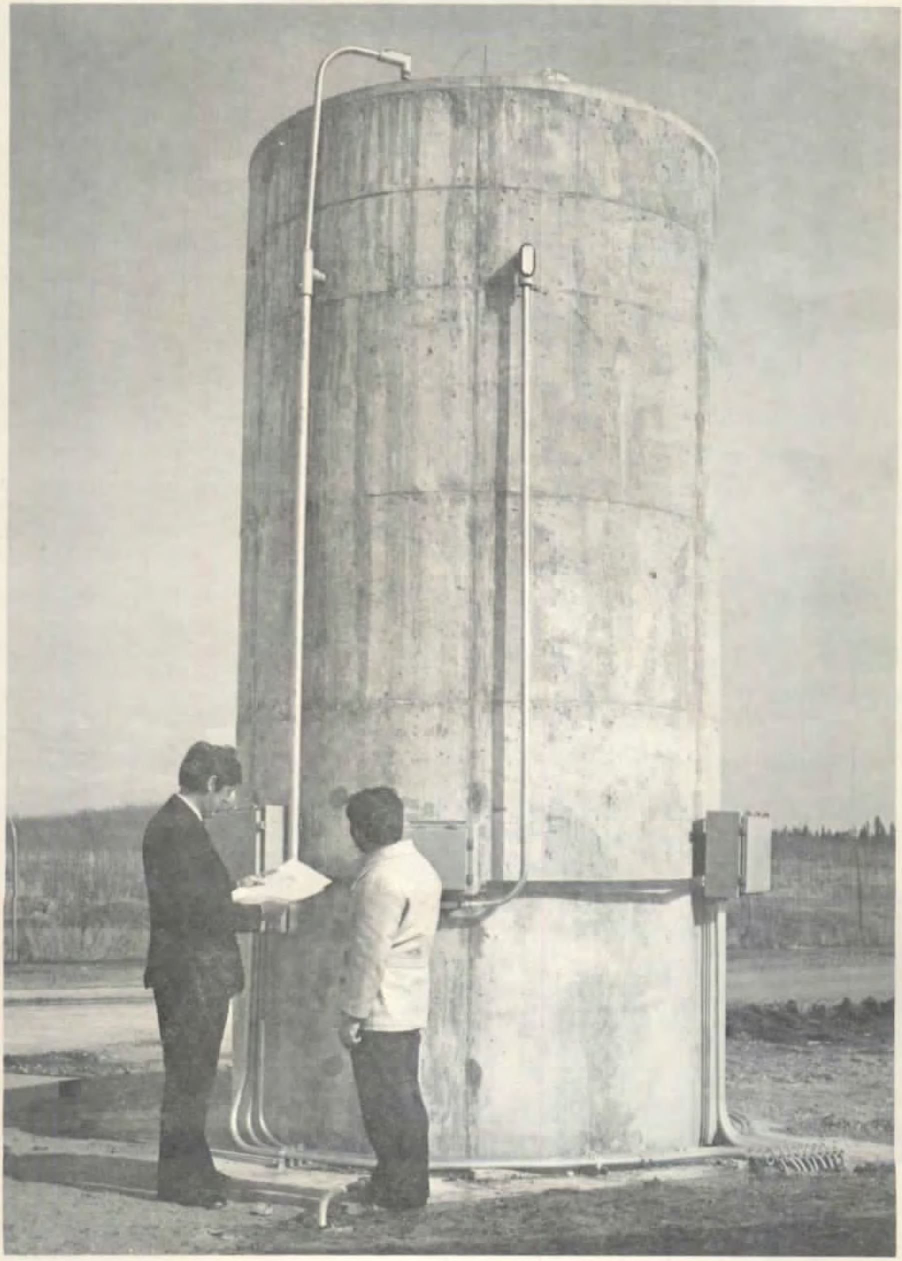


c) AMBIENT RADIATION FIELDS

Preliminary shielding calculations predicted a 15 mR/h field at the surface of the canister. More sophisticated calculations suggest that this result is high. Although no direct surveillance or maintenance of emplaced canisters is required, there will be operators in the area when new canisters are emplaced. It would be useful, therefore, if the field were low. Various methods of improving the effectiveness of the shielding can be considered, but all add mass and cost to the canister and are thus not desirable. We believe the latest calculations are still conservative. If measurements show they are not, the emplacement system could be designed to protect the operators.

An active test program is planned for the next two years. Four canisters are being built. Two will be heated electrically, with heaters capable of producing 20 kW each. The first heated canister is shown in Figure 4. If they survive the temperature tests, they will be put through severe mechanical loading tests, and finally through accelerated life tests. Two canisters will be fuelled, for radiation dose and temperature measurements, but primarily as a demonstration of the concept. Fuel will be emplaced in the first one this August. Some backup work will also be carried out. A design study on a canister storage facility is now in progress, to ensure feasibility and define costs more exactly. Experimental and analytical work on heat transfer in clusters of rodded bundles has also been initiated.

FIG 4
FIRST HEATED CANISTER



ULTIMATE STORAGE

Most of the effort, however, will be directed towards the development of techniques for ultimate storage of nuclear wastes. In common with many other countries, Canada expects that for the long term these wastes must be buried. A program to demonstrate a geological concept is therefore being prepared.

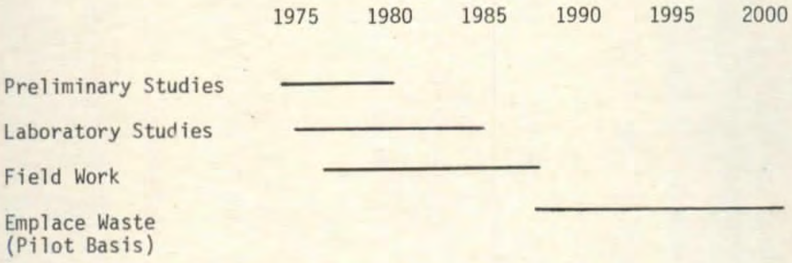
AECL has an agreement for co-operation with the USERDA in this area, and several meetings have been held with ERDA and HNL staff. The rationale for this program is therefore based, in part, on avoiding duplication of effort. However, it is necessary to ensure that U.S. work is applicable to Canadian conditions. Furthermore, the Canadian view is that it will take a long time to demonstrate that acceptably low risks result from burial. Therefore, retrievable storage at modest depths for an interim period seems prudent. The interim period is not defined at the moment, but could be in the range 25 to 100 years. The reference concept is presently based on the retrievable mined cavity concept described by Battelle(5). When the facility has been successfully demonstrated, it can be backfilled and sealed.

At the moment, two host materials for the mined cavity are being examined. One is an igneous intrusive rock such as granite. The second is salt. A scoping study on serpentinite is being carried out as well, but it has some drawbacks. Clays and shales have been ruled out. Mining problems would exist in the short term and there will be glacial problems in the long term. The intent, therefore, is to choose between rock and salt, and to demonstrate the mined cavity concept in the chosen medium.

The program schedule is shown in Figure 5. There are four segments - preliminary studies, laboratory studies, field work, and pilot emplacement of wastes. A period of five years has been allowed for the preliminary studies, and there are four main topics:

FIGURE 5

PROGRAM SCHEDULE - ULTIMATE STORAGE



1. Survey of Canadian salt
2. Choice of hard rock
3. Choice of potential sites
4. Conceptual design study.

Laboratory studies include topics like radiation stability, energy storage, waste/rock interactions, chemical and physical properties. The field studies include an in situ heating experiment, a detailed geological survey of the site, and construction of a mine. Finally, wastes would be emplaced on a pilot basis and monitored for 10 to 15 years. Most of the geological work will be carried out by the Geological Survey of Canada. However, participation by universities, private consultants, and other government agencies will be encouraged.

The final decision to convert the test facility to a repository would not likely be made before the year 2000.

The program is presently in its infancy, but some useful data are beginning to emerge. The information the GSC has already assembled on salt is of considerable interest. The major Canadian salt formations are listed in Table 1. They overlap in some areas, and thus there are five major blocs:

1. In the far north
2. Under Hudson Bay
3. In Saskatchewan and Alberta
4. In southern Ontario
5. In the St. Lawrence-Atlantic region.

A preliminary assessment indicates some drawbacks in each of these areas. The far northern deposits are extremely remote and are currently being intensively investigated for oil and gas. The Hudson Bay Basin is totally under the bay. Similarly, the salt in the St. Lawrence-Atlantic region is nearly all under water. It consists mostly of domes much like the Gulf Coast region in the U.S., and some of the domes extend almost up to the ocean floor. None of these blocs, therefore, seem promising. The large basin underlying the prairies meets many of the obvious requirements, but it too has certain problems. The best salt occurs at the 3000 to 5000 foot levels, which is rather deep for retrievability. This is a major oil and gas area as well as a potash producer. The salt is overlain by a large aquifer known as the Blairmore formation. At least one potash mine has been flooded in the past. And finally, this is primarily an agricultural area and no nuclear facilities are planned there for some time. So for both technical and political reasons this area may not be acceptable. The Michigan Basin in Ontario may contain the Canadian salt best suited for disposal. However, U.S. studies have not placed this area high on the list of good prospects, although it extends into New York and Pennsylvania. Also, one would have to consider the fact that this salt underlies large areas of the Great Lakes system.

In summary - there are large reserves of salt in Canada, but it is not clear at the moment that specific useful areas for waste disposal will be found.

Hard rock in the Canadian Shield seems attractive as a possible alternative. The Shield is a horseshoe shaped region centered on Hudson Bay and covering more than half of the Canadian landmass. It extends south into New England and the Minnesota/Wisconsin area as well. Within the Shield area there are many large granite intrusions which are relatively homogeneous and thought to be free of cracks and joints at relatively modest depths. These intrusions, or plutons, may be useful for waste disposal. Specific advantages which have been identified include:

1. The Shield is billions of years old, and tectonically stable.
2. Most of the Shield is in the Arctic watershed.
3. The geothermal gradient is low.
4. Much of the Shield is almost totally uninhabited.
5. The major load growth areas are within the Shield.
6. Dry mines in granite are known to exist.
7. Future mining within the plutons is not likely because the formations are essentially worthless.

The major potential disadvantage identified is that thermal stresses may cause cracking which could lead to permeability. If this can be shown to be improbable or inconsequential, there seem to be no serious obstacles to construction and operation of repositories in hard rock.

Screening studies have just begun. Topics which are being reviewed include:

1. Seismicity
2. Expected glacial coverage
3. Population density
4. Transportation networks
5. Watersheds
6. Major fault systems
7. Mining activity
8. Land use, parks, etc.

Exploration and drilling are expected to begin in 1976.

SUMMARY

AECL is developing an alternative to water bays for retrievable surface storage. The main thrust of the program, however, is in the direction of geologic storage. Initially, at least, these facilities will have to provide for relatively easy retrieval. A facility should be licensed and available for industrial scale storage by the end of the 20th century. Within the context of Canadian requirements, this timing is entirely satisfactory.

REFERENCES

1. W. W. Morgan - "The Management of Spent CANDU Fuel" - Waste Management '74 - April 1974.
2. R. W. Barnes and S. A. Mayman - "The Canadian Program for Management of Spent Fuel and High Level Wastes" - ANS/CNA Topical Meeting on Commercial Nuclear Fuel Technology Today - April 1975.
3. Report of the Committee Assessing Fuel Storage - AECL-5114 - December 1974.
4. D. C. Nelson and D. D. Wodrich - "Retrievable Surface Storage Facility for Commercial High-Level Waste" - Waste Management '74 - April 1974.
5. Battelle Pacific Northwest Laboratories - "High-Level Radioactive Waste Management Alternatives" - BNWL 1900 - May 1974.

TABLE 1

SALT DEPOSITS IN CANADA

Deposit	Location	Age
Sverdrup Basin	Arctic Islands, parts of Melville, Ellef Ringnes, Amund Ringnes and Heiberg Islands	Pennsylvanian-Permian
Franklinian Miogeosyncline	Arctic Islands, parts of Melville, Cornwallis, Devon and Ellsmere Islands	Ordovician
Mackenzie Trough	District of Franklin Mainland	Cambrian
Elk Point Basin	Manitoba, Saskatchewan and Alberta	Devonian
Hudson Bay Basin	Central Hudson Bay	Ordovician, Silurian, Devonian
Michigan Basin	Southern Ontario	Silurian
Magdalen Basin and Adjacent Sub-Basins	Gulf of St. Lawrence and Adjacent Parts of Nova Scotia, New Brunswick and Prince Edward Island	Mississippian
Sydney Basin	Laurentian Channel and Western Grand Banks	Mississippian
St. Anthony Basin	N.E. Newfoundland Shelf	Mississippian
Scotian Basin and Adjacent Sub-Basins	Scotian Shelf and Western Grand Banks	Triassic-Jurassic
Saglek Basin	S.E. Baffin Shelf	Ordovician-Silurian?