Uranium in Nova Scotia: A Background Summary for the Uranium Inquiry, Nova Scotia

Nova Scotia

Department of Mines and Energy

Report 82-7

PROVINCE OF NOVA SCOTIA

DEPARTMENT OF MINES AND ENERGY

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URANIUM IN NOVA SCOTIA: A BACKGROUND SUMMARY FOR THE URANIUM INQUIRY - NOVA SCOTIA

1982

Honourable Ron Barkhouse, Minister

John J. Laffin, P. Eng., Deputy Minister

HALIFAX, NOVA SCOTIA

1982

FOREWORD

This report was developed for presentation to the Uranium Inquiry - Nova Scotia, on October 8, 1982. Demand for additional copies and the assumption that the technical information on uranium exploration and geological research in Nova Scotia is of interest to a wider audience have prompted the establishment of this document as a Departmental publication.

The submission was prepared by the staff of the Mines and Minerals Branch but more specific acknowledgment of certain contributions is appropriate. Mr. George O'Reilly of the Project Geology Section coordinated report preparation and personally conducted most of the scientific compilation and research, based in part on his direct field studies of the granitic terranes of Nova Scotia.

Staff of the Mineral Inventory and Mineral Titles Sections contributed concise indices of their extensive Assessment Report and Mineral Title Map files. In particular, Norman Lyttle, Janet Gillespie-Wood and Rick Ratcliffe are to be commended. The manuscript was critically reviewed by Dan Murray, John Fowler and Kathy Mills.

Thanks are also extended to staff of the Cartography Section and to Lois Miller, who typed the numerous drafts of this report.

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SECTION 1

INTRODUCTION

Since the mid 1970's Nova Scotia has experienced increased exploration for a number of commodities including uranium. The exploration activity for uranium has resulted in discovery of significant occurrences of the element. It became obvious to the Government of Nova Scotia that a segment of the population of the Province is concerned about the potential hazards associated with the exploration, mining and milling stages of the uranium industry. Public concern has resulted in the appointment of a Commissioner under the Public Inquiries Act of Nova Scotia to inquire and make recommendations to the Governor-in-Council on all aspects of exploration, development, mining, processing, storage, waste management and transportation of uranium in any form.

The regulation of mineral exploration and mining activities is carried out by the Nova Scotia Department of Mines and Energy through the Mineral Resources Act of the Province of Nova Scotia. The regulation of the special radioactive aspects involved in the mining and processing of uranium ore is the responsibility of the federal Atomic Energy Control Board.

The purpose of this report is to:

- outline the history of uranium exploration in Nova Scotia.
- summarize the results of geological surveys by provincial and federal government agencies, universities and exploration companies which document the natural levels of radioactivity in the Province.
- briefly outline the physical and chemical characteristics of uranium and thorium which make these elements unique and a potential environmental and health concern.
- outline chronologically the steps taken by the Nova Scotia Department of Mines and Energy to monitor and regulate uranium exploration activities.
- classify the types of uranium deposits known to occur in Nova Scotia and describe their main geological features.
- outline the role of the Nova Scotia Department of Mines and Energy in the regulation of mining activities in the Province.

The report is written for the interested layman, but some aspects assume the reader has some background knowledge of geological processes.

SECTION 2

HISTORY OF URANIUM EXPLORATION IN NOVA SCOTIA

Introduction

Occurrences of uranium-bearing minerals have been known in Nova Scotia since early in this century. Prior to 1976 only sporadic exploration programs for uranium were conducted. In the years 1976 to 1981, a combination of geological and economic factors resulted in extensive exploration programs being carried out in certain geological terranes of Nova Scotia.

Exploration for Uranium Prior to 1976

Gross (1957) has described many of the occurrences of radioactive minerals known in Nova Scotia up to that time. Radioactive minerals were first identified in Nova Scotia associated with some of the many tin, tungsten and molybdenum occurrences in the New Ross, Lunenburg County area (Johnston, 1915). Faribault (1924 and 1931) indicated these occurrences on geological maps of the New Ross area. Radioactive mineral occurrences similar to those at New Ross were found in granitic rocks near Georgeville, Antigonish County about 1953 (Gross, 1957). The New Ross and Georgeville occurrences compared geologically to commercial uranium deposits in the Bancroft area of southern Ontario, but were much smaller. Evaluations at that time indicated they had little economic potential. This type of occurrence is described in detail in Section 7, Uranium and Thorium Occurrences of Nova Scotia.

Perhaps the most significant uraniferous deposits examined during the pre 1976 era were those known to occur in the coal-bearing sandstone sequences of northern mainland Nova Scotia. Brummer (1958) described uranium mineralization associated with many of the previously known copper sulphide deposits in the sandstones of the Pictou Group. The sub-economic copper mineralization had been known for some time. The recognition of radioactivity in the copper ores in the early 1950's led to re-examination of the showings to determine their potential for uranium. Brummer (1958) concluded that due to the local extent of the mineralization and the uranium prices of the day, the deposits did not have economic potential. These deposits are also described in Section 7.

Appendix I contains a map showing areas where exploration for uranium was conducted prior to 1976. Prior to 1975, exploration for uranium did not require a special licence, since exploration for it was usually conducted as part of the exploration program for other elements. The areas designated as explored for uranium prior to 1976 (Appendix I, Item 1) represent only those areas where uranium was indicated as an element of interest on the general licence application. Since these preliminary exploration programs indicated discouraging results, very little assessment work was submitted to the Nova Scotia Department of Mines and Energy and no licences were renewed for a second year.

During the early-to mid-70's, a change in philosophy regarding mineral exploration in Nova Scotia took place as a result of a number of factors. Methods of regional geochemical and geophysical exploration for uranium had been refined which contribute to greater efficiency in detecting bedrock concentrations of uranium. Regional exploration surveys utilizing these refined techniques were done by the Geological Survey of Canada in various areas of the Province in the mid 70's. The data resulting from these surveys did much to stimulate exploration in Nova Scotia (See Section 5, Natural Levels of Radioactivity in Nova Scotia). At the same time, a number of companies and individuals became interested in fully testing the realization that the geological and mineral deposit evolution of Nova Scotia was comparable to that of western and central Europe. In the past, the types of mineral deposits found in Nova Scotia tended to be compared (generally unfavorably) with those found elsewhere in North America. With the refining of the hypothesis of Continental Drift, it became clear that similar geological processes were active in parts of Nova Scotia and western and central Europe in the period 300-400 million years ago. A reconstruction of the positions of the continents as they existed approximately 350 million years ago (Fig. 2-1) shows the probable position of Nova Scotia, relative to Europe. This relationship suggested to explorationists that Nova Scotia may contain mineral deposits identical to those already common in these other regions. Therefore, similar commercial deposits of tin, tungsten, uranium, molybdenum, antimony, copper, lead, zinc, silver and beryllium, well established in Europe, might also exist in Nova Scotia.

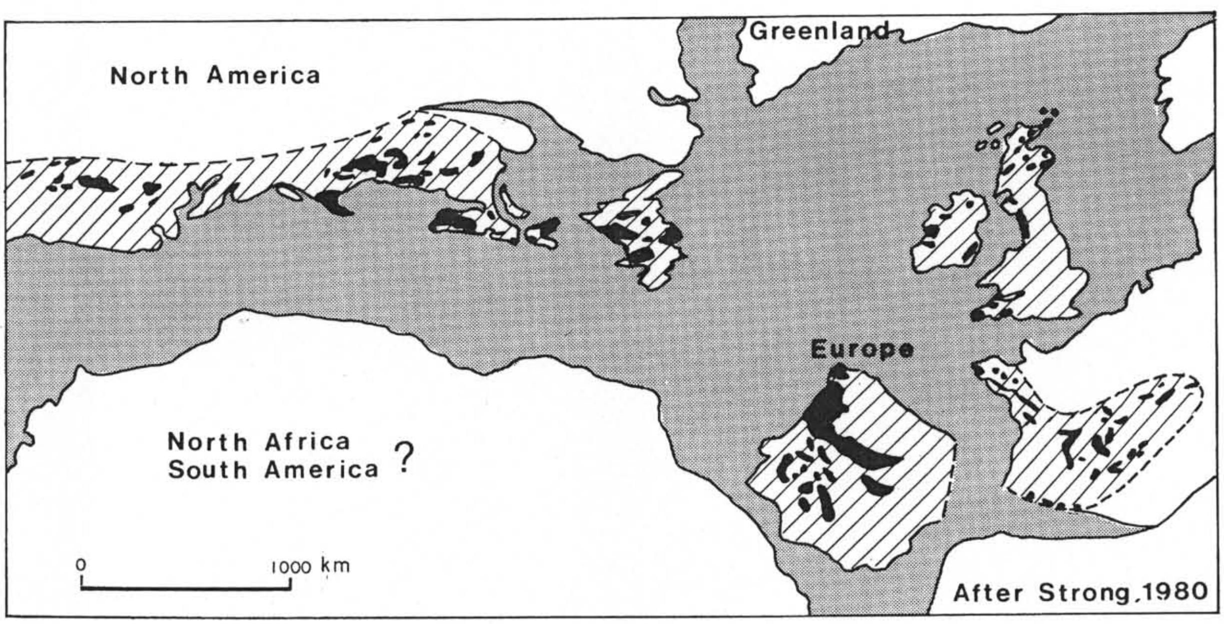


Figure 2-1. Reconstruction of relative positions of circum-Atlantic continents 300-400 million years ago. Major granitic bodies (black) and areas affected by the continental collisions (diagonal lines) are indicated.

During this same period Dyck et al. (1976) published the results of a regional well water survey of northern Nova Scotia, eastern New Brunswick and Prince Edward Island (Fig. 5-5). Uranium, radon and radium contents of groundwater had been recognized as a valuable tool in exploration for concealed uranium orebodies. In areas where good areal distribution of wells exists, such as in northern Nova Scotia, testing well waters is potentially an excellent means of uranium exploration. Dyck (1979) described the hydrogeochemical characteristics of uranium and its daughters which enhance the feasibility of well water surveys relative to detection of bedrock uranium sources.

Exploration for Uranium 1976 to Present

The results of Dyck et al. (1976) directed uranium exploration interest to the large sedimentary basins of northern Nova Scotia. The map showing areas held under exploration licences for uranium, December 1976 (Appendix I, Item 2), indicates the principal areas of interest in Nova Scotia at that time. Since uranium, by this time, had been placed under a special licence category (see Section 3, Government Action Regarding the Exploration of Uranium), these new areas of exploration interest were easily identified.

Lacana, Gulf Minerals and Noranda staked large tracts of land in the sedimentary basins of the Pugwash-Tatamagouche area and Getty Minerals in the sedimentary rocks of the North Mountain region of the Annapolis Valley. The geological setting, high uranium and radon content in well waters and the known existence of small radioactive mineral occurrences in these sedimentary rocks suggested a good potential for sandstone type uranium deposits. This type of deposit is described in Section 7, The Uranium and Thorium Occurrences of Nova Scotia.

The discovery of uranium mineralization at McLean Point, east of Pugwash, during regional exploration by Lacana in 1976 further substantiated the excellent potential of these rocks and resulted in increased exploration activity for this type of deposit in the years to follow.

Getty Minerals exploration activities along the North Mountain of the Annapolis Valley produced unfavourable results and by 1978 exploration for sandstone type deposits in that area ceased.

Gulf Minerals, while exploring for sandstone type deposits in the Pugwash area encountered radioactive boulders of volcanic rock in a breakwater along the Northumberland Strait at Port Howe, Cumberland County. Inquiries as to the origin of the boulders used to construct the breakwater led Gulf to the Folly Lake quarry area of Colchester County where additional radioactive boulders were located. This alerted Gulf Minerals geologists to the potential of uranium mineralization in the volcanic rocks of the Cobequid Highlands. This type of uranium mineralization was previously unknown in Nova Scotia. This finding resulted in Gulf Minerals initiating extensive exploration programs in the Cobequid Highlands which continued until the parent Gulf Oil Corporations decision to cease mineral exploration business in Canada in the spring of 1982.

The Geological Survey of Canada released the results of a regional airborne radiometric survey of southern mainland Nova Scotia in 1976 (No. 1 on Fig. 5-1). The survey indicated many areas of anomalous radioactivity associated with the granitic rocks and resulted in followup airborne and ground surveys by many exploration companies. The ensuing exploration rush into the granitic terrane of southwestern Nova Scotia (South Mountain batholith), and the already extensive areas staked in the sedimentary basins, resulted in a peak in acreage under licence for uranium in Nova Scotia in 1977 (Fig. 2-2; Appendix I).

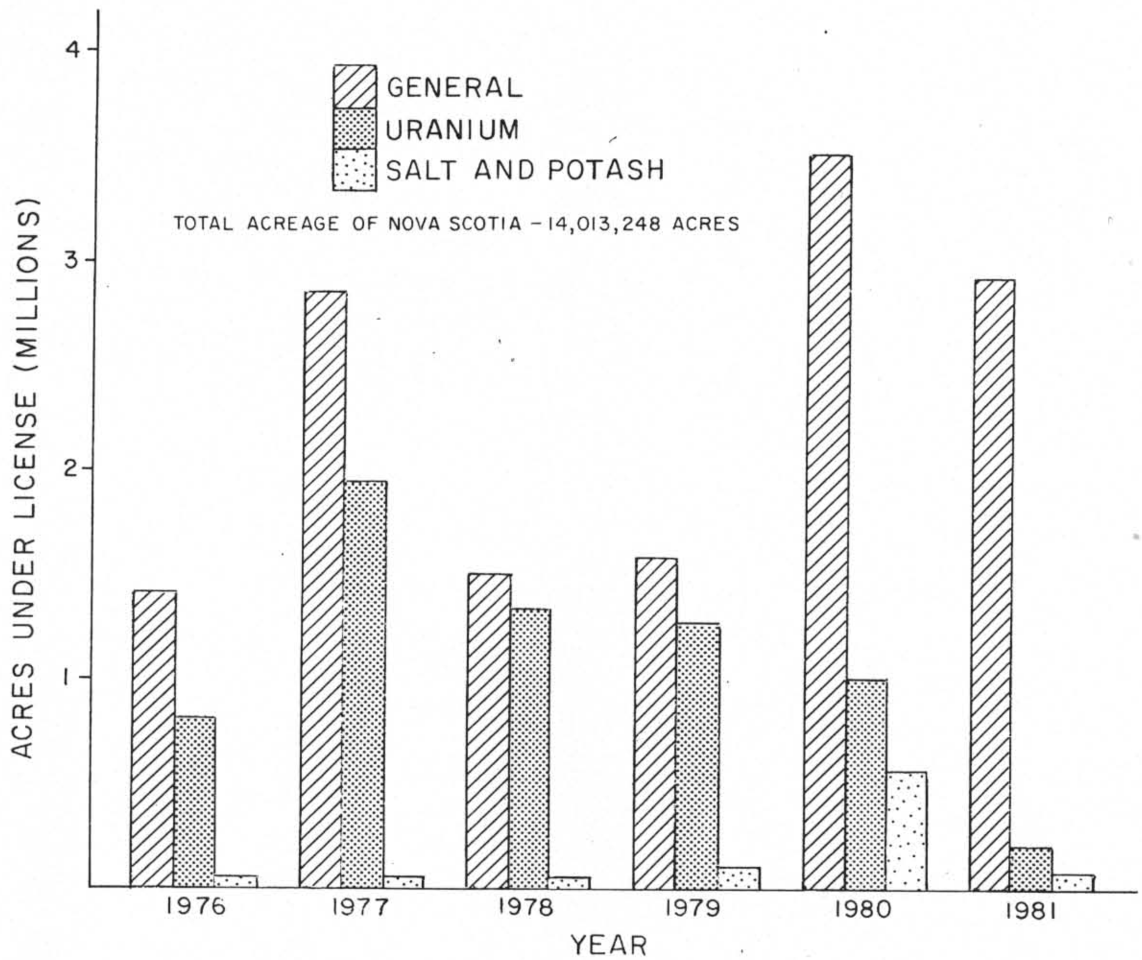


Figure 2-2. Total acreage staked in Nova Scotia for general licence, uranium special licence and salt and potash special licence for the period 1976-1981.

Esso Resources Canada Limited, during reconnaissance radiometric surveys, discovered uranium mineralization in the granitic rocks along a logging road west of Gaspereau Lake, Kings County and in a gravel pit at East Dalhousie, Annapolis County in the summer of 1977 (Lowe and Farstad, 1978a and b). In 1978 uranium mineralization was also discovered by

Aquitaine Company of Canada Limited in the granitic rocks near Vaughan, Hants County and by Shell Canada Resources Limited in the granitic rocks along the south margin of the Annapolis Valley.

The private sector exploration programs subsequently recognized that these occurrences are a type of uranium deposit in the granitic rocks of the South Mountain batholith which was not known previously in Nova Scotia or the Canadian Appalachians. Continued exploration and geological research established that these uranium vein deposits (Fig. 7-2) were quite similar to those described in the European and Russian geological literature. To date, exploration has established significant deposits of tin and uranium in the granitic rocks and interesting occurrences of tungsten, molybdenum, silver and zinc are being tested. This partially confirms the correlation with Europe after only a relatively short period of modern exploration.

By 1979 Esso Resources Canada Limited discontinued uranium exploration activities in Nova Scotia, although they retained some of their holdings to further examine their potential for tin and tungsten deposits. Aquitaine and Shell and companies such as E and B Explorations Limited, Eldorado Nuclear, Norcen and Saarberg Interplan continued a high level of exploration activity in the granitic rocks until the moratorium on uranium exploration in Nova Scotia in September 1981.

Charbonneau and Ford (1978) described uranium mineralization at the base of the Windsor Group sedimentary rocks near South Maitland, Hants County. This discovery was the result of the federal airborne radiometric survey of that area in 1976 (No. 3 on Fig. 5-2) and prompted extensive staking by International Mine Services Limited and Saarberg Interplan in the area between Windsor and Truro in 1977. By 1979 discouraging results led International Mine Services to drop much of their ground but Saarberg had sufficiently encouraging results to continue their exploration.

Figure 2-2 shows a year by year breakdown of the acreage staked in Nova Scotia since 1976 for the three categories; general licence, uranium special licence and salt and potash special licence. Appendix I includes year by year maps for 1976-1981 showing areas of Nova Scotia held under special uranium exploration licences. Figure 2-2 and the maps in Appendix I show a peak in acreage staked for uranium in 1977 with slight yearly decline until 1980. This decline was due to the following factors: (1) decrease in exploration activity within the sedimentary basins (2) companies changing their exploration programs from regional to more detailed and localized scales, thus involving larger expenditures on less ground. It should be noted that although total uranium acreage for the Province declined, the uranium acreage staked within the South Mountain batholith remained at a constant high level.

The map showing areas held under uranium licences for December, 1981 indicates the effect of the moratorium on the issuance and renewal of special uranium exploration licences on September 22, 1981.

Figure 2-3 is a graph of estimated exploration expenditures for the total of all exploration licences compared with one for special uranium licences for the period 1975 to 1982. The anticipated decline in expenditures for 1982 is due to a combination of factors. A nation-wide decline from 1981 was inevitable due to declining metal prices and general recession. In conjunction with this trend a number of energy companies with large programs in Nova Scotia (e.g. Shell, Gulf and Norcen) ceased operation of their Canadian mineral exploration sections early in 1982. Their unexpected cessation of operations will have a marked negative effect on exploration expenditures in the Province in 1982. The decrease in expenditures due directly to the uranium moratorium is therefore difficult to estimate since a significant amount of uranium exploration was conducted by these Energy companies. Figure 2-3 shows an overall decrease from 3.5 million dollars in 1981 to zero in 1982 for uranium exploration. The zero estimate for 1982 is due to the current moratorium on all uranium exploration activity.

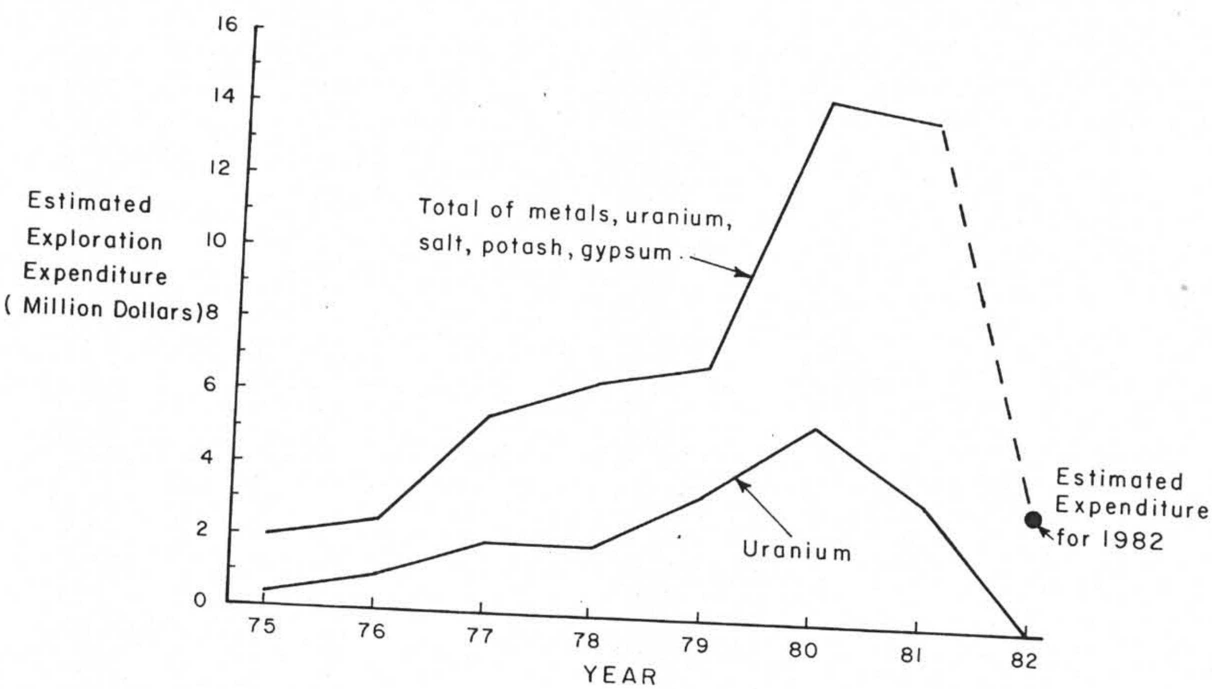


Figure 2-3. Estimated exploration expenditures for all exploration licences and for uranium special licences in Nova Scotia for the period 1975-1982.

Appendix I includes a map showing areas requested for special uranium licences. These lands are closed to exploration for all minerals pending a Cabinet decision as to what action is to be taken on the issue. (See Section 3, Government Action Regarding the Exploration of Uranium).

Uranium Assessment Reports

The Nova Scotia Department of Mines and Energy is responsible for the monitoring and approving of work done on all mineral exploration licences in Nova Scotia. Exploration activity is monitored on a regular basis by regional geologists. Technical assessment reports containing details of all physical and scientific activity performed on a mineral property must be submitted and approved on an annual basis as part of the licence renewal process. Such reports are also required for special uranium licences. All information relating to anomalous distribution of uranium, and its daughter products, are a necessary part of such reports. The assessment reports are required as part of the renewal procedure for all types of mineral exploration licences. Special uranium exploration licences require that a full report on all geological investigations conducted on the property be submitted to the Nova Scotia Department of Mines and Energy on an annual basis. As stipulated in the Regulations under the Mineral Resources Act (Section 8) assessment reports on exploration programs are maintained in confidential files for a period of two years from date of submission to the Department. When information is received documenting potential health and environmental impacts, the appropriate agencies are notified (Fig. 2-4). After the two-year confidential period, or when the ground is dropped, all reports become non-confidential (open file) and are available to the public.

Appendix II is a compilation of open file uranium exploration assessment reports submitted to the Nova Scotia Department of Mines and Energy up to the end of December 1979. The compilation consists of a table indicating what information is available and what types of exploration surveys were conducted. An index map is included (pocket in back) which shows the areas covered by the various assessment reports listed in the table. All reports indexed in Appendix II are kept in the library of the Nova Scotia Department of Mines and Energy offices in Halifax and Stellarton. The Map Sheet/Report Number reference system of the Department is indicated for each report.

Appendix III consists of a similar compilation table and index map (pocket in back) for reports submitted during 1980 and 1981. The date when these reports reach open file status is indicated.

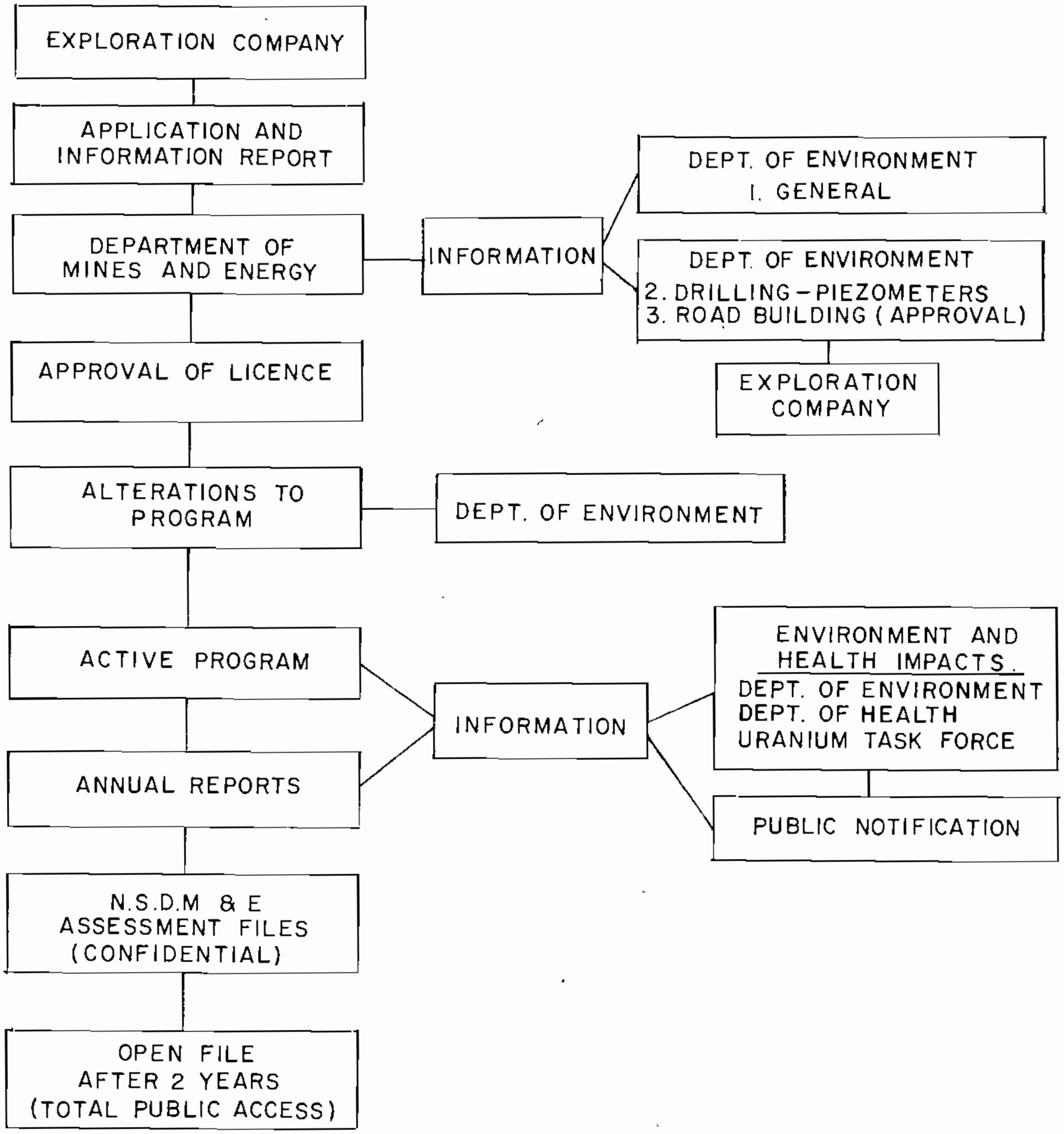


Figure 2-4. Reporting procedures for special uranium licences and renewals.

SECTION 3

GOVERNMENT ACTION REGARDING THE EXPLORATION OF URANIUM

Introduction

The Nova Scotia government has jurisdiction over all the mineral resources of the Province. The issuing and renewing of mineral exploration licences and the monitoring and approval of work done on mineral lands is the responsibility of the Nova Scotia Department of Mines and Energy through the Mineral Resources Act, Chapter 12 of the Statutes of Nova Scotia, 1975. It is the purpose of this section to discuss the sections of the Act which relate to exploration for uranium.

Designation of Uranium to Special Licence Category

In May, 1975 the Mineral Resources Act of Nova Scotia was revised to allow withdrawal of any lands in the Province from application for an exploration licence for all or certain minerals. Coal, uranium, salt and potash were withdrawn in accordance with Section 24 of the Mineral Resources Act (Appendix IV, Item 1). The government felt that, in the case of uranium (the other 3 commodities will not be discussed), it was necessary to monitor the progress of exploration for this energy-related commodity through special Order-in-Council agreements. This action enabled the government to know where and by whom such activity was being carried out for uranium. Section 24, (2) states "Lands withdrawn from application for a licence may be worked, licensed or leased under an agreement or arrangement with the Crown in such a manner and upon such terms and conditions as may be provided by order of the Governor in Council". At that time the only special terms and conditions required were the submission of a work proposal. Other than these, exploration for uranium was carried out in accordance with existing regulations for all minerals.

Formation of the "Guidelines" for Uranium Exploration in Nova Scotia

After the revision of the Act in 1975, monitoring of special uranium exploration licence programs was carried out by Nova Scotia Department of Mines and Energy staff along with monitoring of general exploration programs. In the fall of 1979, Aquitaine Co. of Canada Ltd., approached the Department of Mines and Energy indicating that their initial exploration in the Vaughan area of Hants County suggested a potentially sizable uranium ore body might exist near Millet Brook. With this potential established, the government was made aware that at least one uranium program was ready to enter an advanced exploration stage involving detailed diamond drilling and other forms of ground disturbance. With the now recognized potential that similar prospects might also be found, and that future mine development was a possibility, additional steps were taken to more closely regulate uranium exploration.

On June 16, 1980, a letter was sent to all exploration interests active in the Province informing them of the following points:

(1) Clarification of Department of Mines and Energy policy toward areas of overlap of general and special exploration licences for uranium, salt and potash.

(2) Reminder of Mineral Resource Act regulations regarding trespass on private and crown lands.
(3) Notification that the Department of Mines and Energy was in the process of formulating special guidelines for uranium exploration.

Also on June 16, 1980, a "Notice to Landowners" was placed in regional newspapers throughout the Province. The notice informed the public of Mineral Resource Act regulations pertaining to trespass on private and crown land by those holding mineral exploration licences. (Appendix IV, Items 2 and 3).

A first draft of Guidelines for Uranium Exploration in Nova Scotia was completed and sent to all uranium exploration interests, other government agencies, and the Halifax-based Ecology Action Centre, for constructive comments, on September 23, 1980. (Appendix V).

After consultation with the Nova Scotia Department of the Environment and incorporation of comments from industry and environmental groups, the second draft of the "Guidelines for Uranium Exploration in Nova Scotia" was completed and distributed on April 3, 1981 (Appendix VI).

Guidelines Formalized as "Terms and Conditions"

The covering letters accompanying the first and second drafts of the guidelines (Appendices V and VI) stated that it was the intention of the Department of Mines and Energy to establish formal regulations for uranium exploration from the guidelines. In August 1981, the guidelines were formalized as "Terms and Conditions Governing Special Uranium Exploration Licences in Nova Scotia", pursuant to the existing wording of Section 24, (2) of the Mineral Resources Act, i.e. that detailed uranium exploration may be conducted under a special licence for a period of one year "upon such terms and conditions as may be provided by order of the Governor in Council". This move formally tied the "guidelines" to the granting of each specific special uranium licence by Order-in-Council, therefore enabling Cabinet to revoke any licence if the Terms and Conditions Governing Special Uranium Exploration Licences were not met. In this sense, the Terms and Conditions were more restrictive on licence holders than regulations, since the determination of adherence to the prescribed procedures was a direct Cabinet decision. A copy of the Terms and Conditions Governing Special Uranium Exploration Licences in Nova Scotia is given in Appendix VII.

Uranium Task Force

The Inter-Departmental Uranium Task Force instituted by the Nova Scotia Department of Health in October 1980 used well water analyses reported by exploration companies and government agencies to determine areas of potential health concern throughout the Province. The Task Force is made up of representatives of the Departments of Health, Environment, Mines and Energy, Municipal Affairs and the Victoria General Hospital. The data from assessment files kept by the Nova Scotia Department of Mines and Energy showed that 6% of the 3350 wells tested contained uranium concentration in excess of 20 parts per billion (ppb). The Guidelines for Canadian Drinking Water Quality 1978, recommended the maximum acceptable concentration for uranium in drinking water be lowered from 5000 ppb to 20 ppb. These guidelines became available to the public early in 1979.

It should be noted that sampling was mainly conducted in areas where high background uranium had been established by previous geological, geochemical and/or geophysical surveys.

Formation of a Select Committee

On April 3, 1981, Cabinet announced the formation of a Select Committee of members of the House to investigate all scientific and technical information related to the protection of workers, the public and the environment associated with the uranium mining cycle, and in particular, the relevance of this data to potential uranium mining environments in Nova Scotia. The Select Committee was disbanded with the calling of a provincial election for October 6, 1981.

Calling of a Moratorium on Uranium Exploration and Establishment of the Uranium Inquiry - Nova Scotia

A moratorium on the issuing of new uranium licences or the renewal of existing one year licences was approved by Cabinet and announced by the Minister of Mines and Energy on September 22, 1981. Uranium exploration on existing licences essentially terminated at this time, and as of May 6, 1982, all special uranium licences had expired and no exploration for uranium is currently permitted in Nova Scotia.

On January 22, 1982, the government announced the appointment of Judge Robert J. McCleave, Q.C. as Commissioner under the Public Inquiries Act, to look into the impact of uranium exploration and mining in Nova Scotia. On February 9, 1982, the Uranium Inquiry - Nova Scotia was established by Order-in-Council No. 82-200 of the Nova Scotia government.

Policy Regarding Exploration for Uranium in Nova Scotia

On February 2, 1982, the Minister of Mines and Energy, released a Departmental policy regarding procedures to be followed with respect to uranium exploration in light of the moratorium. It stated,

> "No new Special Uranium Exploration Licences will be issued by Cabinet, existing Special Licences for uranium will not be renewed, and no further uranium exploration will be permitted, pending the findings of the inquiry to investigate environmental and health impacts associated with uranium exploration and mining.
>
> Companies or individuals wishing to retain uranium rights in areas previously held under either General Exploration or Special Licences must submit a request for a Special Uranium Exploration Licence to the Registrar of Mineral Rights. The area will then be withdrawn from further exploration for all minerals, and the request held on file until Cabinet decides what action is to be taken on this issue." (Appendix VIII, Item 1).

On November 17, 1981, an information directive regarding mineral land access to Municipal Water Supply Lands was incorporated into exploration licence requirements issued by the Department of Mines and Energy (Appendix VIII, Item 2). All municipal watershed areas were outlined on Department of Mines and Energy claim maps. Any party(s) exploring within these watersupply areas, with general or special licences, were informed in writing of procedures regarding exploration activities in these areas. Regional exploration activities which cause no surface damage require only notification to the Department of Mines and Energy of entry and completion dates. This information is then forwarded to the Nova Scotia Department of the Environment. More detailed exploration activities, which involve surface damage, require prior approval of the Minister of the Nova Scotia Department of the Environment. Previous to these new procedures, to enter and explore such lands, mineral licence holders were required to get permission of the regulators and/or owners of such lands. These additional constraints were established as a result of concerns brought to the Department's attention.

SECTION 4

PHYSICAL AND CHEMICAL PROPERTIES OF URANIUM

PHYSICAL PROPERTIES OF URANIUM

Introduction

To understand the problems associated with the exploration for and mining of radioactive elements such as uranium and thorium it is necessary to have a basic knowledge of the theories and characteristics of ionizing radiation. Some of the principles of ionizing radiation are briefly summarized in this section, but for a more complete description readers are urged to refer to Bates et al. (1980, p.39-51) or one of many texts on elementary nuclear physics.

Atoms and Isotopes

An atom configuration consists of the major subatomic particles protons, neutrons and electrons. Structurally, the protons and neutrons comprise the nucleus or central part of the atom, while electrons orbit the nucleus in a series of energy levels. Each element has a particular, unique number of protons, referred to as its atomic number. Atoms having an identical number of protons in their nucleii, but differing in their number of neutrons are called isotopes of that element. The total of the number of protons and neutrons is referred to as the atomic weight. Therefore, isotopes of an element have the same atomic number, but different atomic weights. Any element has the same number of protons as electrons, therefore, all isotopes of an element have the same number of electrons. The chemical characteristics of an element are determined, for the most part, by the number of the electrons orbiting the nucleus, therefore, different isotopes of the same element have almost, but not exactly, the same chemical properties. For example, natural uranium as it occurs in the earth's crust consists of three isotopes, U^{238}, U^{235} and U^{234} all of which have an atomic number of 92 (92 protons), but contain 146, 143 and 142 neutrons respectively. Isotopes of an element do not occur in equal proportions in nature. Natural uranium consists of 99.3% U^{238}; 0.71% U^{235} and 0.006% U^{234}. Because of this proportional relationship, almost all radiation from uranium will be the result of decay of U^{238}, although all three isotopes are radioactive.

Radioactive Decay

A radioactive element or radionuclide has a natural configuration of protons, neutrons and electrons that is unstable and tends to reach a stable state by emission of energy in the form of ionizing radiation. This process of radioactive decay is a constant for any particular element and is described by a term referred to as a half-life for that element. A half-life is the time it takes for any given number of atoms of an element to decay to an amount equal to 1/2 the original number (Fig. 4-1).

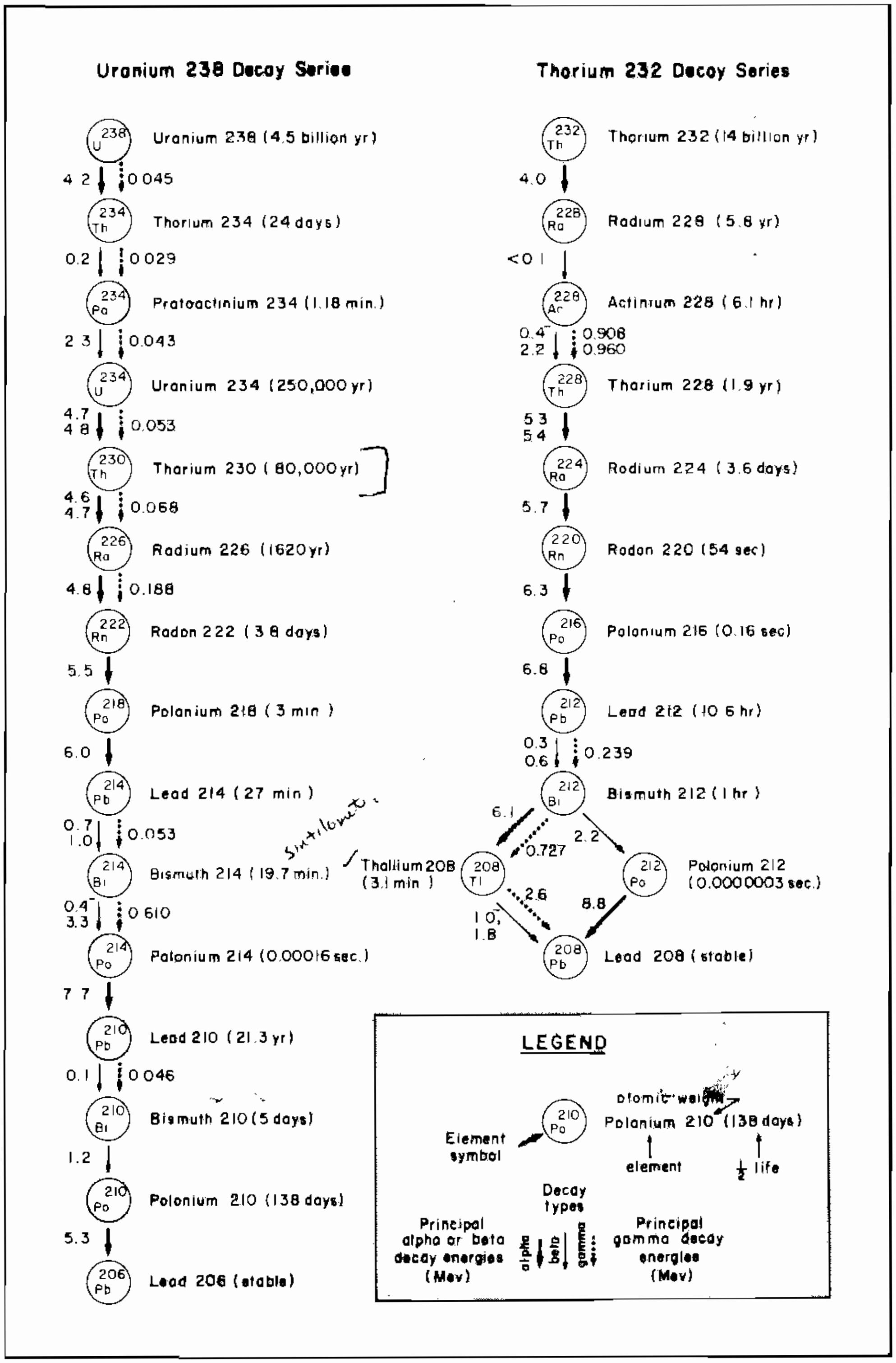


Figure 4-1. Radioactive decay series for uranium-238 and thorium-232.

There are many naturally occurring radioactive isotopes in the earth and its atmosphere. These radioisotopes fall into three categories: (1) those with very long half-lives, in the order of the age of the earth or greater (4.5 billion years), (2) those that are daughter isotopes of the first category, i.e. they are nuclides produced by decay of a parent nuclide and (3) those that are continually being produced by natural processes. Carbon-14 and tritium are radioisotopes which are continuously produced by interaction of their atoms with natural cosmic rays. These two elements comprise the third category. The category of long lived isotopes is comprised of four separate radioactive decay series. A decay series consists of a parent isotope which decays to a stable isotope in a series of steps, with each step forming a different daughter radioisotope. Each daughter has its own half-life and decays further with emission of its own characteristic radiation. For this report only the uranium-238 and thorium-232 decay series are considered as they and their daughters are most abundant in nature. The decay series for uranium-238 and thorium-232 are given in Fig. 4-1. The atomic weights, half-lives and form of radioactive decay are indicated for each daughter isotope in the decay series.

Radioactive decay of a naturally occurring atom takes place by the emission of energy as alpha (α), beta (β) or gamma (γ) radiation.

Alpha radiation or an alpha particle consists of 2 protons and 2 neutrons with a positive electrical charge. An alpha particle, therefore, is essentially the nucleus of a helium atom and is identical in atomic weight and charge to a helium ion. Although alpha particles contain high energy, they have little penetrating ability and can travel only a few centimetres in air. Alpha radiation is almost completely absorbed by the outer layers of skin or a sheet of paper. However, alpha radiation can be a serious health hazard if ingested or inhaled.

Beta particles are either negatively charged electrons or positively charged positrons. These contain lower energy than alpha particles, but travel at almost the speed of light. The penetrative power of beta particles, although greater than alpha particles, does not pose a serious health threat on external exposure unless intense levels are encountered. At high levels, beta emitting sources can cause severe burns to the skin and underlying tissue. Again, as with alpha particles, ingestion or inhalation of beta emitting nuclides can cause serious health problems.

Gamma rays are emissions of electromagnetic radiation similar to x-rays, but of shorter wave length. When an atom undergoes radioactive disintegration, the nucleus goes from a high energy state to a lower one. The energy differential between the two states must be given off and this is done by the ejection of alpha or beta particles or by release of a gamma ray, which is a photon of energy with no mass. Gamma ray emission is usually associated with decay by either alpha or beta radiation, as decay by the latter two forms of radiation often leaves the nucleus with an excess of energy. This energy is then emitted as a gamma ray. Gamma rays are the most penetrative of the three forms of radiation, and are therefore a serious health hazard, as they may cause damage to internal organs without being ingested.

GEOCHEMISTRY OF URANIUM

Introduction

In elemental form, uranium is a lustrous white metal and is the heaviest naturally occurring element. It was first recognized by a German apothecary, Martin Klaproth, in 1789. At least 200 uranium-bearing minerals are known in Canada, although in chemical analyses of samples, the uranium content is usually reported in the oxide form U_3O_8. Common measurement units used today for uranium concentration of samples are displayed in Table 4-1.

TABLE 4-1

Conversion of Common Units of Uranium Concentration

1 part per million (ppm)	=0.001 Kg/tonne	= 0.002 lbs/ton	= 0.0001%
1 per cent (%)	= 10,000 ppm	= 10 Kg/tonne	= 20 lbs/ton
1 Kilogram/tonne (Kg/tonne)	= 2 lbs/ton	= 0.1%	= 1,000 ppm
1 pound/ton (lbs/ton)	= 0.05%	= 500 ppm	= 0.5 Kg/tonne

Chemical Mobility of Uranium

Uranium is very chemically active and under certain conditions can be mobile in the natural environment. As described in the physical properties of uranium and as displayed in Fig. 4-1, uranium-238 decays to stable lead-206 by formation of a series of daughter radioactive isotopes. These daughter isotopes have differing chemical characteristics both among themselves and from the parent uranium isotope. This and the fact that uranium is quite chemically active often results in the various elements of the series being separated from each other by differing natural processes.

The earth's crust has a average thorium to uranium ratio of about 3 to 4. At the high temperatures and pressures encountered at depth in the earth's crust, uranium and thorium behave geochemically in a similar manner and hence have a fairly constant ratio. It may be said that they tend to follow each other around. At the lower temperature and pressure conditions encountered near the earth's surface, uranium becomes more chemically active while thorium remains relatively immobile, and separation of the two elements results. Thus, the ratio of thorium to uranium in the near surface environment can be quite variable.

The most abundant or most common uranium mineral is the oxide uraninite, UO_2. This mineral is generally thought of as a primary mineral (parent mineral from which other secondary minerals are derived by superimposed chemical and physical processes). Uraninite forms at medium to high temperatures in what is termed a water deficient environment. A water deficient environment, geologically speaking, means one in which a liquid or vapor phase is a minor constituent in formation of the rock. These conditions are often met at depth in the earth. A slightly more oxidized form of uraninite is called pitchblende and is also quite common in nature. Pitchblende and uraninite are often used synonomously as they are essentially of the same composition, although many geologists feel pitchblende is the result of oxidation of uraninite.

Perhaps the single most important geochemical feature of uranium, in discussing its mobility in nature, is its ability to be oxidized to the highly water soluble ion UO_2^{++}. This ion is easily mobilized by near surface (oxidizing) waters and hence these waters can often alter the original uranium concentration of a rock mass. This alteration can be in the form of leaching (depletion of the original content) or enrichment (addition of uranium content by ions leached elsewhere). Factors controlling the mobility of uranium include the chemical composition of the affected rocks, ph (acidity) of the sub-surface waters with which the rocks are in contact, and climatic conditions. The enrichment of uranium by these processes can result in formation of an orebody. Circulating fluids of high UO_2^{++} ion content will precipitate uranium-bearing minerals when conditions of low oxidation are met. This is termed a reducing environment and is described in more detail in Section 7, Uranium and Thorium Occurrences of Nova Scotia.

Uranium-Radon Relationship

As stated previously the members of the uranium-238 decay series (Fig. 4-1) have differing physical and chemical characteristics. Radon-222 is one of these daughter isotopes and is a concern as it is a gas at atmospheric temperature and pressure and may be liberated to the atmosphere. Upon liberation into the atmosphere it tends to occupy low lying depressions as it is much heavier than air. Highly concentrated pockets of radon gas are unlikely as its relatively short half life (3.8 days) will result in decay to the nongaseous polonium-218 in a relatively short time.

The solubility of radon-222 and its immediate parental source radium-226 in water often results in concentrations of these elements away from the original uranium-238 source. As radon has a relatively short half life, an anomaly (above average concentration) of radon generally indicates an anomaly of radium-226 is nearby. As radium-226 is relatively long lived (half life 1620 yrs.) an anomaly of this element does not necessarily indicate a uranium concentration as the radium may be transported for some distance within its long half life.

The ability for both radium-226 and radon-222 to be dispersed in groundwater is often used by explorationists in the search for uranium deposits. Many uranium deposits may be concealed by overburden or may exist at shallow depth in the bedrock. By geochemically testing groundwater from an area for its concentration of the relatively water soluable radium and radon an indication of the presence of a uranium-238 deposit may be expressed for further follow-up studies. Geochemical surveys using these elements are common exploration tools in the search for uranium (Section 5, Natural Levels of Radioactivity in Nova Scotia).

URANIUM AND THORIUM IN ROCKS

Introduction

The average uranium content of the earth's crust is estimated to be between 2 and 4 parts per million (ppm) with the average thorium content about 3 times this at 10-12 ppm (Bates et al., 1980). Within particular rock types these contents vary considerably from the crustal averages and similar rock types from different regions may also vary. For this reason, a certain rock type in one region of the earth may be barren of uranium deposits while in another region a very similar rock type may contain deposits. One of the roles of a geologist studying mineral deposits is to develop models to explain why a particular type of deposit is found in one location and not elsewhere. Once outlined, the principles or characteristics of the mineral deposits can be applied in mineral exploration. This aspect of geology is called metallogeny or the study of the genesis of mineral deposits.

Types of Rocks in the Earth's Crust

The rocks of the earth's crust may be classified into 3 main types; igneous, metamorphic and sedimentary. Their most basic characteristics and average uranium and thorium contents are briefly described here, but readers are cautioned that the descriptions are greatly simplified.

Igneous Rocks

This rock type is formed by solidification of hot molten material derived from deep in the earth's crust. This molten material or magma rises through the crust. It is termed extrusive if it reaches the surface, causing volcanic eruptions of molten lavas or termed intrusive if the magma does not reach the earth's surface and solidifies at depth. Common extrusive rocks are rhyolite, andesite and basalt. Intrusive igneous rocks include granite, granodiorite, diorite and gabbro. Laymen and many geologists commonly use the term granite to describe all intrusive rocks although they may vary in composition from true granite to gabbro. It should therefore be kept in mind that often, areas described as being underlain by granitic rocks in the geological literature may vary significantly in composition from "true" granite. The term "granitic rocks" should be taken to mean intrusive rocks, granite-like in appearance and color, although compositionally they may be quite variable.

Intrusive igneous bodies, emplaced at depth, are exposed to the present surface by mountain building processes, erosion and glaciation. Large masses of granitic rocks are called batholiths and often underlie large areas. One of the largest granitic bodies of the Appalachian mountain belt of Eastern North America occurs between Halifax and Yarmouth (Fig. 7-1) and has been named the South Mountain batholith (McKenzie and Clarke, 1975). A batholith is seldom homogeneous and generally includes igneous rocks of different compositions. The South Mountain batholith and the many smaller bodies (plutons) of granitic rocks found throughout Nova Scotia are no exception; they include intrusive rock types from gabbro to true granites.

In the igneous rock suites (intrusive and extrusive) of the world, uranium content usually increases with increasing silica content, therefore uranium minerals are more commonly found in igneous rocks which approach true granite in composition. In an igneous rock suite of granite to gabbro compositions, the gabbroic rocks will contain the least silica (approx. 50% SiO_2) and the granites will contain high silica (approx. 70-75%. SiO_2). In true granites, much of the silica is in the form of the common mineral quartz.

Sedimentary Rocks

Sedimentary rocks are formed by accumulation of sediment derived from erosion or chemical breakdown of pre-existing rocks. The pre-existing rocks may have been igneous, metamorphic, another sedimentary rock or organic matter (e.g. sea shells). The accumulation may take place in fresh or salt water or on land.

In sedimentary rocks, uranium tends to be concentrated in shale or clay rich layers. Sediments rich in bituminous material (coal or peat) are often favourable loci for uranium concentrations. It is important to note that sedimentary rocks are formed at or near the earth's surface where uranium is more chemically mobile than thorium. This preferential mobility of uranium is exhibited by a low thorium/uranium ratio in these rocks since with enrichment in uranium there is a decrease of the Th/U ratio.

Metamorphic Rocks

Metamorphic rocks are formed by the transformation of a pre-existing igneous or sedimentary rock due to increase in pressure and or temperature. This increase in pressure and temperature is called metamorphism and causes progressive chemical and mineralogical changes in the rock. These changes could ultimately end with remelting of the rock to form magma if a sufficient degree of intense heat and pressure were reached.

In nature the original uranium content of a rock will decrease with an increase in metamorphism. Since an increase in metamorphism is accompanied by release in fluids from a rock, any uranium depletion in the rock due to metamorphism will be carried away with this fluid. Low levels of metamorphism tend to have little effect on uranium content, but depletion is common in medium to high level metamorphic rocks. Thorium content of rocks tends to remain relatively constant during metamorphism.

SECTION 5

NATURAL LEVELS OF RADIOACTIVITY IN NOVA SCOTIA

Introduction

In the past, regional geological, geophysical and geochemical surveys have been carried out in various parts of Nova Scotia by government agencies, universities and exploration companies. The results of such surveys allow inferences to be made about the natural or background levels of uranium, and to a lesser extent, thorium in Nova Scotia. The initial and primary aim of the surveys was to outline favourable target areas for exploration for a variety of commodities, among which uranium was included. The data generated are also of use in formulation and further refinement of mineral deposit models and estimation of relative levels of radioactivity in the various regions of the Province. This natural concentration of uranium and thorium coupled with cosmic or extraterrestial radiation accounts for most of the natural radiation to which the population of the Province may be subjected.

Geological Surveys

Geological surveys involve mapping and chemically analyzing the different bedrock types which occur in the Province. These surveys are an ongoing slow and expensive procedure, but are the most accurate method available for identifying concentrations of radioactive elements in rocks and obtaining answers as to why and where mineral deposits might form. Since 1975, geological studies carried out by the Mineral Resources Division of the Nova Scotia Department of Mines and Energy, various universities in the Province, and mineral exploration companies have considerably increased an almost nonexistent database on the average values of uranium and thorium in the rocks of Nova Scotia. The studies are continuing, but certain trends and concentration levels are becoming apparent. Table 5-1 summarizes the average contents of uranium and thorium in the different granitic terranes of Nova Scotia. The levels in granitic terranes are emphasized here because these rocks are generally enriched in these radioactive elements relative to most other rock types. The results of regional geophysical and geochemical surveys (discussed next) indicate that the expected general relationship of increased radioactivity in granitic bedrock holds in Nova Scotia.

Geological research studies of Cape Breton granitic rocks were conducted by the Nova Scotia Department of Mines and Energy during 1978 and 1979 and include uranium analyses (Barr et al. 1982). Distribution of uranium and thorium in granites of the South Mountain batholith southwest of Halifax are discussed by Chatterjee and Muecke (1982). Analyses of uranium and thorium in the granitic and volcanic rocks of the Cobequid Highlands are found in an assessment report submitted to the Department of Mines and Energy by Gulf Minerals of Canada, Ltd. (Gulf Minerals Canada Limited, 1980).

Chatterjee and Strong (in preparation) discuss the distribution of radioactive elements in igneous rocks of Nova Scotia and Newfoundland. They incorporate data from a number of sources and discuss radioelement concentrations in the rocks and explain differences in light of genetic theories explaining the separate origins of the different granitic terranes.

Table 5-1. Average content of U and Th for the different granitic terranes of Nova Scotia and world averages for major granitic rock types.

AREA	REFERENCE	ROCK TYPE	U ppm	Th ppm
South Mountain Batholith	Chatterjee and Muecke (1982)	granodiorite	3.9	11.5
		monzogranite	6.1	11
		leuco-monzogranite	8.3	4.3
Cobequid Highlands	Gulf Minerals Canada Limited (1980)*	diorite	1.1	2.25
		granite	7.9	33.8
Cape Breton	Barr et al. (1982)**	diorite	1-2	4-7
		granodiorite	1-2	6-9
		granite	2-5	12-20
World Averages	Bates et al. (1980)	dioritic	2	5
		granitic	4	12
	Vinogradov (1962)	dioritic	1.8	7
		granitic	3.5	18

* Includes only 4 analyses of each rock type
** Includes only uranium analyses, Th analyses from Barr (unpublished data)

Geophysical Surveys

A more visual display of anomalous or higher background areas of radioactivity in the Province are presented in a series of regional airborne radiometric surveys by the Geological Survey of Canada (G.S.C.). The basic theories for running a survey of this type are briefly outlined in Section 6, Exploration for Radioactive Elements. Figure 5-1 is an index map showing the areas covered by the many airborne surveys of the federal government to date. Table 5-2 accompanies this map and gives the pertinent data on each survey such as area surveyed, reference, flight line spacing, elevation and air speed.

The G.S.C. recently released (May 4, 1982) a compilation of all of these surveys as a series of three coloured maps of Nova Scotia displaying uranium, thorium and potassium levels in the province. Copies of the uranium (Fig. 5-2) and thorium (Fig. 5-3) maps are included in this report. A comparison of these maps with the generalized geology of Nova Scotia on Fig. 7-1 shows an association of regional uranium and thorium highs in areas underlain by granitic rocks. Another striking feature is the higher radiometric response of the southern mainland granitic terranes relative to those of Cape Breton and to a lesser extent of the Cobequid Highlands. This supports the findings of the geological surveys that the southern mainland granites have a high content of uranium and thorium relative to the Cape Breton and Cobequid granites. This is discussed further in Section 7, the Uranium and Thorium Occurrences of Nova Scotia.

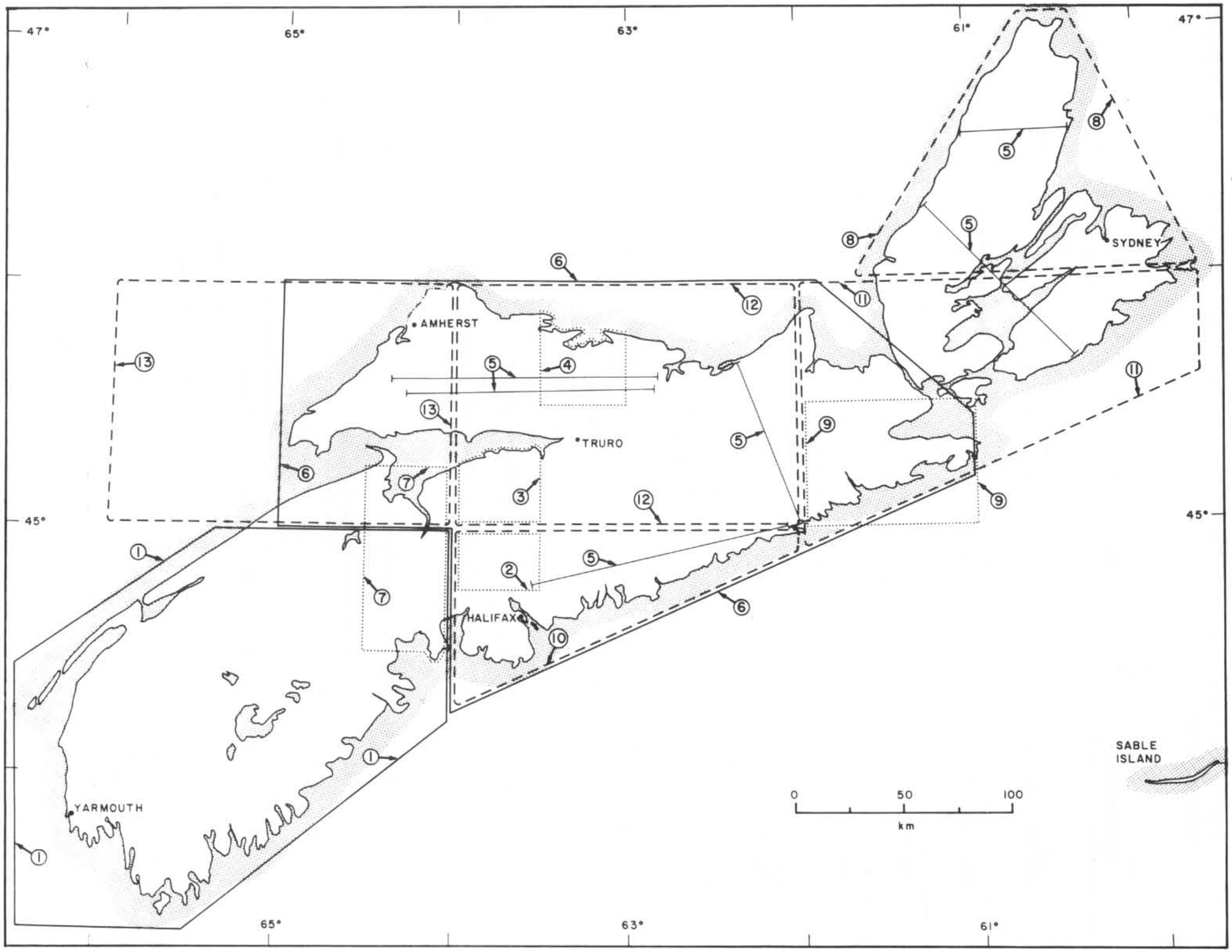


Figure 5-1. Map of Nova Scotia showing areas covered by various federal airborne radiometric surveys flown since 1976. (Numbers refer to Table 5-2 in text).

Table 5-2. Index to federal airborne radiometric surveys flown in Nova Scotia since 1976.

No. (Fig.5-1)	REFERENCE NSDME*	GSC*	SURVEY AREA	FLIGHT LINE Spacing (km)	Elevation (m)	Air Speed (km/hr)
1	OFR** 250	OFR 429	Southwestern Nova Scotia, N.T.S. 21A, 21B, 20O, 20P	5	123	190
2	OFR 322	OFR 466	Uniacke area, Hants and Halifax County, N.T.S. 11D13	1	123	190
3	OFR 323	OFR 67	Kennetcook, Hants County, N.T.S. 11E4 and part 11E5	1	123	190
4	OFR 324	OFR 468	Tatamagouche area, Colchester, Cumberland and Pictou Counties, N.T.S. 11E11 and part 11E14	1	123	190
5	OFR 332	OFR 503	Single flight lines, province wide	-	153	190
6	OFR 471	OFR 789	Central Nova Scotia, N.T.S. 11D, 11E, part 11F and 21H	5	120	190
7	OFR 472	35121(9)G***	Chester, Lunenburg County, N.T.S. 21A9	1	123	190
		35121(16)G	Windsor, Hants County, N.T.S. 21A16	1	123	190
		35821(1)G	Wolfville, Kings County, N.T.S. 21H1	1	123	190
8	-	OFR 816	Northern Cape Breton, N.T.S. 11K	5	123	190
9	-	35611(3)G	Larrys River, Guysborough County, N.T.S. 11F3	1	123	190
		35611(4)G	Country Harbour, Guysborough County, N.T.S. 11F4	1	123	190
		35611(5)G	Guysborough, Guysborough County, N.T.S. 11F5	1	123	190
		35611(6)G	Canso, Guysborough County, N.T.S. 11F6	1	123	190
10	-	35411G	Halifax County, N.T.S. 11D	5	123	190
11	-	35611G	Southeastern Cape Breton and Guysborough County, N.T.S. 11F	5	123	190
12	-	35511G	Central Nova Scotia, N.T.S. 11E	5	123	190
13	-	35821G	Cumberland County, N.T.S. 21H	5	123	190

*NSDME = Nova Scotia Department of Mines & Energy
G.S.C. = Geological Survey of Canada
**OFR = Open File Report
***G = Geophysical Series No.

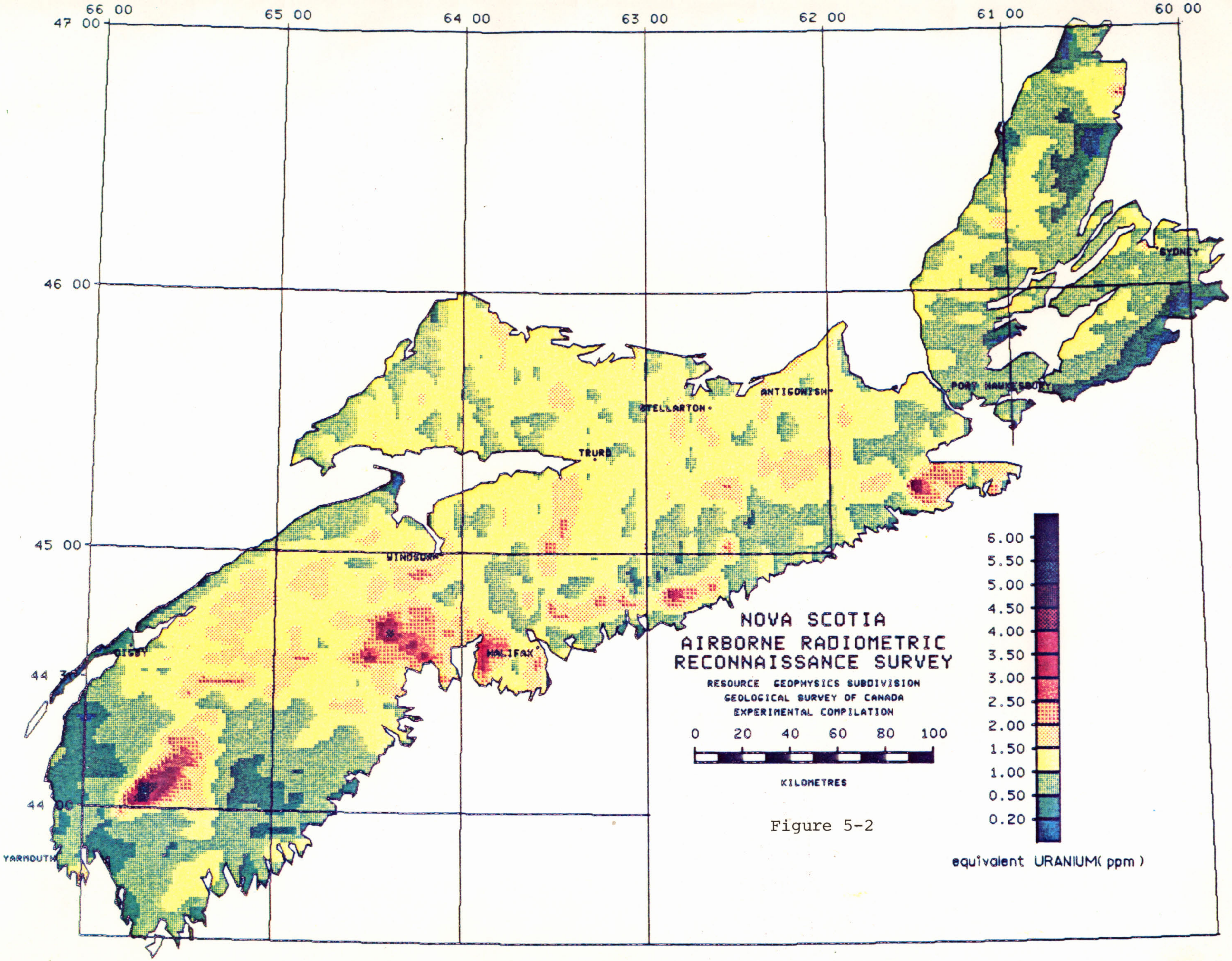

66 00
65 00
64 00
63 00
62 00
61 00
60 00
47 00
46 00
45 00
44 30
44 00
SYDNEY
PORT HAWKESBURY
ANTIGONISH
STELLARTON
TRURO
WINDSOR
HALIFAX
DIGBY
YARMOUTH
NOVA SCOTIA
AIRBORNE RADIOMETRIC
RECONNAISSANCE SURVEY
RESOURCE GEOPHYSICS SUBDIVISION
GEOLOGICAL SURVEY OF CANADA
EXPERIMENTAL COMPILATION
0 20 40 60 80 100
KILOMETRES
6.00
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.20
equivalent URANIUM(ppm)

Figure 5-2

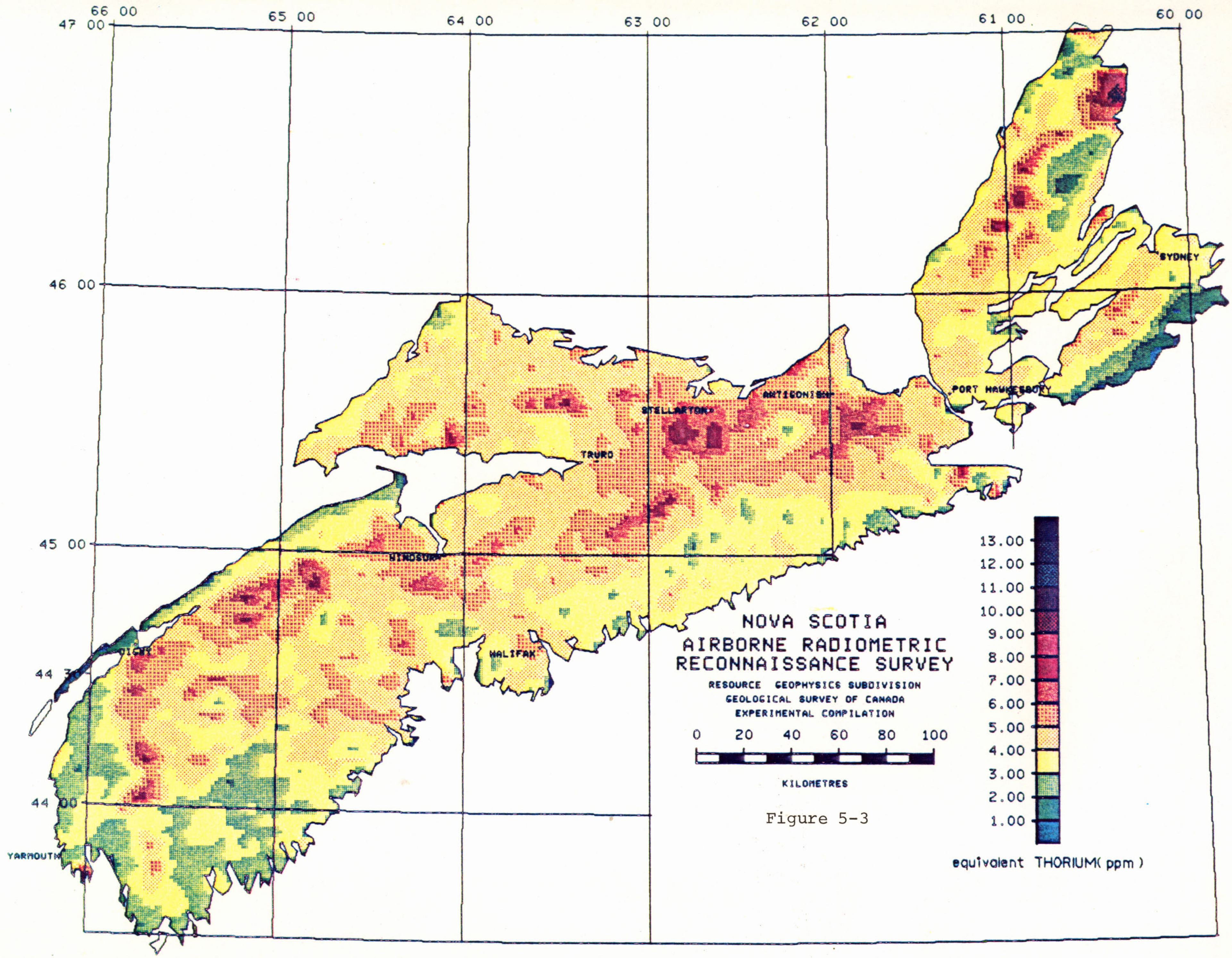

66 00
65 00
64 00
63 00
62 00
61 00
60 00
47 00
46 00
45 00
44 30
44 00
SYDNEY
PORT HAWKESBURY
ANTIGONISH
STELLARTON
TRURO
WINDSOR
HALIFAX
DIGBY
YARMOUTH
NOVA SCOTIA
AIRBORNE RADIOMETRIC
RECONNAISSANCE SURVEY
RESOURCE GEOPHYSICS SUBDIVISION
GEOLOGICAL SURVEY OF CANADA
EXPERIMENTAL COMPILATION
0 20 40 60 80 100
KILOMETRES
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
equivalent THORIUM(ppm)

Figure 5-3

Appendices II and III include indices of assessment reports submitted to NSDME by companies exploring for uranium. In many of these reports the companies have submitted the independent results of airborne and ground radiometric surveys.

Geochemical Surveys

As with the geophysical surveys, the GSC and NSDME have published the results of regional geochemical surveys of different types. Due to the different types of terranes found throughout Nova Scotia, no one type of geochemical survey would be successful in evaluating all regions of the Province. Figure 5-4 shows the types of surveys and the regions covered by these studies. A glacial till and lake sediment survey of southern and eastern mainland Nova Scotia was ideal because this region has thick glacial till cover and many lakes distributed evenly throughout. Fewer lakes and variable topographic relief favoured a stream sediment survey in the northern mainland region. A well water survey (Dyck, et al. 1976) of the northern mainland was also conducted because this area is quite evenly populated and hence contains many wells.

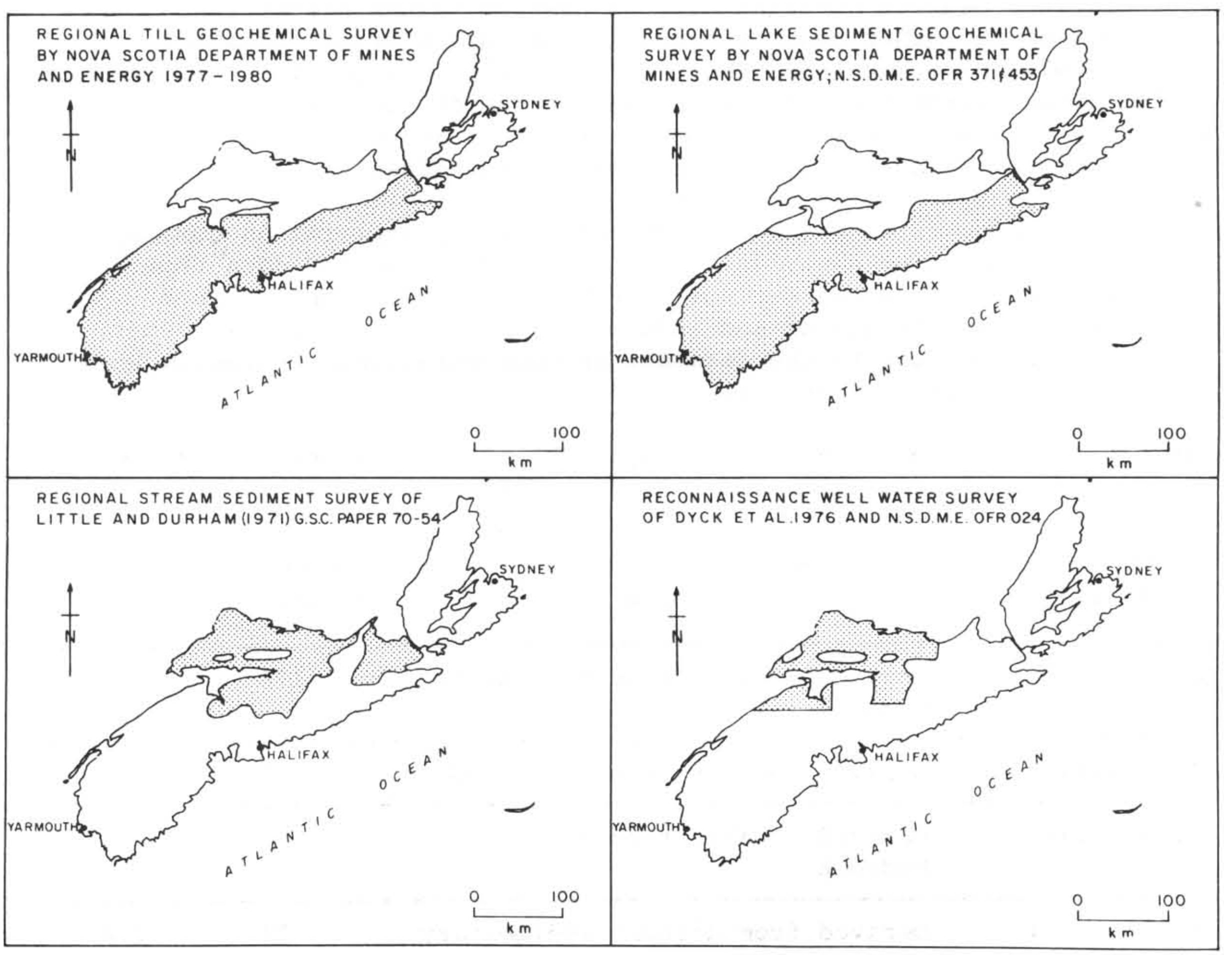


Figure 5-4. Areas covered by federal and provincial regional geochemical surveys of Nova Scotia which include uranium.

Figure 5-5 shows areas of high values of uranium and radon in well water of northern Nova Scotia as outlined by Dyck et al. (1976). The elevated uranium and radon content of the Tatamagouche-Pugwash sedimentary basin is a striking feature of this map.

The results of the regional lake sediment surveys of the NSDME have been published (NSDME Open File Reports (OFR) 371 & 453) and clearly show the elevated values of uranium in lake sediments from lakes underlain by granitic rocks compared to lakes underlain by other rock types (Fig. 5-6). It is interesting to note the areas of elevated values of uranium outlined by the lake sediment survey correlate positively with anomalous areas of uranium indicated by the airborne radiometric surveys (Fig. 5-2).

A regional till geochemical survey conducted by staff of NSDME has been completed for the area shown on Figure 5-4. The data and maps for the area east of Mahone Bay-Kentville are published (Stea and Fowler, 1979; 1981) and the data and maps for the area west of Mahone Bay-Kentville will be published in the near future. The entire data set was made available for this report. Table 5-3 lists the uranium content of the various types of till outlined in the survey. Glacial till derived from granitic bedrock contains average uranium values higher than tills derived from the other bedrock types in the survey area. Stea and Fowler (1979) have concluded that the geochemical values for the elements tested often mirror the relative values of the original bedrock from which the till was derived. The overall effect is to slightly dilute and homogenize original high bedrock areas (anomalies).

Again, as with the geophysical surveys, exploration companies searching for uranium deposits in the past have submitted data from more detailed geochemical surveys of various areas of the Province. These reports are tabulated and indexed in Appendices II and III and have contributed much to the database on concentrations of uranium and thorium throughout Nova Scotia.

Table 5-3. Uranium content of various till types of southern Nova Scotia (data from Stea and O'Reilly, 1982).

Till Type	Origin	# Samples	U(ppm)
Quartzite till	Derived locally from quartzitic bedrock	176	5.6
Slate till	Derived locally from slate bedrock	37	4.1
Granite till	Derived locally from granitic bedrock	83	8.2
Red clay till	Derived from distant sedimentary and carbonate rocks (northern Nova Scotia and New Brunswick)	77	2.8

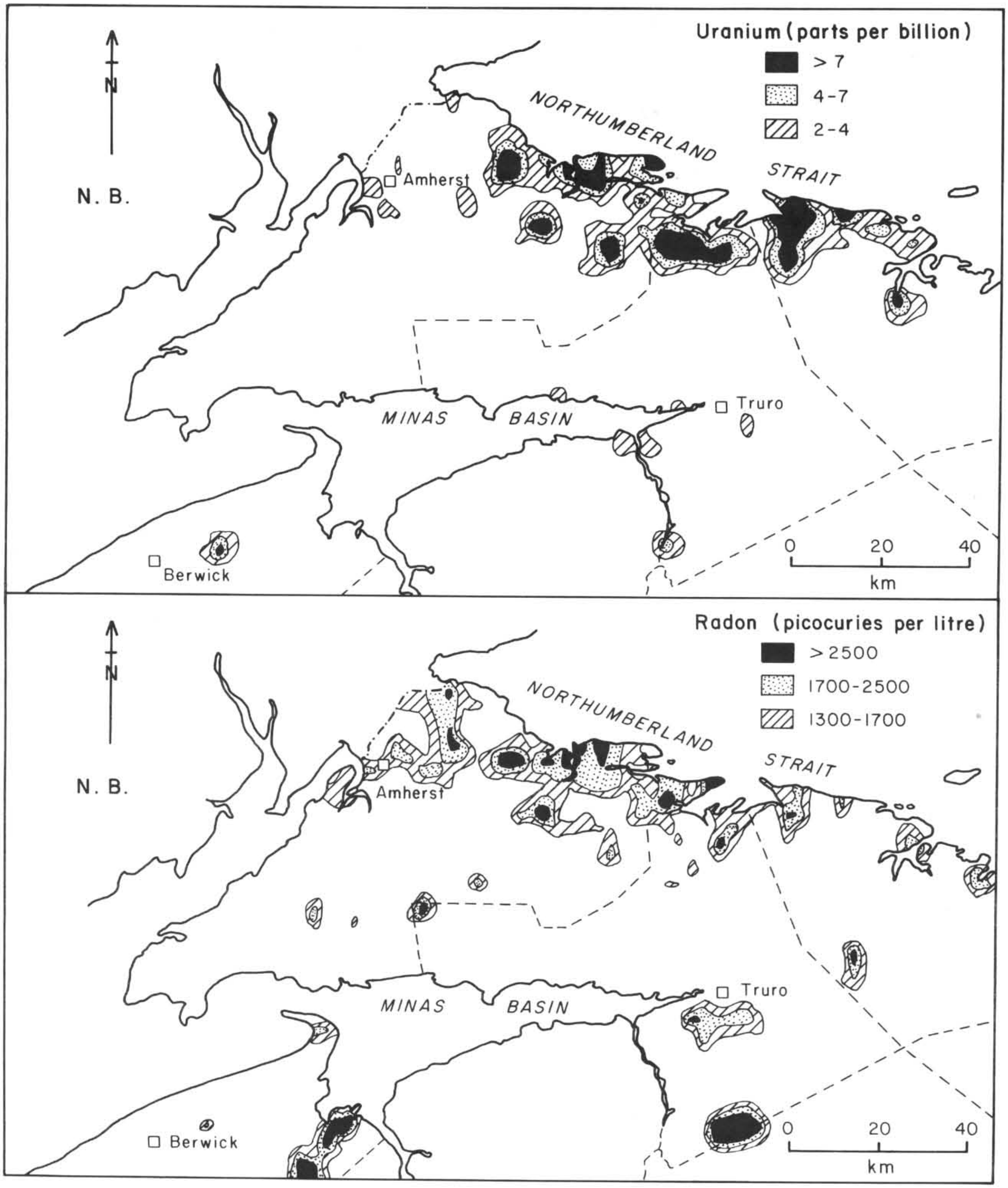


Figure 5-5. Uranium and radon content of well water of northern Nova Scotia. From the regional well water survey of Dyck et al. (1976).

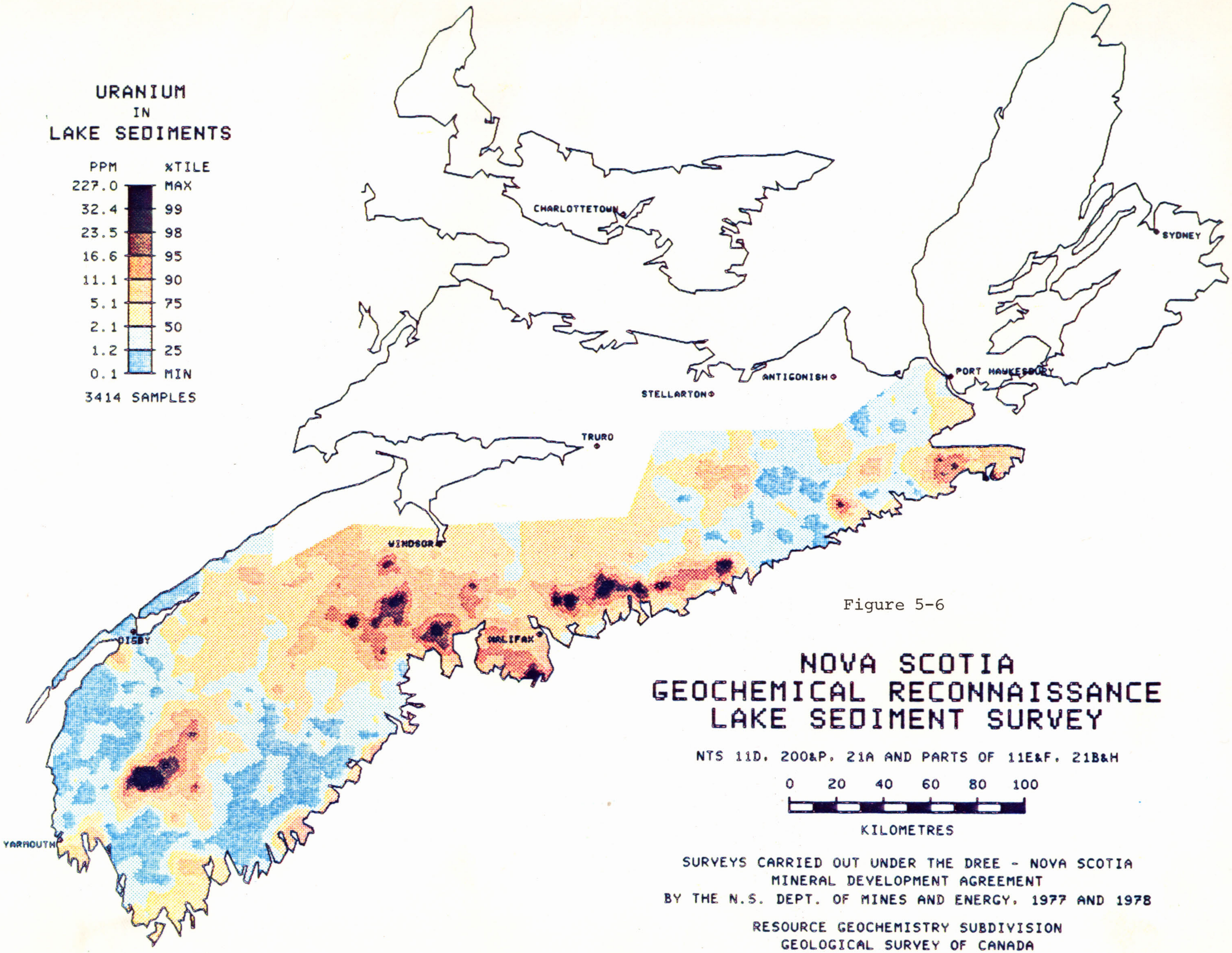

URANIUM
IN
LAKE SEDIMENTS
PPM
%TILE
227.0
MAX
32.4
99
23.5
98
16.6
95
11.1
90
5.1
75
2.1
50
1.2
25
0.1
MIN
3414 SAMPLES
CHARLOTTETOWN
SYDNEY
PORT HAWKESBURY
ANTIGONISH
STELLARTON
TRURO
WINDSOR
HALIFAX
DIGBY
YARMOUTH
NOVA SCOTIA
GEOCHEMICAL RECONNAISSANCE
LAKE SEDIMENT SURVEY
NTS 11D, 20O&P, 21A AND PARTS OF 11E&F, 21B&H
0
20
40
60
80
100
KILOMETRES
SURVEYS CARRIED OUT UNDER THE DREE - NOVA SCOTIA
MINERAL DEVELOPMENT AGREEMENT
BY THE N.S. DEPT. OF MINES AND ENERGY, 1977 AND 1978
RESOURCE GEOCHEMISTRY SUBDIVISION
GEOLOGICAL SURVEY OF CANADA

Figure 5-6

SECTION 6

EXPLORATION FOR RADIOACTIVE ELEMENTS

EXPLORATION TECHNIQUES

Introduction

The principles of radioactive decay can and are used successfully in the exploration for radioactive and related nonradioactive elements. Techniques and equipment have been developed to take advantage of the physical characteristics of radioactive disintegration. These are coupled with the more common exploration techniques used in the search for mineral commodities and are often quite efficient in outlining radioactive sources in nature.

Radiation Detection

As described in the section on the physical and chemical properties of uranium, a radioactive element decays to a stable state by emission of three main forms of energy; alpha (α), beta (β), and gamma (γ) radiation. The ability of alpha and beta radiation to penetrate air and solid material is much less than that of gamma radiation. Therefore, geophysical exploration for uranium often involves the search for local areas of abnormally high gamma radiation (Fig. 6-1).

In exploration, gamma radiation from radioactive disintegration can be measured with three instruments, a geiger counter, a scintillometer and a gamma ray spectrometer. A geiger counter consists of a glass tube filled with a gas (usually argon) attached to a small electrical device. When a voltage is applied to the glass tube, gamma rays passing through the gas are ionized when they collide and then react with gas molecules. This ionization causes a current to flow in the tube. The amount of current generated is proportional to the amount of radiation reacting with the gas and this is amplified and registered as audible clicks on a gauge. The geiger counter's main disadvantage is its poor efficiency. Only about 0.1% or 1/10th of 1% of the gamma rays which enter the tube cause an electrical reaction.

A scintillometer is much more efficient than a geiger counter in detecting gamma radiation and is used extensively in exploration. Scintillometers use detectors made of certain crystals (commonly sodium iodide) which on absorption of gamma radiation emit visible flashes of light. These flashes are received by light sensitive detectors, processed electronically and displayed on a meter or as audible clicks. Scintillometers have a detection efficiency of almost 100% in detecting gamma radiation (Sharma, 1976).

A gamma ray spectrometer is a refined version of a scintillometer and receives and processes gamma radiation in the same way. Radioactive disintegration of atoms of different elements results in emmission of gamma rays of different energies (measured in million electron volts, Mev.). This is to say that the gamma rays emitted when uranium, thorium and potassium and daughter elements decay are of different

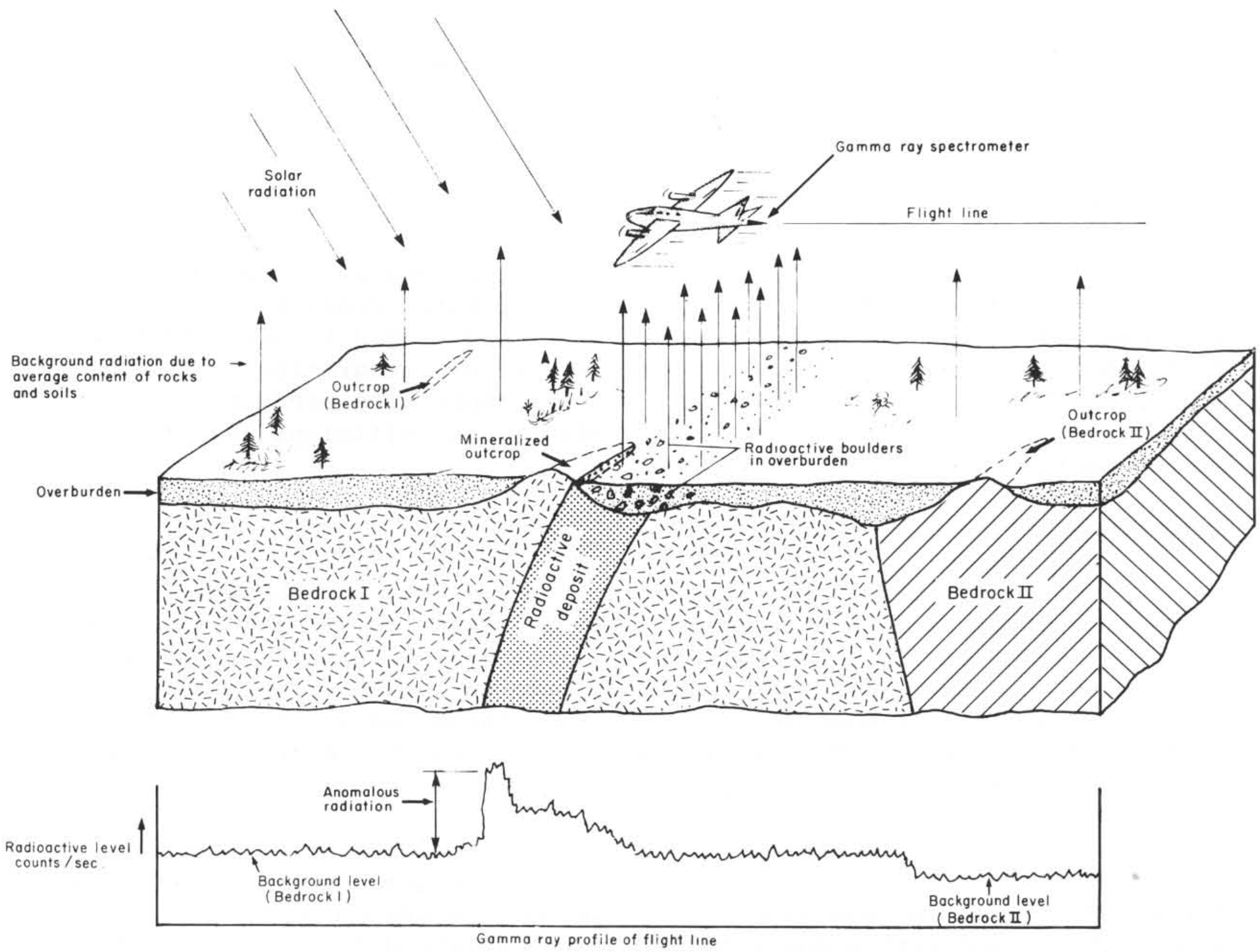


Figure 6-1. Schematic representation of a typical airborne radiometric survey.

energies (Fig. 4-1). A spectrometer can differentiate gamma rays of different energies and thus can distinguish which radioactive element has produced the detected radiation. Most airborne surveys for radioactive elements utilize gamma ray spectrometers. Figure 6-2 shows the spectral plots of all energies produced by the uranium, thorium and potassium decay series and the energy ranges (called windows by explorationists) commonly monitored in exploration. For an estimate of the uranium content, the energy emitted by the bismuth-214 (Bi^{214}) decay in the uranium decay series is monitored. For a thorium estimate the energy emitted by the thallium 208 (Tl^{208}) decay in the thorium decay series is monitored. The potassium 40 (K^{40}) decay is also monitored for an estimate of potassium content.

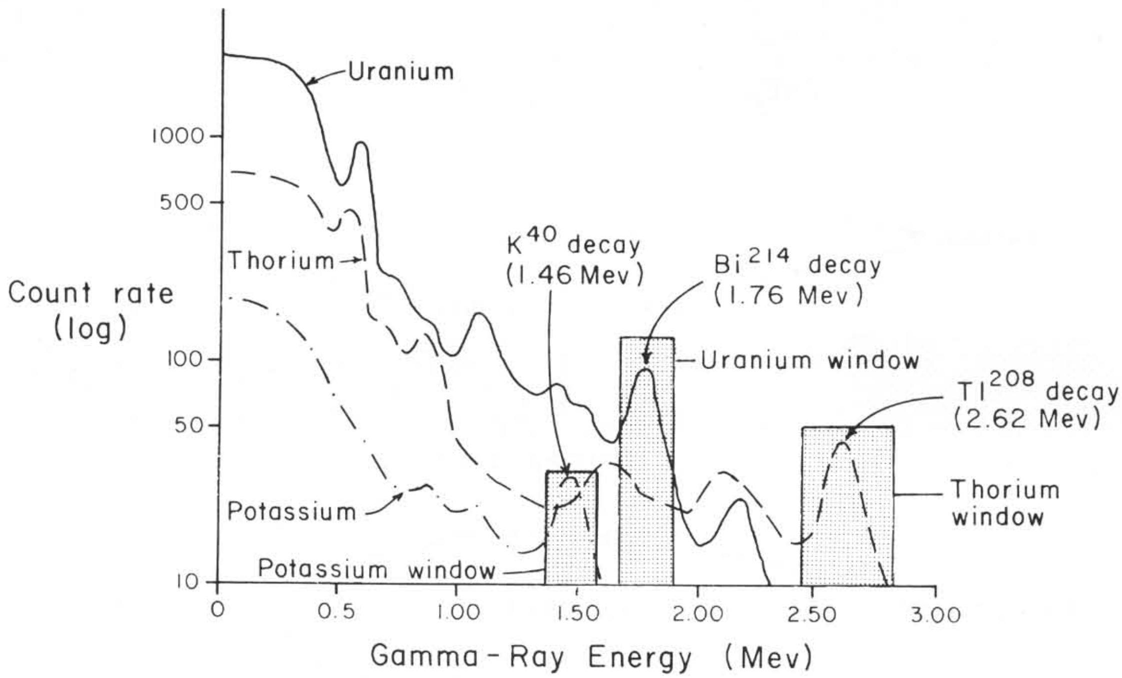


Figure 6-2. Spectral plots of gamma ray energies produced by radioactive decay of the uranium, thorium and potassium decay series. Energy ranges (windows) characteristic of each parent isotope are indicated.

STAGES OF EXPLORATION

Introduction

A typical program used in the exploration for most commodities has been adapted to show a common approach to the search for a radioactive orebody (Fig. 6-3). An exploration program consists of three main stages: preliminary, initial and advanced. If results are still positive, property investigations then enter the mine development stage.

Preliminary Exploration Stage

This involves regional surveys of a geophysical, geochemical and geological nature and a search and compilation of relevant assessment reports and pre-existing data on past studies and exploration work done in the surveyed area. The regional surveys involve airborne geophysical surveys over large tracts of land as well as ground reconnaissance geochemical and geophysical surveys. Regional geological mapping may be done to further refine or confirm theoretical geological models. As in exploration for almost all commodities, actual prospecting of the ground, either on a regional or more localized basis, is perhaps the most useful and important tool in exploration.

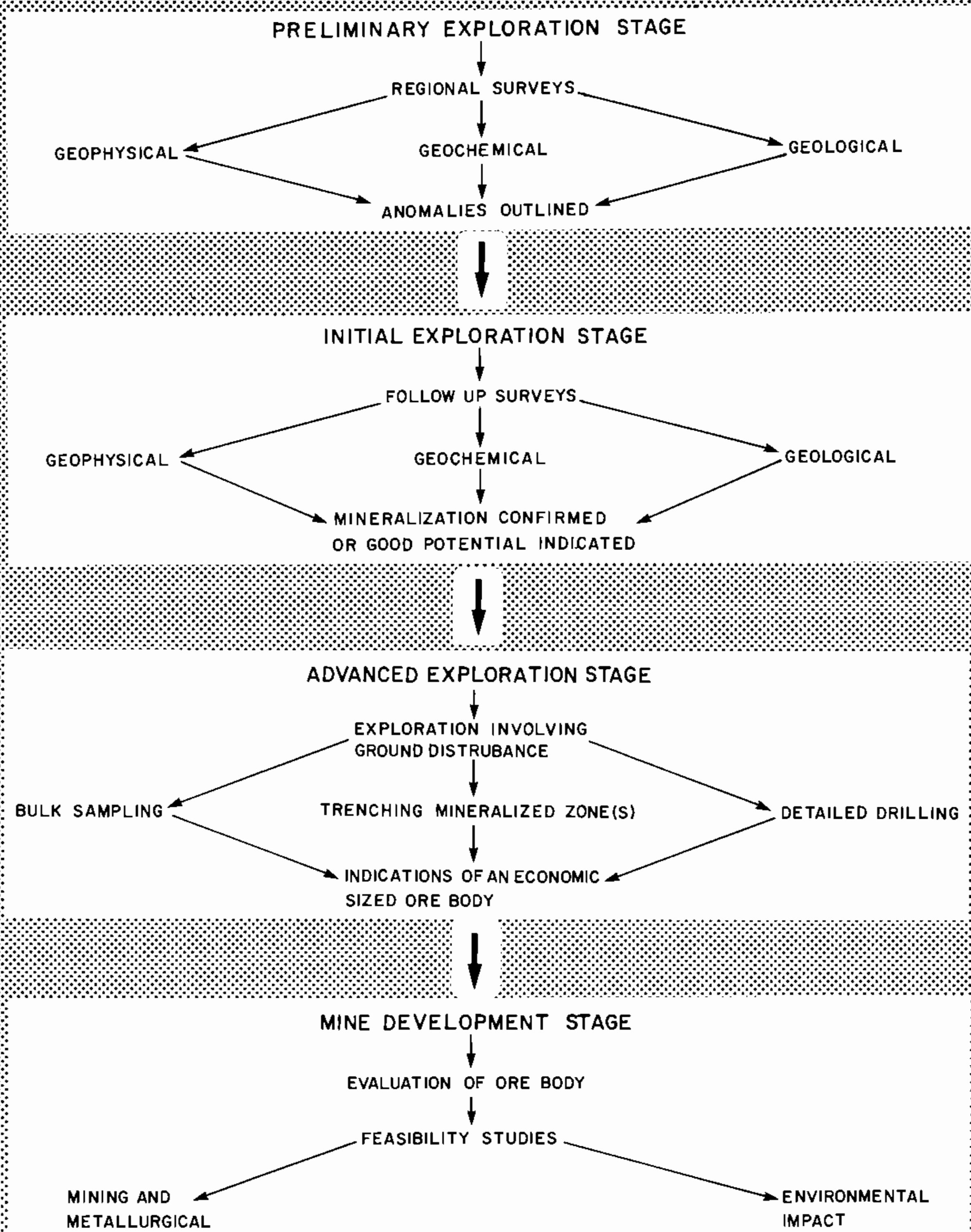


Figure 6-3. Stages of a typical exploration program for uranium.

In addition to the previously documented regional government surveys conducted since 1976, private companies exploring in Nova Scotia have done regional geophysical and geochemical surveys and have submitted results in assessment work to the Department of Mines and Energy (Appendices II and III). From a mineral exploration stand-point the successful conclusion of this phase is when a localized area of higher than average metal content (an anomaly) has been targeted.

Initial Exploration Stage

Once regional surveys are completed, all data are brought together and potential anomalies are outlined for follow up surveys. These follow up surveys are similar to regional surveys, but are much more concentrated and localized. For example, in the area of an anomaly outlined by regional surveys, all wells, springs and bodies of water may be tested for uranium and/or daughter element concentrations as well as detailed prospecting and soil sampling along a flagged grid. A flagged grid consists of surveyed lines through the bush marked with bright survey flagging tape. This grid allows the accurate plotting of all sample locations, bedrock outcrops, and radiation readings.

If the results of surveys and mapping in the initial stage confirms the presence of mineralization or indicates a good potential for mineralization under the overburden, the exploration program moves into an advanced stage.

Advanced Exploration Stage

The purpose of an advanced stage is to test for a subsurface concentration of mineralization which has economic potential. This is accomplished by initiation of detailed trenching and drilling programs. Procedures for the proper conduct of all aspects of this ground disturbance phase is defined in the Terms and Conditions governing Special Uranium Exploration Licences in Nova Scotia (Appendix VII). If bulk testing is required, the licencee must obtain an Ore Removal Permit from the Atomic Energy Control Board (AECB) if 10 Kg of uranium and/or thorium in ore exceeding 0.05% (500 ppm) concentration is anticipated.

If indications of an economic sized ore body are found, then the program enters a mine development stage. The boundary between an advanced exploration stage and a mine development stage is somewhat arbitrary and generally there is a transition into the development stage.

Mine Development Stage

When detailed and systematic diamond drilling and significant excavation work (surface or underground) is planned within an ore zone to more accurately define the size and grade of an orebody, then an Underground Exploration Permit from the AECB is required.

During the development stage, two types of feasibility studies are initiated.

(1). Mining and metallurgical studies are contracted to determine if the metal(s) of interest can be profitably extracted from the ground and concentrated by milling. Future market conditions are predicted, to decide if the mine/mill can be operated at a profit over the life of the mine, taking into consideration construction and operating costs; costs of transporting processed ore to markets, and costs of maintaining the mine site in a safe and environmentally acceptable condition.

(2). Environmental impact studies are contracted in which the conceptual design of the overall mining facility is evaluated and a public information process on the proposed project is completed. These studies and the associated procedures are adjudicated and approved by the Atomic Energy Control Board of Canada as well as appropriate provincial agencies.

SECTION 7

URANIUM AND THORIUM OCCURRENCES OF NOVA SCOTIA

Introduction

This section provides a general description of the main geological features of the different types of known uranium and thorium occurrences and prospects of Nova Scotia. An occurrence is defined as a locality where an interesting concentration of a certain mineral(s) has been found. A prospect is an occurrence on which a significant amount of post discovery exploration or assessment work has been carried out to determine its potential. Consequently, an occurrence is the initial find and with further testing and assessment work the occurrence becomes a prospect. Once ore is removed from the ground for processing and commercial sale, the prospect may be called a mine. At present, in Nova Scotia, many occurrences and some prospects of uranium and thorium are known, but no properties have reached a stage ready to make the transition to where mining is considered feasible.

Figure 7-1 shows the location of significant uranium and thorium occurrences and prospects in Nova Scotia. As indicated in the legend, the symbol shape identifies the type of deposit as described in this section and symbol size denotes occurrence or prospect status.

Deposit Types

The different types of uranium and thorium deposits of Nova Scotia and their geological features are listed in Table 7-1. A discussion of each deposit type and description of the Nova Scotia examples of each follows.

Magmatic deposits: These deposits were among the first recognized occurrences of uranium bearing minerals in the Province and have been known since the early years of this century (Gross, 1957). In these deposits, minerals containing small amounts of a number of radioactive metals occur mainly in granitic rocks formed through a process called magmatic differentiation. A magmatic differentiate is any one member of a series of igneous rock types, all of which formed from a single molten magma derived deep in the earth. The process of magmatic differentiation exhibits similar characteristics throughout the various regions of the world. This is why the type of granitic rocks found in Nova Scotia are similar in composition to granitic suites of other areas in the world.

Granitic rocks consist of three main minerals, quartz, feldspar and mica. The proportions of these minerals determine what a rock is named. During magmatic differentiation, the original molten mass crystallizes these minerals and forms solid rock. The relative volume of crystallized rock to remaining molten material is continually changing. The change in the proportion of molten material to solid rock results in a change in composition of the magma. This change in composition is due to the fact that the major minerals which crystallize out (quartz, feldspar and mica) have specific chemical compositions and in forming these minerals, the magma is progressively depleted in the common rock forming elements which make up these minerals. The remaining elements

Table 7-1. Different types and main geological features of the uranium and thorium deposits of Nova Scotia. Locations on Fig. 7-1.

Deposit Type	Elemental Association	Geological Features
Magmatic	* U, Sn, W, Mo, Be and Cu (New Ross area of Lunenburg County)	Radioactive minerals occur in pegmatite dykes and veins in intrusive bodies of alaskite and leuco-monzogranite.
	U, Th and Cu (Georgeville area of Antigonish County)	
Vein	U, P, Sn, W, Cu, Ag, Fe, Mn and Sb	Veins and shear zones altered and mineralized by hot hydrothermal fluids in the interval 280-340 million years ago. The hydrothermal fluids are at least in part derived from specialized granitic intrusions enriched in incompatible elements. Occur predominantly in southern mainland granitic rocks.
Sandstone	Cu and U	Low grade copper and uranium mineralization associated with sandstone layers containing coal fragments and fossil plant detritus in the large Carboniferous sedimentary basins of northern Nova Scotia.
Basal Windsor Group	U	Uranium bearing minerals occur disseminated in the solution-collapse Pembroke breccia and underlying Macumber Formation limestone at the base of the Carboniferous Windsor Group.
Black Shales	U and Ba	Black shale horizons containing anomalous uranium content occur within the Cambrian sedimentary rocks of southeastern Cape Breton Island.
Devonian Volcanic Rocks	U and Th	Uranium and thorium bearing minerals in veins and shear zones occur in hydrothermally altered volcanic rocks of the Lower Devonian Byers Brook Formation. The mineralization is confined to rhyolitic volcanic units which have been intruded by granitic rocks.

* U = uranium, Sn = tin, W = tungsten, Mo = molybdenum, Be = beryllium, Cu = copper, Th = thorium, P = phospherous, Ag = silver, Fe = iron, Mn = manganese, Sb = antimony, Ba = barium

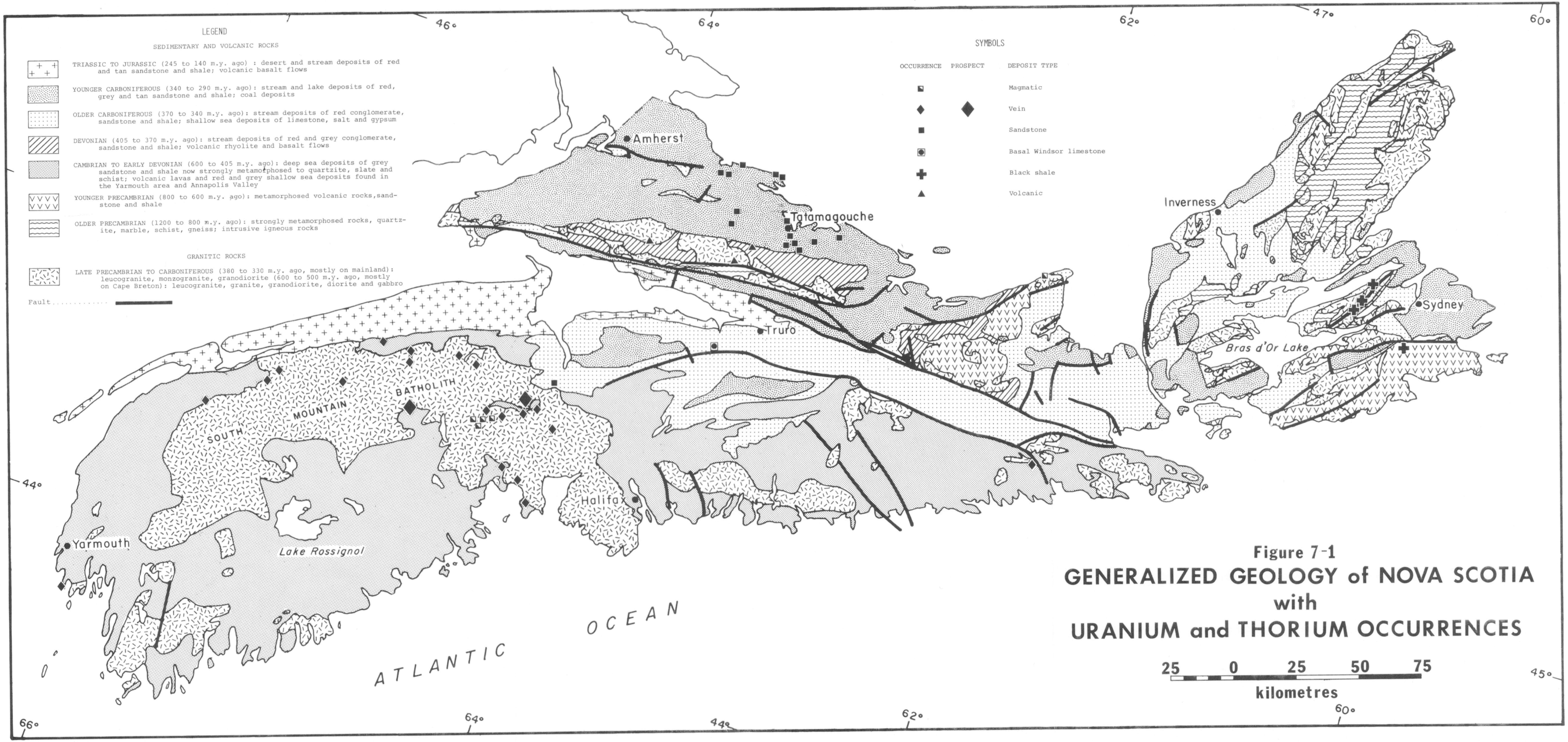


Figure 7-1
GENERALIZED GEOLOGY of NOVA SCOTIA with URANIUM and THORIUM OCCURRENCES

in the molten fraction are termed incompatible, meaning they are both rare and do not fit easily into the crystal structure of the rock forming minerals. Therefore the molten magma, although decreasing in volume, is continually enriching in these incompatible elements. A point is reached when most of the magma has solidified and any minerals crystallizing from the remaining molten fraction must contain a certain amount of these incompatible elements.

Uranium, thorium, tin, tungsten, beryllium, lithium, fluorine and rubidium are a few of these "incompatible" elements. From the description of magmatic differentiation above, it follows that the rocks which are the last to crystallize from the molten magma will contain more of these elements. Granitic rock types which are the last to crystallize from a magma are called late stage differentiates and include monzogranite, leuco-monzogranite, granite, alaskite and pegmatite. All of these rock types are found in the granitic terranes of Nova Scotia and often contain uranium-bearing minerals.

The New Ross-Vaughan area of southwestern Nova Scotia contains many late stage differentiates. This high proportion of such rocks led Charest (1976) to conclude that this region represents the portion of the South Mountain batholith which crystallized last. Radioactive minerals have been reported from pegmatites and other late stage differentiates from the New Ross area, many of which are described by Charest (1976) and O'Reilly et al. (in prep.).

A similar concentration of occurrences of radioactive minerals in pegmatites is found in the Georgeville area of Antigonish County. At Georgeville, Gross (1957) described the uranium-thorium minerals cyrtolite and uranothorite in pegmatite and alaskite bodies exposed along the shores of the Northumberland Strait (Figure 7-1).

Uraniferous deposits of this type, although common, as in the New Ross and Georgeville areas, are seldom large enough or in rich enough concentration to be economical to mine. However, there is a location in South Africa (Dahlkamp, 1978) where an alaskite body contains a very large tonnage of low grade uranium mineralization (300-400 ppm). The ore body is economical to mine because the large tonnage and even distribution of the uranium minerals in the alaskite make an open-pit mining operation feasible. Alaskite bodies in Nova Scotia are enriched in uranium (leuco-monzogranite in Table 5-1; Fig. 7-2) relative to other granitic rock types, but none have been found which approach the levels of concentration of the African example. In the Bancroft area of Ontario pegmatite bodies containing uranium and thorium-bearing minerals have also been mined. These pegmatite bodies are significantly larger than those yet found in Nova Scotia.

<u>Vein type deposits</u>: Since 1977 many uranium occurrences have been discovered on mainland Nova Scotia in granitic rocks or in metamorphic rocks close to granitic rocks. With post discovery exploration and geological investigations it became apparent that these deposits are unlike the rich pitchblende and uraninite-bearing vein deposits mined in the Canadian Shield of Ontario and Saskatchewan. Instead, they are quite similar to the uranium deposits of western and central Europe.

This new understanding, and the fact that at least one prospect (Millet Brook, Hants Co.) might be a mineable size (Fig. 7-1), created a significant increase in exploration for these deposits not only in Nova Scotia, but in many other parts of Atlantic Canada. The geological setting of Nova Scotia suggests that many of the granitic rocks of mainland Nova Scotia have excellent potential for uranium deposits of this type.

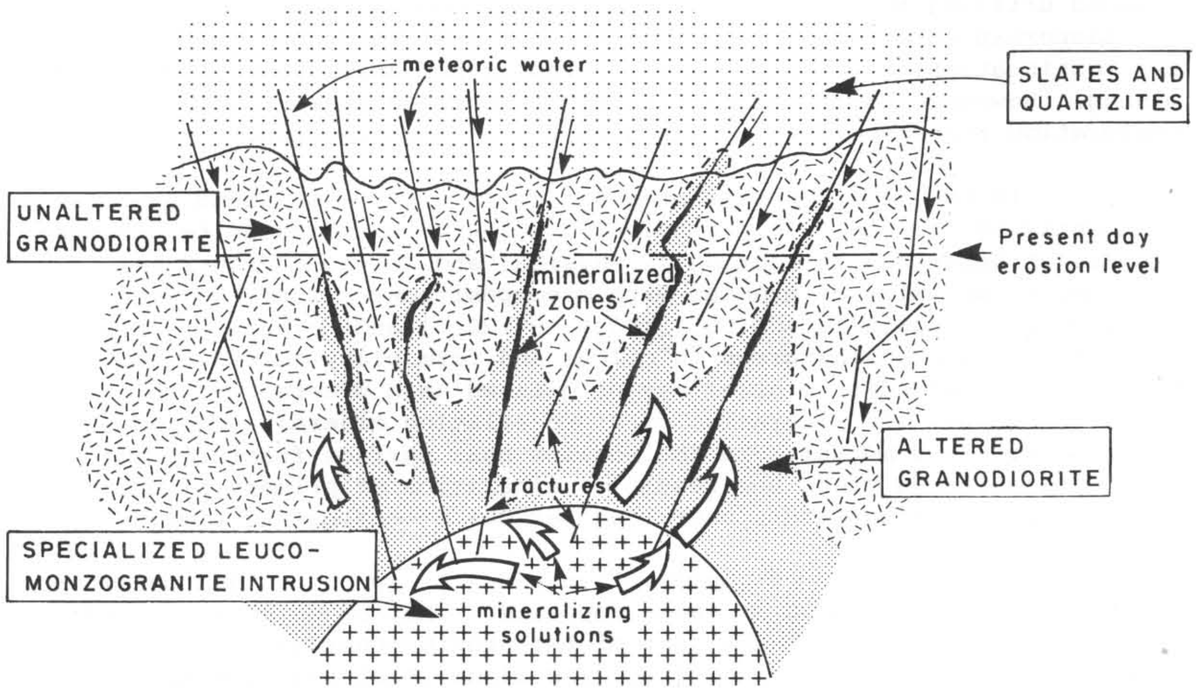
A common feature, recognized here as well as in many other uranium regions world-wide, is the presence of what are called two mica granitic rocks. A two mica granitic rock is one which contains the two micas biotite and muscovite along with feldspars and quartz as the main rock forming minerals. These micas are not directly involved in the formation of uranium deposits, but the presence of two micas indicates that the parent magma from which the granitic rocks crystallized, had a high fluid and/or volatile phase incorporated in the molten magma. The amount and composition of this liquid and volatile phase is perhaps one of the most important factors in the dissolving, transporting and concentration of elements to form many types of ore deposits, including uranium. The liquid and volatile phase is therefore the medium or vehicle by which the ore elements are carried to a particular location and precipitated to form an ore deposit. Many of the granitic rocks of Nova Scotia, especially on the mainland, are two mica granitic rocks.

Another common feature of regions containing vein uranium deposits is that the host granitic rocks generally have an unusually high average uranium content relative to world averages for granitic rocks. Table 5-1 shows the average content of uranium in the main granitic rock types of Nova Scotia compared to world averages for granitic rocks. The higher content of South Mountain batholith and Cobequid Highland granitic rocks relative to world averages is obvious. The fact that the average uranium content of most of the Cape Breton granitic rocks are comparable to the world averages suggests the granitic rocks of that region have less potential to host this type of deposit. It may also be significant that Cape Breton granitic rocks are usually one mica granites (Barr et al., 1982) indicating their parent magmas had a lower volatile and fluid phase content.

A third feature of regions hosting uranium vein deposits is that associated deposits of tin, tungsten, and related elements are present. Occurrences of these elements have been known to exist in the granitic rocks of mainland Nova Scotia, especially the South Mountain batholith, for many years (Charest, 1976; O'Reilly et al., in prep.). The association of tin-tungsten deposits with granites hosting uranium vein deposits is well known and described from the uraniferous granitic terranes of Europe. The major increase in exploration for uranium deposits in Nova Scotia has therefore been accompanied by an increase in exploration for deposits of tin and tungsten. The East Kemptville tin deposit in Yarmouth County is an example of a recently discovered (1977) sizable ore-body found as a result of this overall exploration thrust.

The previous paragraphs described the regional association of uranium vein deposits with granitic rocks. The specific geological features of a typical uranium vein deposit are summarized here as observed in the uranium deposits at Millet Brook, East Dalhousie and

Gaspereau Lake. These prospects are currently the best studied prospects of this type in Nova Scotia. For more detailed descriptions, readers are referred to Lowe and Farstad (1978a and 1978b), Chatterjee et al. (1982), O'Reilly et al. (in prep.) and Robertson and Duncan (1982).



ROCK TYPE	# SAMPLES	$\bar{X}$ U (ppm)	$\bar{X}$ Th (ppm)	AGE (million yr.)
Mineralized Zone	8	1249	8.3	283
Altered Granodiorite	51	107	10.0	300
Specialized Leuco-Monzogranite	135	13.6	5.2	340
Unaltered Granodiorite	45	5.8	10.9	370

Modified after Chatterjee et al.,1982

Figure 7-2. Schematic cross section of the Millet Brook uranium prospect.

At Millet Brook, East Dalhousie, and Gaspereau Lake uranium-bearing minerals occur in veins, fractures, and shear zones. At Millet Brook the mineralization consists of zones of closely spaced veins (Fig. 7-2). The close spacing of the veins enhances the possibility of mining because the amount of nonmineralized rock that would have to be removed in the mining process is low. At Millet Brook the mineralized fracture zone systems extend for over 1100 m at surface and have been found by diamond drilling to extend to at least 125 m depth. At East Dalhousie and Gaspereau Lake detailed exploration has indicated that the spacing and continuation of uranium-bearing veins is not sufficient to consider mining. However, there is still interest in these areas to continue exploration for associated metals such as tin and tungsten.

In the vein deposits of Nova Scotia uranium is found predominantly in the minerals pitchblende, torbernite and autunite. Pitchblende, as described in Section 4, Physical and Chemical Properties of Uranium, is an oxide of uranium with a composition variable between UO_2 and U_3O_8. Autunite [$Ca(UO_2)_2(PO_4)_2 \cdot 8\text{-}12H_2O$] and torbernite [$Cu(UO_2)_2(PO_4)_2 \cdot 8H_2O$] are yellow-green in colour and form platy soft secondary minerals. A secondary mineral may be defined as a mineral derived from, or as the result of, alteration of a pre-existing mineral. The existence of torbernite and autunite in the shallow near surface fractures is therefore believed to be the result of alteration of primary pitchblende by circulating groundwater, over long periods of geological time.

Minor amounts of copper, lead and zinc sulphides and tungsten and tin oxides are common in these deposits. Chatterjee et al. (1982) reported that at Millet Brook most of the uranium-bearing minerals are found within 1 m of the actual fractures along which the mineralizing fluids passed. Adjacent to the narrow, heavily mineralized fractures, the granitic wall rocks are often altered for up to 30 m from the veins, since hot hydrothermal fluids carrying uranium and other elements have the potential to physically and chemically change the rocks through which they move.

The altered zone may be described as a zone transitional between the barren or unaffected rock and the highly mineralized veins. The altered zone contains more uranium than the unaltered barren rock, but much lower levels of uranium than the mineralized zones (Fig. 7-2).

The origin of uranium vein deposits may be summarized by describing three main models: (1) supergene or near surface model for uranium deposition, (2) uranium deposited deep in the crust from solutions of surface (meteoric) origin, (3) uranium deposited from hydrothermal solutions of meteoric and magmatic origin.

Model (1), Supergene or near surface model

This model involves deposition of uranium along fractures in granitic rocks within 100 m of the earth's surface. Barbier (1974) explained the model in detail but the main features are graphically displayed on Fig. 7-3. The waters which leach and transport the uranium originate near the earth's surface (meteoric water). The meteoric waters must be highly oxidizing, which means they must contain an abundance of oxygen and/or carbon dioxide. An oxidizing solution has a strong potential to decompose many of the minerals with which it comes in contact. A common example of the process of oxidation is the rusting of steel which, in the presence of an oxidizing medium (air and water), decomposes and releases iron oxide into the environment.

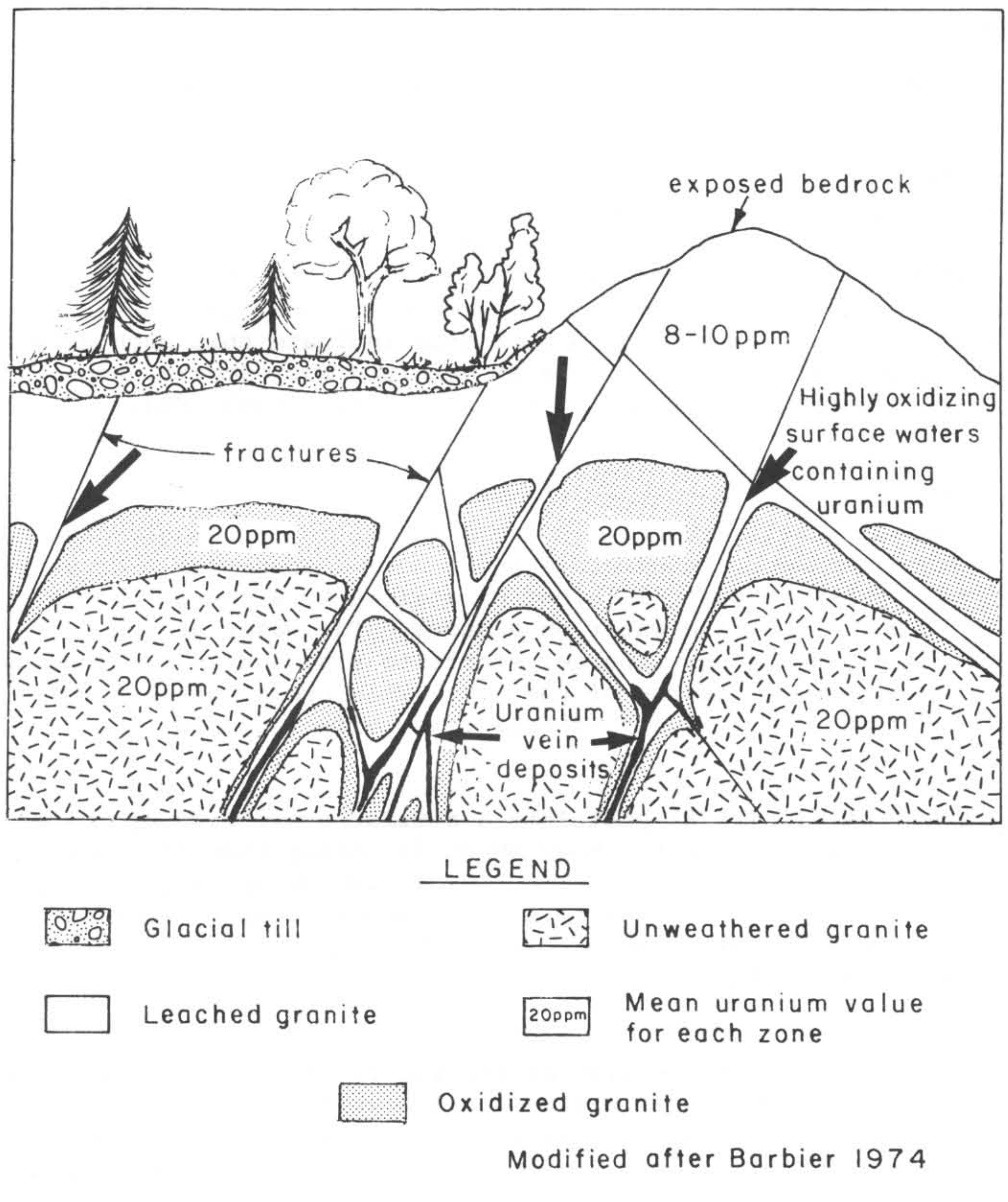


Figure 7-3. Model for uranium deposition by highly oxidizing surface waters.

Some of the small primary uranium-bearing minerals (usually uraninite) present in most granitic rocks decompose in the presence of an oxidizing solution and their uranium ions are carried along in solution.

These uranium enriched waters migrate downward along fractures until groundwater is encountered which is not as oxidizing. The mixing of the two waters of differing oxidizing potentials results in a solution which no longer has the ability to hold the uranium in a dissolved state. At this point uranium-bearing minerals are precipitated along the fractures. The process of solution, migration and localized precipitation to form an orebody may take millions of years. The fact that many uranium vein deposits in France occur only to a depth of less than 100 m supports this model.

Model (2), Uranium deposited deep in the crust from solutions of meteoric origin:

The close association of uranium vein deposits with granitic rocks of high background uranium content (specialized granites) was noted by Rich et al. (1977). The uranium deposits usually are found within granitic rocks having average uranium content greater than 10 ppm uranium or in rocks, close to such granites. Geological studies on the various granitic terranes of Nova Scotia indicate that such anomalous granitic plutons exist in many areas of mainland Nova Scotia, especially in the South Mountain batholith (Chatterjee et al., 1982; Fig. 7-2).

Fehn et al. (1978) stated that in a specialized granitic body of high radiation, the long-term radioactive decay of uranium, thorium, potassium and all their daughter isotopes is sufficient to generate heat to drive what is called a convective hydrothermal system. A convective hydrothermal system is best explained by analogy to a common everyday example of a pot of boiling water on a stove. The water at the bottom of the pot close to the heat source, starts to rise and is replaced by cooler water from near the top of the pot. This cycle continually repeats itself and gives rise to the swirling effect common to boiling water.

Fehn et al. (1978) postulate a similar convective hydrothermal system in and around a granitic body which is hotter than its enclosing rocks. This anomalous heat is due to radioactive decay of naturally occurring radioisotopes. Two factors that are critical to this model are a granitic body of high radioactive content and a sufficiently developed natural fracture system in the bedrock to allow circulation of waters.

In this model the source of the waters is meteoric (atmospheric and groundwater), oxidizing in nature and low in temperature. These waters are drawn down along well developed fracture systems by convection generated by a hot radioactive granite. The waters as they near and enter the source of heat, the specialized granite, become hotter and their ability to oxidize the primary uranium-bearing minerals in the granite is enhanced. Leaching of uranium and other elements occurs. The now hot uranium enriched solutions begin to permeate upward along the fracture system according to the convective cycle and eventually leave the hotter environment and enter colder rocks. With the drop in temperature the ability of the waters to hold uranium and other elements in solution is lost and therefore precipitation of pitchblende (U_3O_8) and other uraniferous minerals occurs. The result is a halo of mineralization occurring in fractures either along the periphery of the granite or within the nearby bedrock types.

Model 3, Uranium deposited from hydrothermal solutions derived by a combination of meteroic and magmatic water:

This model best explains the features observed in the major uranium vein deposits of Nova Scotia. It involves some features of model 2 (hydrothermal convective system) and solutions derived as the very end product of magmatic differentiation (magmatic derived solutions). Many geologists feel that the heat generated solely by radioactive decay of elements within a granite of anomalous uranium content may not be sufficient to drive a convective system described in model 2. Simpson et al. (1979) described a model for formation of uranium vein deposits in the British Isles in which the heat source causing the convective cycle is due to intrusion of a molten magma of high uranium content (specialized granite) into cold and solid bedrock (Fig. 7-4). This model suggests that the magma is a late stage differentiate and therefore highly enriched in such incompatible elements as uranium, tin, tungsten, lithium, fluorine, molybdenum and rubidium. The intrusion of the hot magma into a colder bedrock initiates a convective hydrothermal system. In this way this model is similar to model 2 except that the total heat driving the system is a combination of heat derived by cooling of the hot magma and heat from radioactive decay of the anomalous radioelement content of the specialized granitic intrusion.

Colder water from the surrounding bedrock is drawn into or near the cooling and solidifying pluton and becomes mixed with magmatic solutions escaping from the magma. The resulting solution is volatile rich and is carried upward and outward from the heat source. These hydrothermal solutions may also leach the surrounding rocks of some of their content of uranium and other incompatible elements. When the solutions encounter a region of lower pressure and temperature, the fluids ability to keep many of these elements in solution is altered and precipitation results, in rare cases forming an ore body.

Figure 7-4 shows the close relationship of deposits of uranium with deposits of elements such as tin, tungsten, molybdenum, antimony, and manganese. As the temperature, pressure and composition of the migrating fluid changes, different incompatible elements will in turn be precipitated and may form ore deposits. Their zonal separation away from the location where uranium was precipitated indicates that the conditions under which uranium is precipitated must be different than the conditions under which tin, tungsten and the other incompatible elements are precipitated. This zonal pattern of the various metals displayed on Figure 7-4 is the result of the changing physical and chemical conditions of the ore-bearing hydrothermal solutions.

Although it seems that in Nova Scotia, deposits such as Millet Brook may be due to processes conforming to model 3, smaller vein type deposits conforming to models 1 and 2 may also exist. Additional geological studies are required on more of the uranium deposits of Nova Scotia to determine which ones are best answered by the various models.

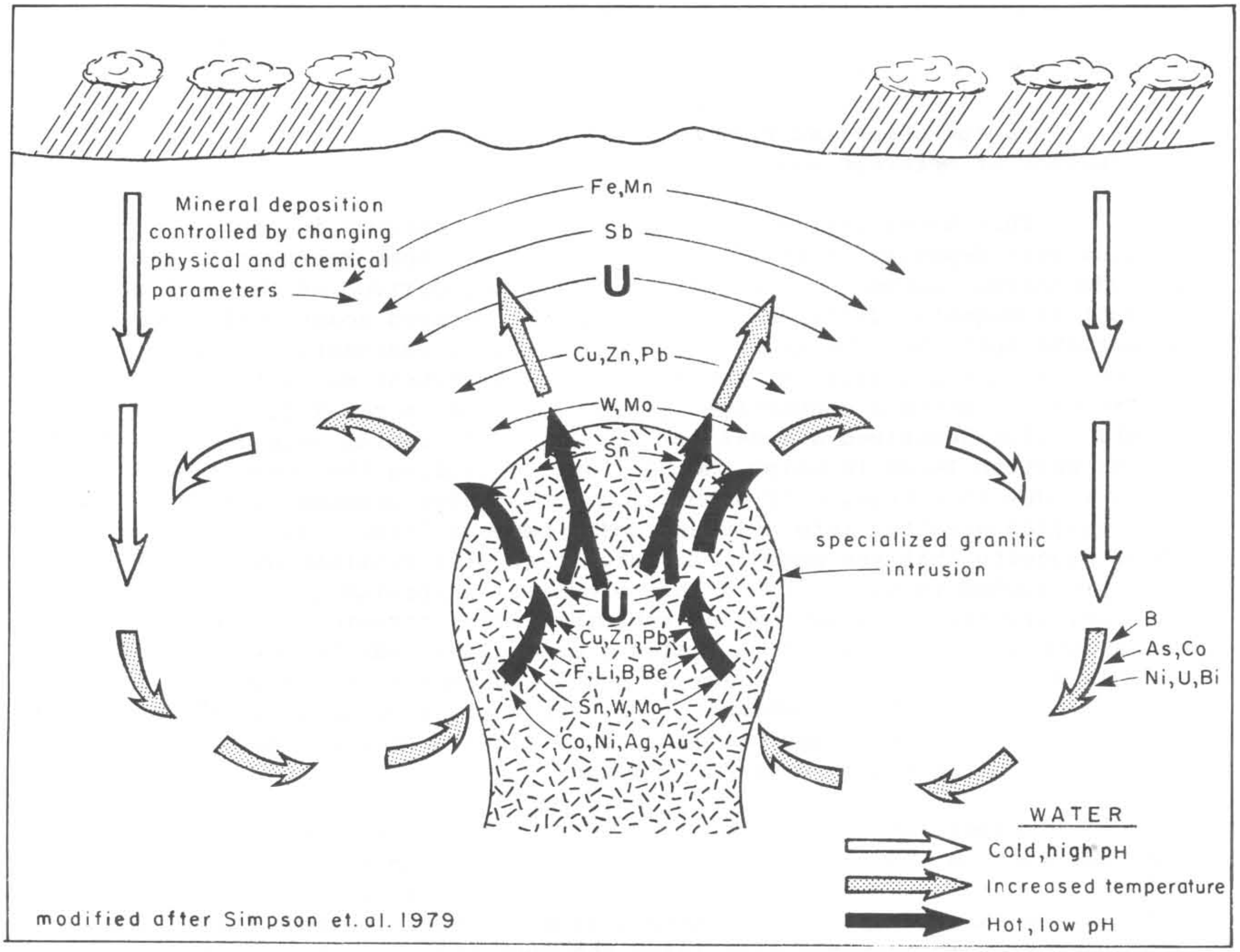


Figure 7-4. Model for deposition of uranium and related elements from a specialized granitic intrusion.

Sandstone type deposits: Gross (1957) and Brummer (1958) indicated the existence of low grade uranium mineralization associated with many of the previously known copper sulphide deposits in the large sedimentary basins of northern Nova Scotia (Fig. 7-1). The existence of copper mineralization had been known for many years (Fletcher 1905a-d) and the recognition of radioactive material in the copper ores in the 1950's generated some short lived exploration activity.

Deposits of uranium in sandstone sequences similar to those in northern Nova Scotia are known to occur in the Colorado Plateau area of the southwestern United States and are well described in the geological literature. The main features of these deposits were summarized by Dahlkamp (1978; Fig. 7-5).

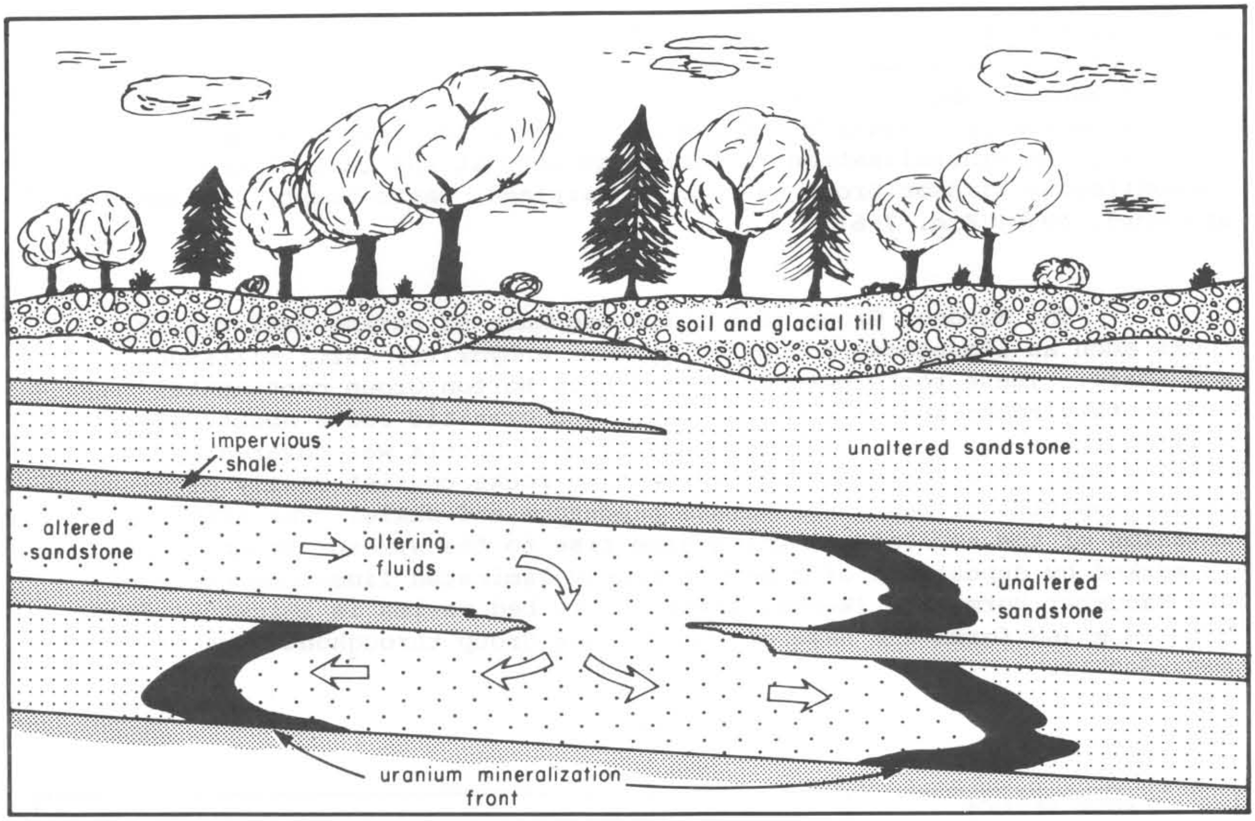


Figure 7-5. Features of a typical sandstone type uranium deposit.

In Nova Scotia, common sandstone type deposits have been observed (Brummer, 1958; Dunsmore, 1977; Chatterjee, 1977; and MacNabb and Guardia, 1980). Many of these uranium occurrences are distributed throughout the sedimentary basins of northern and north central Nova Scotia, but at present none have proved to be encouraging enough to enter an advanced stage of exploration.

The origin of the uranium and the solutions which transported the uranium to its present depositional site is not completely understood in the geological literature. Dunsmore (1977) wrote that both the uranium and solutions were derived from the thick evaporite sequences (gypsum and salt) known to underlie much of the Carboniferous sedimentary basins in Nova Scotia. With accumulation of sediment on the evaporites, the solutions were squeezed out and migrated along the more porous layers in the sediments (coarse sandstones) and precipitated uranium minerals when the proper chemical conditions were encountered.

Chatterjee (1977) suggested that sediments derived by erosion of the Cobequid Highlands, which formed the sedimentary basin, contained small amounts of primary uranium minerals. A solution of unknown origin, but oxidizing in nature, leached large volumes of these sedimentary rocks of some of their uranium content and redeposited the uranium at chemically favourable locations.

Basal Windsor Group: The Geological Survey of Canada (G.S.C.) released the results of an airborne radiometric survey of the Maitland-Kennetcook area of Hants County in 1976 (No.3 on Fig. 5-1). The survey indicated several radiometric highs in the area. Further investigation documented minor uranium mineralization in limestone beds at the base of the Lower Carboniferous Windsor Group near South Maitland, Hants County (Charbonneau and Ford, 1978; Fig. 7-6).

The Windsor Group is a thick sequence of marine sedimentary rocks such as limestone, dolomite, gypsum, anhydrite, salt, siltstone and shale. These rocks were deposited upon Horton Group continental sedimentary rocks and older metamorphic and granitic rocks about 340 million years ago at a time when much of Nova Scotia was covered by a shallow sea. The Horton Group sedimentary rocks consist mostly of stream deposits of red conglomerate sandstone and shale. The first invasion of the ancient sea which gave rise to the Windsor Group rocks is marked by deposition of a bed of finely laminated limestone called the Macumber Formation (Weeks, 1948). This bed varies in thickness from 3 to 18 m and forms the base of the Windsor Group throughout much of Nova Scotia.

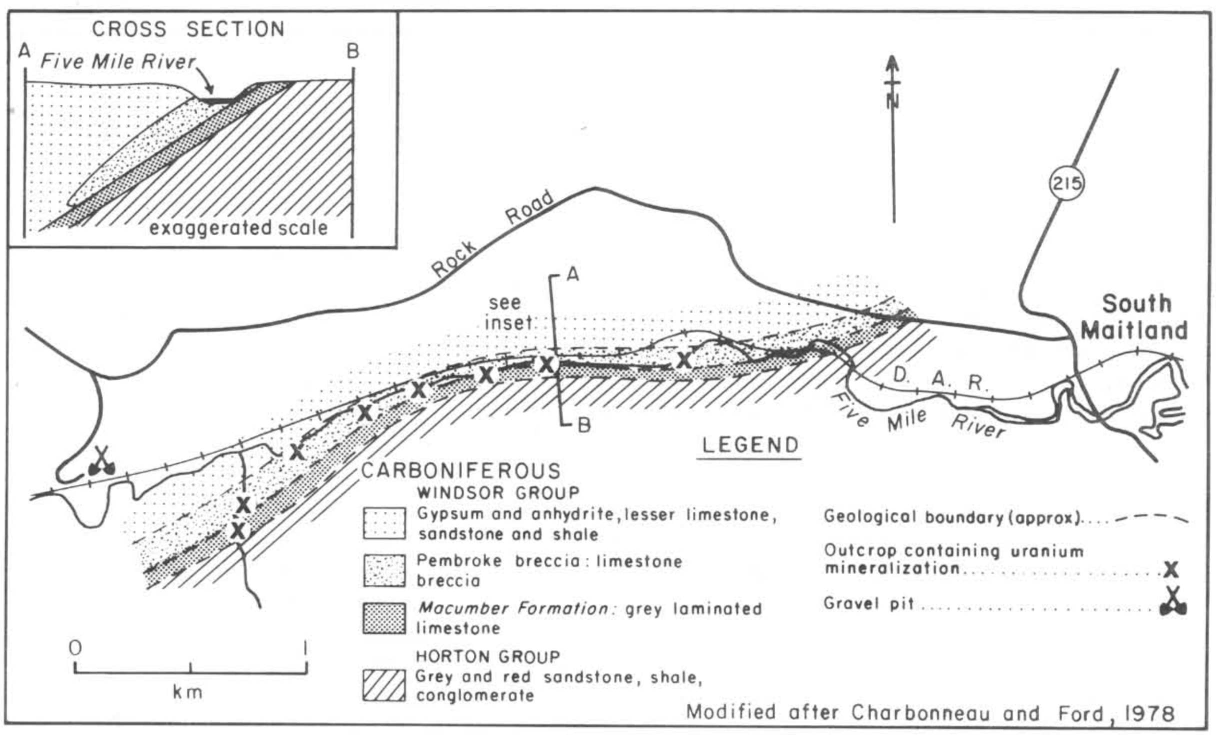


Figure 7-6. Uranium mineralization at South Maitland, Hants County.

Overlying the Macumber Formation in many areas is a limestone breccia (fragmented or broken up rock) called the Pembroke breccia. Clifton (1967) concluded that this unit formed near an ancient erosion surface where anhydrite layers in the limestones near the top of the Macumber Formation and overlying anhydrite and gypsum beds were dissolved by groundwater. After dissolution of the anhydrite layers, the remaining limestone layers collapsed, forming a large cavity containing angular limestone fragments. This cavity was then filled in by sediment and other debris and solidified to form what is called a solution-collapse breccia. Due to the fragmented nature of this unit, it acted as an excellent porous medium along which ore-bearing solutions moved. The formation of a collapse-breccia is a near surface process and the unit does not continue to great depth below the original erosion surface. Clifton (1967) suggested that the brecciation does not exist below about 150 m from surface.

At South Maitland, Hants County, uranium mineralization occurs as disseminated uranium-bearing minerals in the Pembroke breccia and underlying Macumber Formation limestone (Charbonneau and Ford, 1978). Figure 7-6 shows the distribution of uranium mineralization at surface and in schematic cross-section along the Five Mile River at South Maitland.

Additional work is required to determine the age and source of this type of uranium mineralization in Nova Scotia. Charbonneau and Ford (1978) reported low grade analyses of 32 and 135 ppm uranium for samples from the South Maitland occurrences. The Windsor and Horton Groups in the Hants County and southwestern Colchester County areas were intensively explored for deposits of this type from 1977-1979 (Appendix I). This investigation concluded that the mineralization was of low grade and the main mineralized unit, the solution-collapse Pembroke breccia, was found not to extend to depth. Kirkham (1978) examined the potential for uranium mineralization in the basal Windsor Group limestones of Cape Breton Island. Although he concluded the same geological setting exists in Cape Breton as the South Maitland area, no significant uranium mineralization was found.

Black shales: Low grade (10-100 ppm) uranium mineralization has been recognized in black shale horizons of Cambrian age (approximately 500 million years old) on Cape Breton Island (Fig. 7-1). The Cambrian sedimentary rocks form an elongate narrow basin stretching the length of the Boisdale Hills from Eskasoni to Georges River and also underlie much of an area east of the Mira River to the south of Marion Bridge, Cape Breton County (Hutchinson, 1952).

The uranium in black shales association is well known in other regions of the world (Bell, 1978). The Ranstad district of Sweden contains a black shale unit 3 m wide which extends for many kilometres and has an average uranium content of 300 ppm. The Chattanooga black shale of eastern Tennessee, U.S.A. is estimated to have an average of 30 ppm U_3O_8 for a volume of 2500 km^3 of shale. Although the black shale environment of uranium mineralization is known to contain vast low grade reserves, deposits of this type are only mined extensively in China. By free world standards, these deposits are currently too low grade to be mined economically.

Little is known about the extent of this type of uranium deposit in Nova Scotia, because only preliminary and initial exploration surveys have been done. Felderhof et al. (1979) examined the Cambrian sedimentary rocks of the Barachois Harbour area of the Boisdale Hills and reported the results of geological mapping, a ground radiometric survey, and some bedrock sampling. Anomalous radioactivity (up to 10 times background) was observed in shales exposed along Johnston Brook at Barachois Harbour. Samples from outcrops in the area assayed between 10 and 100 ppm U_3O_8. The exploration work showed uranium enrichment exists along certain sections of the shale, but no followup work was done.

Cheve (1980) submitted an assessment report to the Nova Scotia Department of Mines and Energy on behalf of Uranerz Exploration and Mining Limited for an exploration program in Cambrian sedimentary rocks of the Boisdale Hills. The surveys consisted of ground radiometric surveys and geological mapping. Anomalous radiation readings up to 1700 counts per second (10-12 times background) were recorded. Bedrock samples assayed up to 112 ppm U_3O_8. Their geological mapping showed that radioactive layers exist within the black shale units of the McLeod Brook and MacMullin Formations. Cheve (1980) concluded that the Cambrian shale beds contained a natural high uranium content on original deposition. This was due to the ability of clay minerals, of which shale is comprised, to scavenge and fix uranium. This high content of uranium was later mobilized when the shales were deformed and faulted and uranium was concentrated in certain highly chemically reducing horizons within the black shales.

The existence of low grade uranium mineralization is confirmed in the Cambrian shales of southeastern Cape Breton, but their abundance, lateral extent, and potential has yet to be determined.

Uranium and thorium in Devonian volcanic rocks: Occurrences of uranium and thorium have been discovered by exploration in the Cobequid Highlands of northern Nova Scotia since 1976 (Fig. 7-1). Although interesting, none of the prospects has reached an advanced stage of exploration. The uranium and thorium mineralization, as exploration has indicated to date, is confined to volcanic units within the Lower to Middle Devonian sedimentary and volcanic Byers Brook Formation. Preliminary indications are that they are of similar origin to the vein type deposits which occur in the granitic rocks of the southern mainland (Gulf Minerals Canada Limited, 1980).

The Byers Brook Formation is of Lower to Middle Devonian age (370-405 million years old) and consists of the sedimentary rocks conglomerate, greywacke, mudstone and shale and the volcanic rocks rhyolite, ignimbrite, tuff, ash and agglomerate. Both the sedimentary and volcanic units are of continental origin (deposited on continents above seawater). In the Cobequid Highlands other Devonian Formations occur, but uranium and thorium has only been found as yet in Byers Brook Formation rocks. For more detailed descriptions of the geology of the rocks of the Cobequid Highlands, readers are referred to Donohoe and Wallace (1980) and exploration assessment reports of Gulf Minerals Canada Ltd. (Appendices II and III).

SECTION 8

MINING LEGISLATION IN NOVA SCOTIA

The Nova Scotia Department of Mines and Energy has the responsibility for administering the occupational health and safety programs for the mining industry in the province. In this regard, the Department inspects all mines and quarries under the authority of the Mineral Resources Act, the Coal Mines Regulation Act and the Metalliferous Mines and Quarries Regulation Act. The Department of Mines and Energy is also responsible for administering the Health Act and its various regulations and the Workers Compensation Board regulation respecting first aid, where these apply to mines and quarries. At present, Departmental staff of the Engineering Division inspect over 120 operations in the province, employing approximately 2400 workers.

Exceptions to this mandate are those coal mines in Cape Breton operated by the Cape Breton Development Corporation, gravel pits and quarries specifically related to construction projects, and gravel pits operated solely in conjunction with the construction or repairs of public roads. Mining operations of the federal crown corporation, Cape Breton Development Corporation, are subject to federal coal mine regulations and are inspected by personnel of the federal Department of Labour. Surface facilities related to construction fall under the jurisdiction of the Construction Safety Act, administered by the provincial Department of Labour and Manpower. The Department of Mines and Energy has over-all responsibility for all aspects of occupational health and safety on a mine site, however, a high level of co-operation exists between the various government departments and the Workers' Compensation Board. The available expertise in other departments is frequently utilized to supplement departmental resources and to avoid duplicating of effort and expertise. The Department of Health is responsible for providing and maintaining standards for occupational health and have personnel employed who are experts in this field. They also provide technical assistance and advice on general health matters and conduct surveys and educational programs with mines inspection personnel.

In October 1975 an Interdepartmental Committee was established at the level of Deputy Minister to co-ordinate all matters related to occupational health and safety in the Province. Departments represented on the committee are: Mines and Energy, Labour and Manpower, Health, Environment, and the Workers' Compensation Board. A Standing Technical Committee was also established at the Director level and is composed of people who are directly responsible for the administration of occupational health and safety programs. The Standing Technical Committee meet regularly to discuss ongoing problems of mutual concern and to formulate policy recommendations for the Deputy Ministers. Individual members of the Standing Technical Committee are frequently in contact on a daily basis which contributes substantially to the overall effectiveness of the occupational health and safety administration.

The prime vehicle for provincial control of a mining operation is the mine lease which is granted under the Mineral Resources Act.

Before a lease is granted, both the Department of Mines and Energy and Department of the Environment must be satisfied that the project conforms to their legislated responsibilities. The approval process therefore involves the submission, evaluation and collective government approval of technical feasibility, socio-economic and environmental impact analyses.

Uranium, as a metallic metal requiring extraction by standard mining techniques, falls under the general rules contained in the existing provincial legislation outlined above. However, uranium mining represents a unique constitutional situation with respect to the regulatory process. This situation has been outlined in detail in previous inquiries and will only be reviewed briefly here.

The British North America Act gives the provinces ownership and control of minerals found in the province. However, it also allows the Parliament of Canada to declare local works and undertakings to be for the general advantage of Canada. Under this power, Parliament passed the Atomic Energy Control Act in 1946, giving legislative authority for uranium mining to the federal government. Therefore, the regulatory process for uranium mining is in a unique category. Although it can be argued that the Atomic Energy Control Act excludes provincial authority, in practise the provinces of Ontario and Saskatchewan, the only provinces with active uranium mining operations, are fully involved in its regulation, and all provinces retain control of uranium exploration activities. A number of studies have been completed on the differing procedures developed between the federal Atomic Energy Control Board, set up to administer the Act, and the provincial agencies. Although highly comprehensive regulations and inspection procedures with respect to health, safety and security aspects in uranium mines have been established by mutual federal/provincial cooperation, it is fair to say that problems with respect to this special constitutional arrangement regarding jurisdiction of uranium mines still exist. (Bates et al, 1980; Ontario Commission, 1976; Saskatchewan Inquiry, 1978)

The position of the Government of Nova Scotia regarding provincial Uranium Mining Regulations was clearly stated in the Legislature by the Minister of Development on April 3, 1981. He stated, in part, that it was the intention of the government

> "to investigate all scientific and technical information related to the protection of workers, the public and the environment associated with the uranium mining cycle, and in particular the relevance of this data to potential uranium mining environments in Nova Scotia, to receive public input on these matters and to allow the opportunity for meaningful public review of all aspects of the investigation, and to determine terms and conditions, submission requirements, and approval procedures to be established as provincial regulations, prior to any evaluation of applications for leases to mine uranium, to ensure that, if approved, mining will be conducted under acceptable standards of worker and public safety, and the protection of the environment."

This cabinet decision was preceded by a request to this Department to provide factual information on the current status of uranium exploration and the potential for uranium mining in the province. The pertinent aspects of that evaluation were as follows:

(a) on the basis of government sponsored scientific documentation of the natural distribution of uranium in certain rock formations in Nova Scotia and the encouraging exploration programs conducted by the private sector, there is a reasonable possibility that, if a comparable level of exploration is maintained, commercial deposits of uranium as well as other associated metals, may be found and developed in the future.

(b) on the basis of our present technical knowledge of the known uranium occurrences, no commercial deposits of uranium currently exist in Nova Scotia. Only one significant prospect has been documented to date, near Millet Brook in Hants County. This is still in an exploration stage, and under the most optimistic continuing success in developing proven uranium ore reserves, could not be in production for at least five years.

This situation is still accurate, in the professional opinion of this Department. It therefore allows time to fully develop acceptable regulations prior to any evaluation of applications for leases to mine uranium.

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APPENDIX I

Areas Held Under Exploration Licences for Uranium in Nova Scotia

Item 1. Areas held under exploration licences for uranium prior to 1976.

Item 2. Areas held under exploration licences for uranium, December 1976.

Item 3. Areas held under exploration licences for uranium, December 1977.

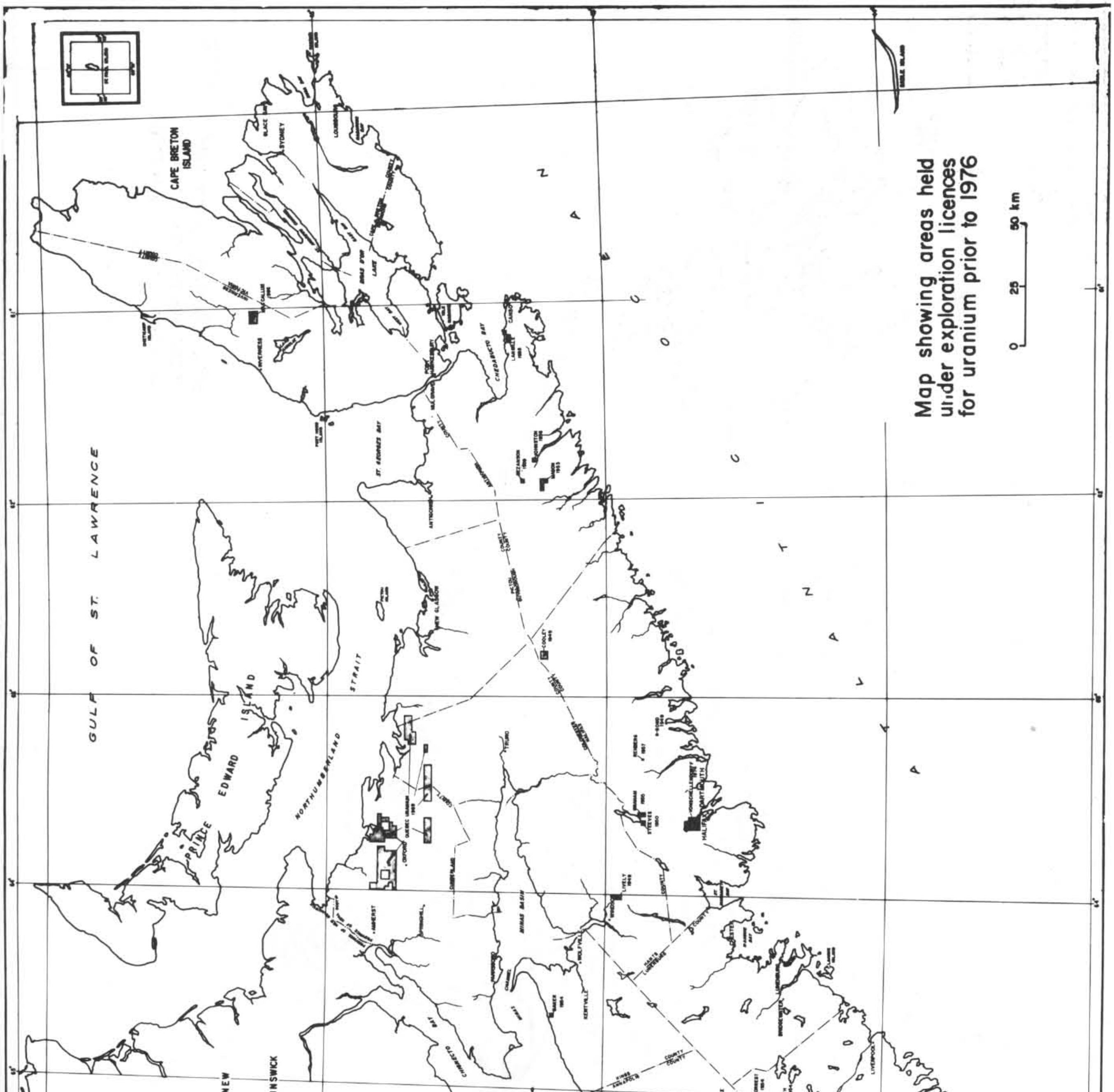
Item 4. Areas held under exploration licences for uranium, December 1978.

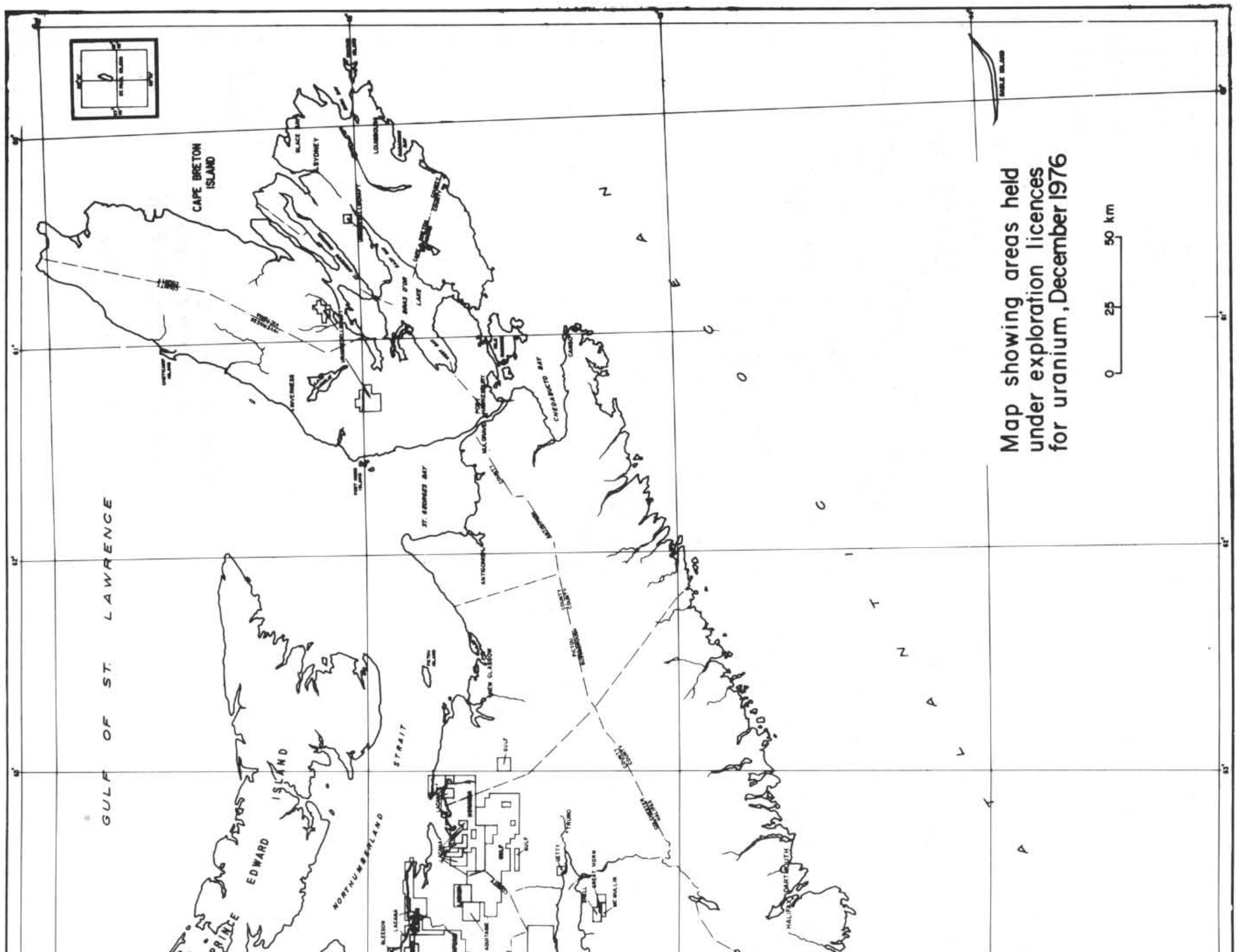
Item 5. Areas held under exploration licences for uranium, December 1979.

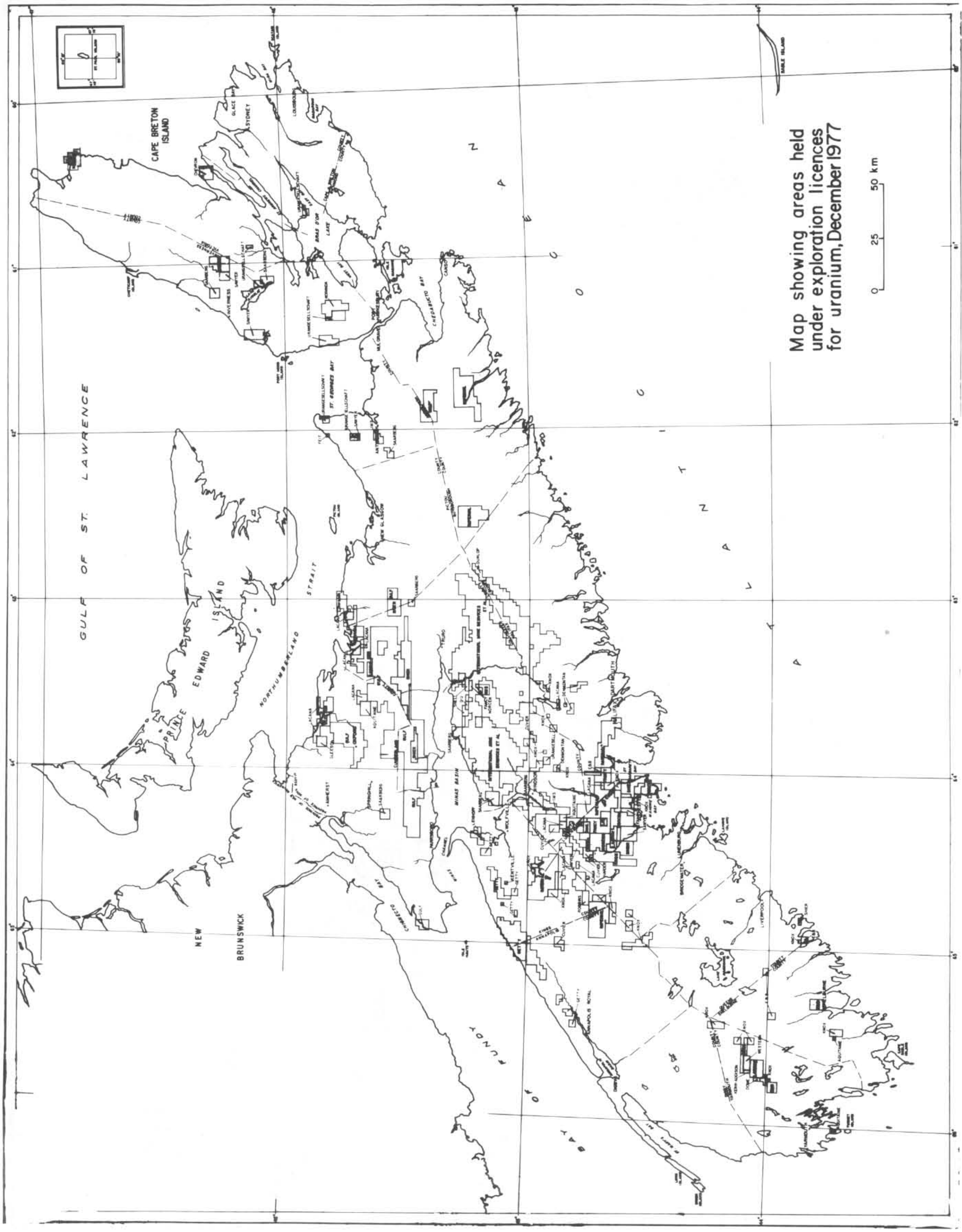
Item 6. Areas held under exploration licences for uranium, December 1980.

Item 7. Areas held under exploration licences for uranium, December 1981.

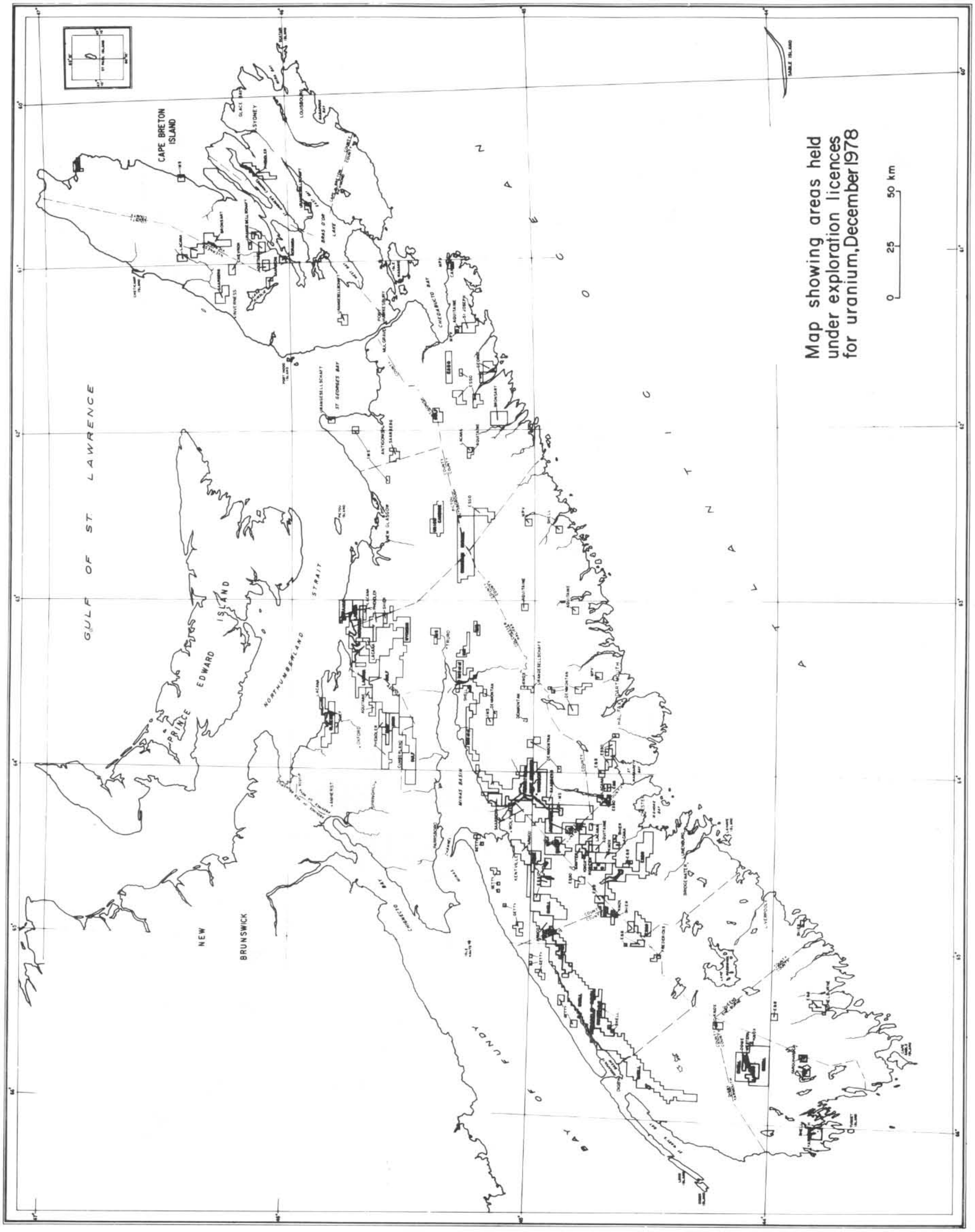
Item 8. Areas requested for special uranium exploration licences, July 22, 1982.

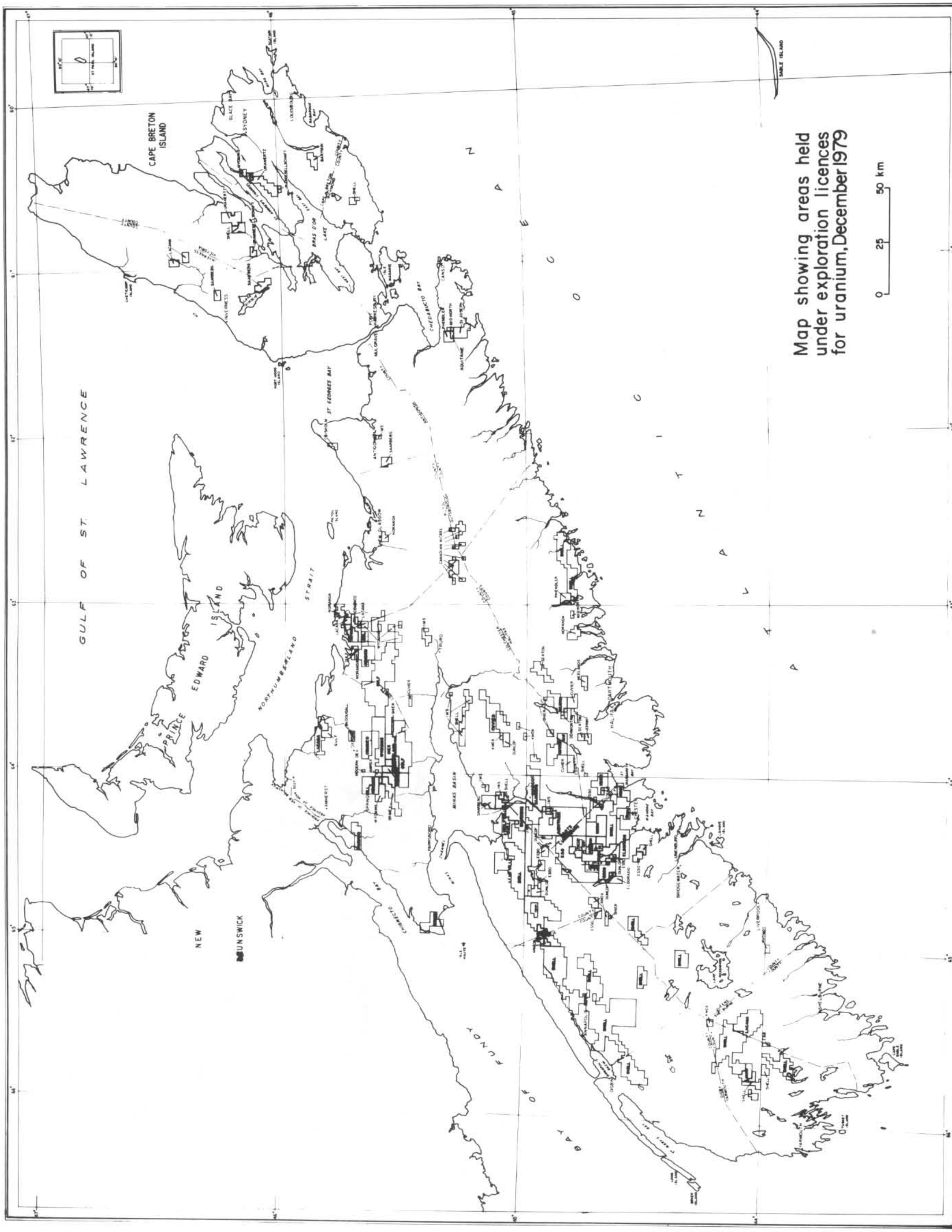

Map showing areas held
under exploration licences
for uranium prior to 1976
0 25 50 km
GULF OF ST. LAWRENCE
PRINCE EDWARD ISLAND
NORTHUMBERLAND STRAIT
NEW BRUNSWICK
CAPE BRETON ISLAND
ST. GEORGES BAY
CHEDABUCTO BAY
MINAS BASIN
BAY OF FUNDY
ATLANTIC OCEAN
SYDNEY
AMHERST
LIVERPOOL
SABLE ISLAND

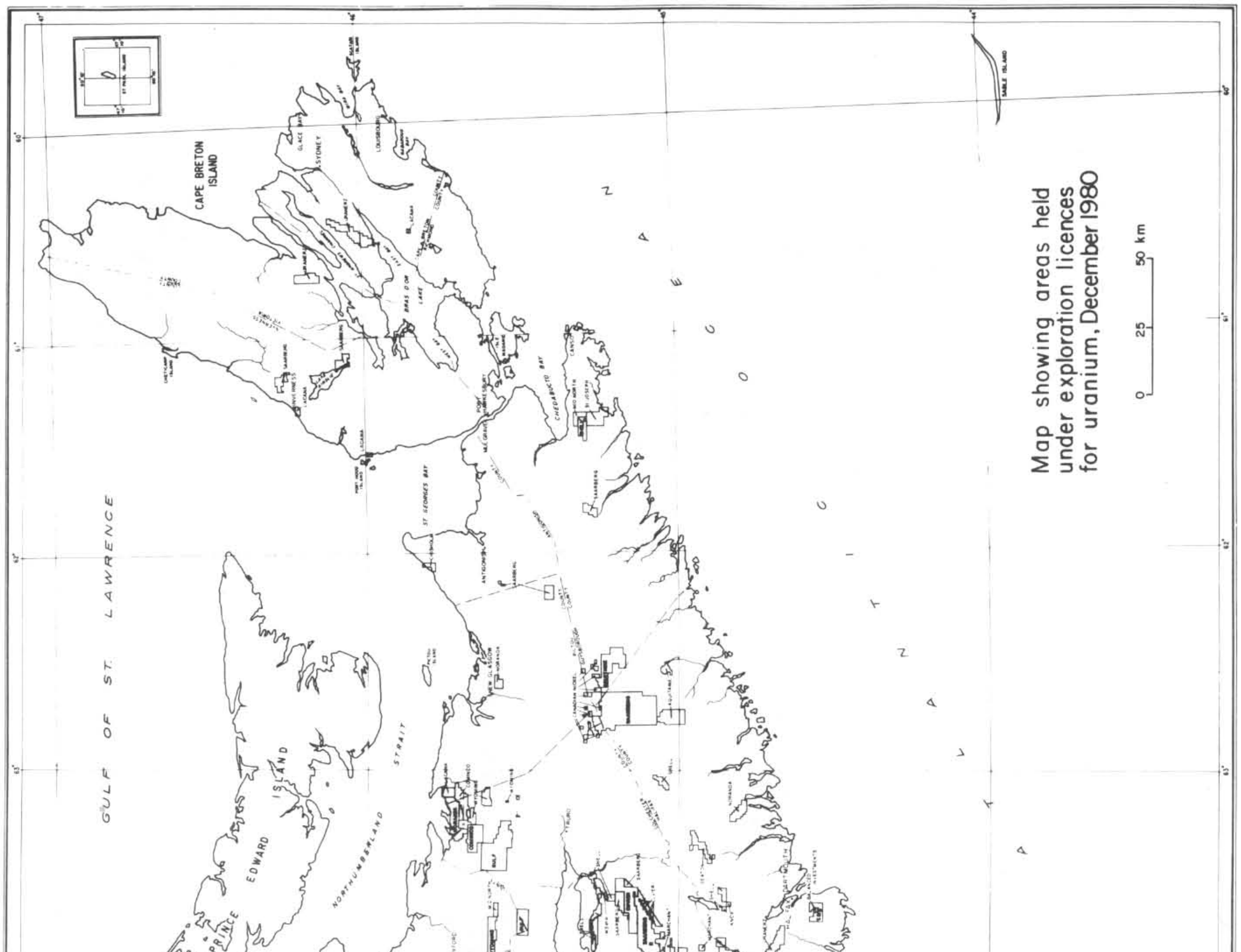

Map showing areas held
under exploration licences
for uranium, December 1976
0 25 50 km
GULF OF ST. LAWRENCE
CAPE BRETON ISLAND
PRINCE EDWARD ISLAND
NORTHUMBERLAND STRAIT
NEW BRUNSWICK
BAY OF FUNDY
ATLANTIC OCEAN



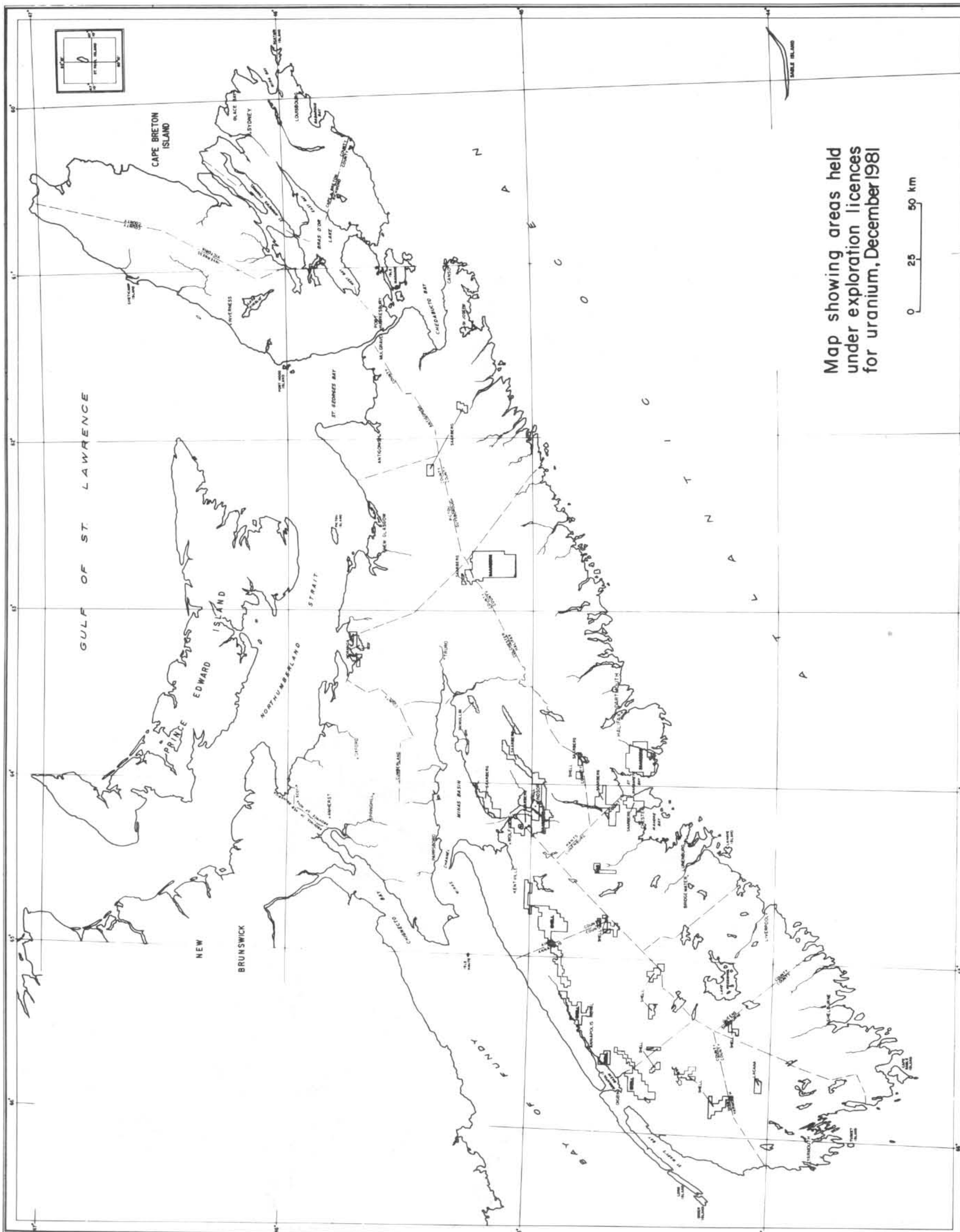
Map showing areas held under exploration licences for uranium, December 1977

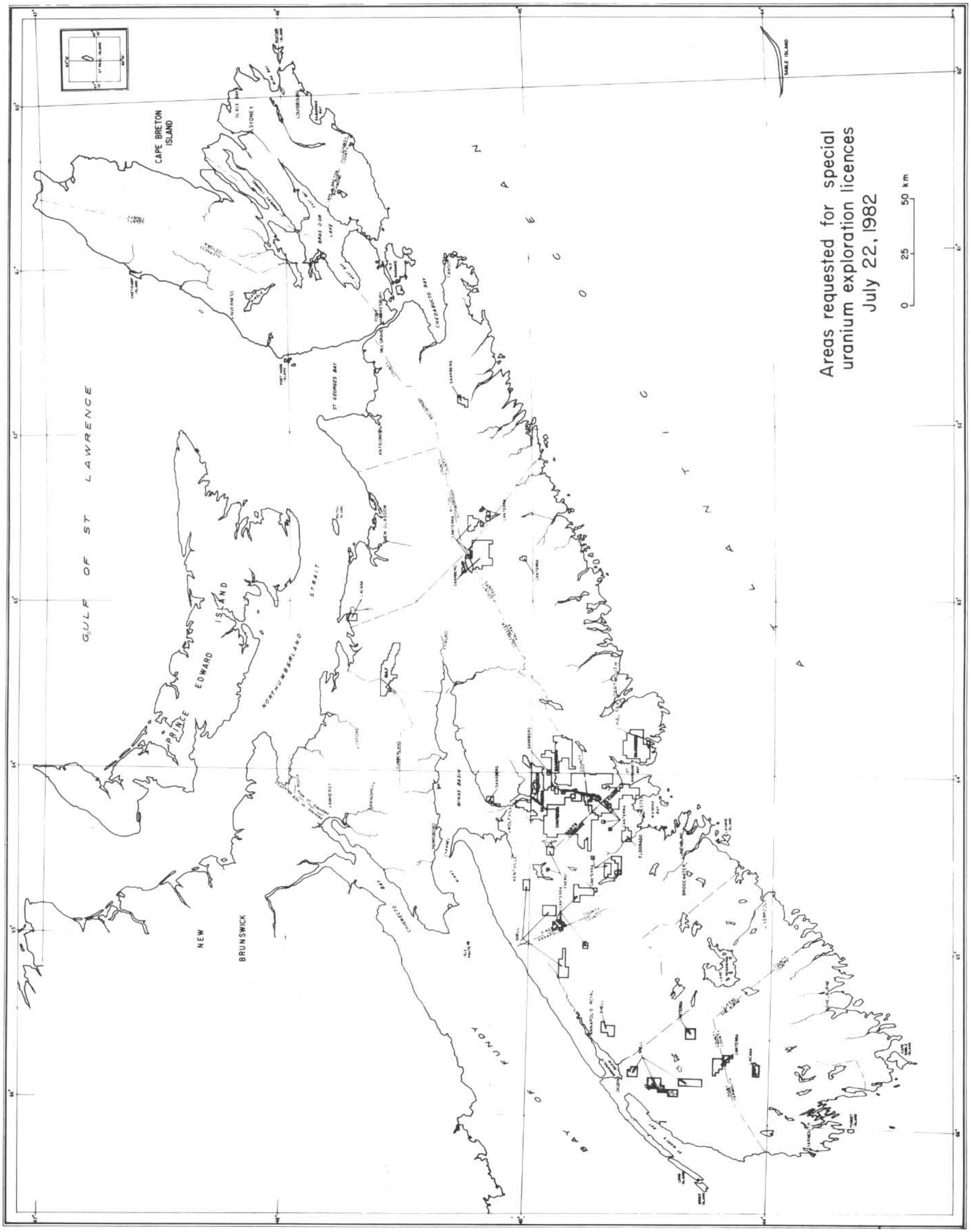

Map showing areas held
under exploration licences
for uranium, December 1978
0 25 50 km
GULF OF ST LAWRENCE
CAPE BRETON ISLAND
PRINCE EDWARD ISLAND
NORTHUMBERLAND STRAIT
NEW BRUNSWICK
MINAS BASIN
BAY OF FUNDY
ATLANTIC OCEAN
SYDNEY
NEW GLASGOW
ST GEORGES BAY
CHEDABUCTO BAY
BRAS D'OR LAKE
INVERNESS
AMHERST
OXFORD
KENTVILLE
LIVERPOOL


Map showing areas held
under exploration licences
for uranium, December 1979
0 25 50 km
GULF OF ST. LAWRENCE
PRINCE EDWARD ISLAND
NORTHUMBERLAND STRAIT
CAPE BRETON ISLAND
NEW BRUNSWICK
ATLANTIC OCEAN
BAY OF FUNDY
ST GEORGES BAY
MINAS BASIN
CHEDABUCTO BAY
SYDNEY
HALIFAX
SABLE ISLAND



Map showing areas held under exploration licences for uranium, December 1980


Map showing areas held
under exploration licences
for uranium, December 1981
0 25 50 km
GULF OF ST LAWRENCE
CAPE BRETON ISLAND
PRINCE EDWARD ISLAND
NORTHUMBERLAND STRAIT
NEW BRUNSWICK
BAY OF FUNDY
ATLANTIC OCEAN
ST GEORGES BAY
MINAS BASIN
CHEDABUCTO BAY
SYDNEY
INVERNESS
ANTIGONISH
NEW GLASGOW
AMHERST
KENTVILLE
HALIFAX
DARTMOUTH
LIVERPOOL
YARMOUTH
SABLE ISLAND


Areas requested for special
uranium exploration licences
July 22, 1982
0 25 50 km
GULF OF ST LAWRENCE
PRINCE EDWARD ISLAND
NORTHUMBERLAND STRAIT
CAPE BRETON ISLAND
NEW BRUNSWICK
BAY OF FUNDY
ATLANTIC OCEAN
MINAS BASIN
ST GEORGES BAY
CHEDABUCTO BAY
BRAS D'OR LAKE
SYDNEY
SABLE ISLAND

APPENDIX II

Item 1. Compilation of Open File Uranium Exploration Assessment Reports up to the end of 1979.

Item 2. (In Pocket) Index map to Open File Reports Submitted for Areas Explored for Uranium up to the end of 1979.

COMPILATION OF URANIUM EXPLORATION ACTIVITIES IN NOVA SCOTIA UP TO THE END OF 1979

The information in the following Table and accompanying Index Map has been compiled from all the non-confidential (i.e. open) uranium exploration assessment reports submitted to the NSDME up to the end of December, 1979. These assessment reports were all submitted to the NSDME on the basis of exploration surveys conducted for uranium on uranium exploration licences. Uranium exploration assessment reports submitted after December 1979 and still confidential (i.e. not publically available) at this time of writing, and are not included in this compilation. However, information from these confidential uranium assessment reports submitted during 1980 and 1981 has been compiled into a similar, but separate, report like this one.

The following Table shows what information is available or what types of exploration surveys (geological, geochemical, geophysical) were conducted on specific areas of the province. Thus, the accompanying Index Map shows the actual areas of ground on which exploration activities were conducted. A detailed explanation of the contents of the Table is provided below.

EXPLANATION OF TABLE

x means that information exists in a particular category for a specific assessment report.

\- means that no information exists in a particular category for a specific assessment report.

No. refers to a numbered block of land on the Index Map. This block of land represents an area of ground on which some type of exploration activity has been conducted.

Map Sheet/Report Number the map sheet (e.g. 11D/12C) refers to the NSDME Claim Reference map on which the exploration activity was conducted. The report number (e.g. 54-H-84(01)) is an alpha-numeric code that classifies all assessment reports on the basis of commodity (54 = Uranium), county (H = Halifax), location (84 = Pogwa Lake) and successive report number (01 = first report on Pogwa Lake). The bracketed, six-digit number (e.g. 433006) is a unique number assigned to each assessment report for storage in a computerized database.

Open refers to the year in which a particular assessment report became non-confidential. The Mineral Resources Act states that assessment reports submitted to the NSDME must be held confidential for a period of two years after the date of receipt of the assessment report.

Company refers to the company or person who held the uranium exploration licence(s) on which the assessment report was submitted.

County/Place refers to a specific location (e.g. Pogwa Lake) in a county (e.g. Halifax) of Nova Scotia, which lies within or near the area of the exploration activity.

Trench. refers to information on trenching.

Drill. refers to information on drilling.

Geol. refers to information on geological survey.

Soil refers to information on a single or multi-element, soil geochemical survey. Rock refers to a lithogeochemical survey.

Sed. refers to information on a single or multi-element, stream or lake-bottom sediment geochemical survey.

Rock refers to information on a single or multi-element, analyses of rock outcrop samples, float or drill core samples.

Water refers to information on a single or multi-element, analyses of water from springs, streams, lakes, swamps or wells.

Vapour refers to information on geochemical surveys for radon or helium gas, generally in soil or water.

Geophysics refers to information on various types of ground(g) or airborne(a) geophysical surveys, such as magnetic(=Mag), electromagnetic(=EM) very low frequency electromagnetic(=VLF), induced polarization(=IP), resistivity(=Res) or track etch. Logs refers to down-hole radiometric probing of drillholes.

Radiometric refers to information on ground or airborne radiometric surveys.

No.	Map Sheet/ Report Number	Open	Company	County/Place	Trench.	Drill.	Geol.	Geochemistry Soil	Sed.	Rock	Water	Vapour	Geophysics	Radiometric
1.	11D/12C 54-H-84(01) (433006)	1981	E and B	Halifax, Pogwa Lake	-	-	x	x	stream	x	-	-	-	ground
2.	11D/12C 54-H-81(01) (432947)	1980	Esso	Halifax, Head Harbour	-	-	x	-	lake	-	lake	-	VLF(g)	ground air
2.	11D/12C 54-H-81(02) (433222)	1980	Esso	Halifax, Head Harbour	-	-	-	x	-	-	-	-	-	-
2.	11D/12C 54-H-81(03) (433223)	1980	Esso	Halifax, Head Harbour	-	-	-	x	-	-	-	-	-	-
3.	11D/13D 54-H-80(01) (432324)	1979	Seaton,B.	Halifax, Grand Lake	-	x	-	-	-	x	-	-	-	-
4.	11E 54-I-47(01) (433063)	1980	Int.Mine Services	Hants,Hfx., Colchester	-		-	-	-	-	-	-	Mag(a)	air
5.	11E 54-I-06(02) (432978)	1980	Denison	Halifax, Hants	x	-	x	x	-	x	well lake	radon helium	-	ground
6.	11E/NW 54-D-45(01) (433076)	1980	Lacana	Colchester, Tatamagouche	-	x	x	x	stream	-	well stream	radon	logs	ground
6.	11E/NW 54-D-45(02) (433077)	1981	Lacana	Colchester, Tatamagouche	-	x	-	x	stream	-	-	radon	logs	-
7.	11E/01C 54-G-56(01) (433036)	1981	Esso	Guysborough, Big Liscomb Lake	-	-	x	-	-	-	-	-	-	air ground
8.	11E/04A 54-I-73(01) (433171)	1980	Orange-sellschaft	Hants, Hardwood Lands	-	-	x	x	stream	-	well	-	-	ground

No.	Map Sheet/ Report Number	Open	Company	County/Place	Trench.	Drill.	Geol.	Geochemistry Soil	Sed.	Rock	Water	Vapour	Geophysics	Radiometric
9.	11E/04B 54-I-74(01) (433066)	1981	Int.Mine Services	Hants, Woodville	-	-	x	-	-	x	-	-	-	ground air
10.	11E/04C 54-I-51(01) (433067)	1981	Int.Mine Services	Hants, Walton	-	-	x	-	-	-	-	-	-	ground air
11.	11E/04D 54-I-59(01) (433045)	1980	Int.Mine Services	Hants, Pitts Brook	-	x	x	-	-	x	-	radon	EM(g)	ground air
12.	11E/04D 54-I-75(01) (433068)	1981	Int.Mine Services	Hants, Georgefield	-	-	x	-	-	x	-	-	-	ground air
13.	11E/06C 54-D-55(01) (431884)	1977	Getty	Colchester, Bass town	-	-	x	-	stream	-	stream well	-	-	ground
14.	11E/07A 54-G-60(01) (433261)	1981	Canadian Nickel	Guysborough, Trafalgar	-	-	x	-	stream	x	-	-	-	ground air
15.	11E/09A 54-B-36(01) (433136)	1980	Saarberg	Antigonish, James River Station	-	-	x	-	stream	-	well stream spring	radon	-	ground
16.	11F/09A 54-B-36(02) (433243)	1981	Saarberg	Antigonish, James River Station	-	-	x	-	stream	-	stream well spring	radon	-	ground
17.	11E/10B 54-M-27(01) (433053)	1980	Gulf	Pictou, Balfour Mountain	-				-	x	-	-	Mag(a) EM(a) VLF(a)	air
18.	11E/11A 54-D-67(01) (433083)	1981	Kyom[illegible]	Colchester, [illegible]	-	-	x	x	stream	x	stream well	radon	Mag(a,g) VLF(g)	ground air
19.	11E/11B 54-D-16(01) (433048)	1980	Gulf	Colchester, East New Annan	-	x	x	-	-	x	well	-	EM(a) Mag(a) VLF(a,g) logs	air
20.	11E/11B 54-D-16(02) (433056)	1980	Gulf	Colchester, East New Annan	-	x	x	-	-	x	-	-	logs	ground
21.	11E/11B 54-D-16(03) (433420)	1981	Gulf	Colchester, East New Annan	-	x	x	x	-	x	-	-	VLF(g)	ground
22.	11E/11C 54-D-45(01) (430286)	1976	BP Minerals	Colchester, Tatamagouche	-	x	x	x	stream	x	stream	radon	-	ground
23.	11E/11C 54-D-45(02) (432010)	1979	Noranda	Colchester, Tatamagouche	-		x	-	-	x	well	radon	-	ground
23.	11E/11C 54-D-45(06) (433100)	1980	Noranda	Colchester, Tatamagouche	-	x	-	x	-	-	-	-	logs	-
24.	11E/11C 54-D-45(03) (432471)	1979	Noranda	Colchester, Tatamagouche	-	x	x	x	-	x	well	radon	logs	ground
25.	11E/11C 54-D-45(04) (432122)	1979	Noranda	Colchester, Tatamagouche		x	x	x	-	-	-	radon	logs	ground
26.	11E/11C 54-D-45(05) (433109)	1980	Noranda	Colchester, Tatamagouche	-	-	-	x	-	x	-	radon	IP(g)	ground
27.	11E/11C 54-D-45(07) (433093)	1980	Noranda	Colchester, Tatamagouche	-	-	-	x	-	-	-	-	-	ground
28.	11E/11C 54-D-45(08) (433096)	1980	Noranda	Colchester, Tatamagouche	-	x	-	-			-	-	logs	-
29.	11E/11C 54-D-45(09) (433097)	1980	Noranda	Colchester, Tatamagouche	-	x	-	-	-	-	-	-	logs	-
30	11E/11C 54-D-45(10) (433098)	1980	Noranda	Colchester, Tatamagouche	-	x	-	-	-	-	-	-	logs	-
31.	11E/11C 54-D-45(11) (433100)	1980	Noranda	Colchester, Tatamagouche	-	x	-	-	-	-	-	-	logs	-
32.	11E/11C 54-D-45(12) (433104)	1980	Noranda	Colchester, Tatamagouche	-	x	x	x	x	-	stream	radon	IP(g)	ground
32.	11E/11C 54-D-45(13) (433105)	1980	Noranda	Colchester, Tatamagouche	-	x	-	-	-	-	-	-	logs	-

No.	Map Sheet/ Report Number	Open	Company	County/Place	Trench.	Drill.	Geol.	Soil	Geochemistry Sed.	 Rock	 Water	 Vapour	Geophysics	Radiometric
32.	11E/11C 54-D-45(14) (433114)	1981	Noranda	Colchester, Tatamagouche	-	x	x	-	-	-	-	-	logs	-
32.	11E/11C 54-D-45(15) (433269)	1981	Noranda	Colchester, Tatamagouche	-	x	x	-	-	-	-	-	logs	-
33.	11E/11D 54-D-63(01) (433110)	1980	Noranda	Colchester, Black Brook	-	-	-	x	-	x	-	radon	IP(g)	ground
34.	11E/11D 54-D-63(02) (433095)	1980	Noranda	Colchester, Black Brook	-	-	-	x	-	-	-	-	-	ground
35.	11E/11D 54-D-68(01) (433279)	1981	Wyoming/ Cominco	Colchester, Balfron	-	-	x	x	stream	x	well	-	-	ground
36.	11E/12A 54-E-61(01) (433049)	1980	Gulf	Cumberland, Westchester Station	-	x	x	-	-	-	-	-	EM(a) Mag(a) VLF(a)	air
36, 37.	11E/12A 54-E-61(02) (433055)	1980	Gulf	Cumberland, Westchester Station	-	-	x	x	-	-	-	-	-	-
38.	11E/12A 54-E-64(01) (433182)	1981	Wyoming/ Cominco	Cumberland, Westchester	-	x	x	x	stream	x	stream well	radon	Mag(a) EM(g)	ground air
39.	11E/12A 54-E-64(02) (433278)	1981	Wyoming/ Cominco	Cumberland, Westchester	-	-	x	x	stream	-	stream well	-	-	ground
40.	11E/12B 54-D-64(01) (433051)	1980	Gulf	Colchester, Cobequid Mountains	-	-	x	x	-	x	-	-	-	ground air
40, 41.	11E/12B 54-D-64(02) (433213)	1981	Gulf	Colchester, Cobequid Mountains	-	-	x	x	-	x	-	-	EM(g) Mag(g) IP(g)	ground
42.	11E/12B 54-D-64(03) (433215)	1981	Gulf	Colchester, Cobequid Mountains	-	-	x	-	-	-	-	-	-	ground
43.	11E/12C 54-E-23(01) (432897)	1979	Gulf	Cumberland, Oxford	-	x	x	-	stream	x	well	-	logs	air
43.	11E/12C 54-E-23(02) (433046)	1980	Gulf	Cumberland, Oxford	-	x	-	-	-	-	-	-	logs	-
44.	11E/12D 54-E-52(01) (433047)	1980	Gulf	Cumberland, Wentworth	-	x	x	x	-	x	well	-	EM(a,g) Mag(a,g) IP(g) SP(g) VLF(a,g) Res.(g) logs	air
44.	11E/12D 54-E-52(02) (433054)	1980	Gulf	Cumberland, Wentworth	-	x	x	x	-	x	-	-	logs	ground
44.	11E/12D 54-E-52(03) (433419)	1981	Gulf	Cumberland, Wentworth	-	x	x	x	-	x	-	-	EM(g)	ground
45.	11E/12D 54-E-60(01) (432917)	1979	Aquitaine	Cumberland, Henderson Brook	-	-	-	x	stream	-	stream swamp	radon	-	-
45.	11E/12D 54-E-60(02) (432960)	1980	Aquitaine	Cumberland, Henderson Brook	-	-	-	x	-	-	-	radon	-	ground
46.	11E/13 54-E-33(01) (432895)	1979	Lacana	Cumberland, Pugwash	-	-	x	-	stream	-	stream well	-	-	-
46.	11E/13 54-E-33(02) (432896)	1979	Norcen	Cumberland, Pugwash	-	x	x	-	-	x	well	-	logs	-
80, 46.	21A/09 54-L-0(01) (433115)	1980	Norcen	Lunenburg, Hants, Cape Breton, Inverness, Antigonish, Cumberland	x	x	x	-	stream	x	well	[illegible]	-	ground air
46.	11E/13 54-E-33(03) (433079)	1980	Lacana	Cumberland, Pugwash	-	x	x	-	stream	x	well	radon	-	-
46.	11E/13 54-E-33(04) (433080)	1980	Lacana	Cumberland, Pugwash	-	x	x	x	stream	-	well	radon	logs	-
47.	11E/13A 54-E-63(01) (433081)	1980	Lacana	Cumberland, Rockley	-	x	-	-	-	x	-	-	logs	-

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48.	11E/14A 54-M-37(01) (432909)	1979	Noranda	Pictou, River John	-	-	x	-	-	x	well	radon	-	ground
49.	11E/14A 54-M-37(02) (433103)	1980	Noranda	Pictou, River John	-	x	-	-		-	-		logs	-
50.	11E/14A 54-M-37(03) (433102)	1980	Noranda	Pictou, River John	-	x	-	-	-	-		-	logs	-
51.	11E/14A 54-M-37(04) (433112)	1981	Noranda	Pictou, River John	-	x	-	-	-	-	-	-	logs	-
52.	11F/03C 54-G-24(01) (431252)	1981	[illegible]	Guysborough, Larrys River	-	-	x	x	stream	-	stream	-	[illegible]	ground
53.	11F/04C 54-G-57(01) (433037)	1981	[illegible]	Guysborough, Country Harbour Mine	-	-	x	-				-		ground air
54.	11F/05C 54-G-55(01) (433052)	1980	[illegible]	Guysborough, [illegible]	-		x	x	-	-	-	-	-	ground air
55.	11F/13B 54-B-10(01) (433175)	1980	Orange-sellschaft	Antigonish, Cape George	-	-	x	-	stream	x	well	-	-	ground
56.	11F/14B 54-J-80(01) (433174)	1980	Orange-sellschaft	Inverness, Kingsville	-	-	x	x	stream	-	well	radon	Mag(g)	ground
57.	11F/15D 54-C-100(01) (433170)	1980	Orange-sellschaft	Cape Breton, Castle Bay	-	-	x	x	stream	x	well	radon	-	ground
58.	11K/01C 54-C-02(01) (433181)	1981	Wyoming	Cape Breton, Baracbois	-	-	x	-	-	x	stream well	-	-	ground
59.	11K/02C 54-Q-41(01) (432998)	1979	Orange-sellschaft	Victoria, Harris Brook	-	-	x	x	stream	-	well	radon	Mag(g)	ground
59.	11K/02C 54-Q-41(02) (433172)	1980	Orange-sellschaft	Victoria, Harris Brook	-	x	x	-	-	x	-	-	logs	-
60.	11K/03A 54-J-31(01) (433137)	198[illegible]	Saarberg	Inverness, Lake Ainslie	-	-	x	-	-	-	-	radon	-	ground
60.	11K/03A 54-J-31(02) (433138)	1980	Saarberg	Inverness, Lake Ainslie	-	-	x	-	stream	-	stream	radon	-	ground
60.	11K/03A 54-J-31(03) (433246)	1981	Saarberg	Inverness, Lake Ainslie	-	-	x	x	stream		stream	radon	-	ground
61.	11K/03A 54-J-81(01) (433173)	1980	Orange-sellschaft	Inverness, Trout River	-	-	x	x	stream	-	well	radon	Mag(g)	ground
62.	11K/06A 54-J-85(01) (433139)	1980	Saarberg	Inverness, SW Margaree	x	-	x	-	stream	-	stream well swamp	radon	-	ground
63.	11K/06A 54-J-85(02) (433244)	1981	Saarberg	Inverness, SW Margaree	-	x	-	-	-	-	-	-	logs	-
63.	11K/06A 54-J-85(03) (433245)	1981	Saarberg	Inverness, SW Margaree	-	x	x	-	stream	-	stream well	radon	-	ground
64.	11K/07B 54-J-76(01) (433084)	1980	Lacana	Inverness, NW Margaree River	-	-	-	-	stream	-	stream	-	-	-
65.	11K/16B 54-Q-44(01) (433035)	1981	Esso	Victoria, Neils Harbour	-	-	x	-	-	-	-		-	ground air
66.	20P/13C 54-R-29(01) (432997)	1981	E and B	Yarmouth, Peter Lake	-	-	x	x	stream	x	-	-	-	ground
67.	20P/14D 54-P-09(01) (433004)	1980	E and B	Shelburne, Shelburne	-	-	x	x	stream	x	-	-	-	ground
68.	20P/14C 54-P-11(01) (433282)	1981	E and B	Shelburne, Upper Ohio	-	-	x	x	stream	x	-	-	-	ground
69.	20P/15B 54-N-29(01) (432994)	1981	E and B	Queens, Path Lake	-	-	x	x	stream	x	-	-	-	ground

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70.	20P/15C 54-N-28(01) (433000)	1980	E and B	Queens, SW Port Mouton	-	-	x	x	stream	x	-	-	-	ground
71.	21A/NW 54-A-25(01) (433281)	1981	Shell	Annapolis, Digby, Kings, South Mountain	-	-	x	biog. x	-	x	-	-	-	ground air
72.	21A/03C 54-R-32(01) (433002)	1981	E and B	Yarmouth, Whiteway Lake	-	-	x	x	stream	x	-	-	-	ground
73.	21A/04A 54-R-25(01) (433060)	1980	Dome	Yarmouth, East Kemptville			-			x	-	-	-	air ground
74.	21A/04A 54-R-25(02) (433073)	1980	Kerr Addison	Yarmouth, East Kemptville	-				-	-				ground
75.	21A/04A 54-R-25(03) (433382)	198[illegible]	[illegible]	Yarmouth, East Kemptville		-	-	-	stream	-	stream	radon	[illegible]	[illegible]
75.	21A/04A 54-R-25(04) (433081)	1981	Lacana	Yarmouth, East Kemptville	-	x	x	-	-	x	-	[illegible]	[illegible]	air
76.	21A/04A 54-R-25(05) (433231)	1981	[illegible]	Yarmouth, East Kemptville		x	x	x	stream lake	x	stream lake	-	[illegible]	ground air
77.	21A/04B 54-R-27(01) (433180)	1980	Western Mines	Yarmouth, Bear Lake	-	-	x			x	stream			ground
78.	21A/04A 54-R-30(01) (432998)	1981	E and B	Yarmouth, Beaver Brook Lake	-	-	x	x	stream	-	-	-	-	ground
79.	21A/04B 54-R-31(01) (433999)	1981	E and B	Yarmouth, [illegible] Lake	-	-	x	x	stream	-	-	-	-	ground
80. 46.	21A/09 54-L-9(01) (433115)	1980	Noranda	Lunenburg, Hants, Cape Breton, [illegible], [illegible], Cumberland	x	x	x	-	stream		[illegible]	radon	-	ground air
[illegible]	21A/16B 54-D-47(01) (433116)	1980	Noranda	[illegible], [illegible] Lake	x	x	x	x		x	-	-	-	ground
81.	21A/09C 54-L-19(01) (433078)	1981	Lacana	Lunenburg, New Ross		x		x	-	x	-	radon	[illegible] logs	ground
82.	21A/09C 54-L-19(02) (433260)	1981	E and B	Lunenburg, New Ross	x	-	x	x	stream	-		radon	logs	ground
83.	21A/09C 54-L-34(01) (432996)	1981	E and B	Lunenburg, Middle River	-	-	x	x	stream	-	-	-	-	ground
84.	21A/09D 54-B-82(01) (433001)	1981	E and B	Halifax, Hubbards River	-	-	x	x	stream	x		-	-	ground
85.	21A/09B 54-L-12(01) (433026)	1980	Esso	Lunenburg, Timber Lake	-	-	x	-	lake	-	lake		-	air
86.	21A/09B 54-L-32(02) (433274)	1980	Esso	Lunenburg, Timber Lake	-	-	x	x	-	-	-	-	-	ground
87.	21A/10B 54-A-19(01) (433005)	1980	E and B	Annapolis, Lake Pleasant	-	-	x	x	stream	x		-	-	ground
87.	21A/10B 54-A-19(02) (434022)	1980	E and B	Annapolis, Lake Pleasant	-	-	x	x	-	x	-	radon		ground
88.	21A/10B 54-A-22(01) (433003)	1981	E and B	Annapolis, Cranberry Lake	-	-	x	x	stream	x	-	-	-	ground
89.	21A/10C 54-A-20(01) (433028)	1980	Esso	Annapolis, Dalhousie East	-	-	x	x	lake	x	lake		track etch VLF(q)	ground air
90.	21A/10C 54-A-20(02) (433219)	1981	Esso	Annapolis, Dalhousie East	-	x	x	-	-	x	-	-	-	on core
90.	21A/10C 54-a-20(03) (433220)	1981	Esso	Annapolis, Dalhousie East	-	-	-	x	-	-	-	-	track etch	ground
90.	21A/10C 54-A-20(04) (433226)	1981	Esso	Annapolis, Dalhousie East	-	-	x	x	-	-	-	-	track etch	ground

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91.	21A/10C 54-A-23(01) (433007)	1981	E and B	Annapolis, Falkland Ridge	-	-	x	x	stream	-	-	-	-	ground
92.	21A/10D 54-K-28(01) (432995)	1980	E and B	Kings, East Dalhousie	-	-	x	x	stream	-	-	-	-	ground
93.	21A/10D 54-L-31(01) (433218)	1981	Esso	Lunenburg, Sherbrooke Lake	-	-	x	x	lake	-	lake	-	track etch	ground air
94.	21A/11C 54-A-24(01) (433229)	1981	Shell	Annapolis, Lambs Lake	x	x	x	x	-	-	-	-	-	-
94.	21A/11C 54-A-24(02) (433230)	1981	Shell	Annapolis, Lambs Lake	x	x	x	x	-	x	-	-	VLF(g) Mag(g) track etch	ground air
95.	21A/12B 54-F-11(01) (431865)	1979	Getty	Digby, Rossway	-	-	x	-	stream	-	stream well spring	-	-	ground
96.	21A/14A 54-A-21(01) (433059)	1980	M.E.X. etc.	Annapolis, Nictaux South	-	-	x	x	-	x	-	-	-	ground
97.	21A/14B 54-A-02(02) (432825)	1979	Getty	Annapolis, Bridgetown	-	x	x	-	stream	-	stream well spring	-	-	ground
98.	21A/14B 54-A-07(02) (432828)	1979	Getty	Annapolis, Belleisle	-	x	-	x	stream	x	stream well spring	-	-	ground
99.	21A/14B 54-A-07(03) (432829)	1979	Getty	Annapolis, Belleisle	-	x	x	-	stream	x	stream well spring	-	-	ground
100.	21A/14D 54-A-09(02) (432827)	1979	Getty	Annapolis, Middleton	-	x	x	-	stream	x	stream well spring	-	-	ground
101.	21A/15A 54-K-27(01) (433121)	1980	Riddell, J.E.	Kings, Lake Paul	-	x	-	-	-	-	-	-	-	ground
102.	21A/15A 54-L-33(01) (433025)	1980	Esso	Lunenburg, Gully lake	-	-	x	-	lake	-	lake	-	-	air
103.	21A/15C 54-A-17(01) (433153)	1981	Shell	Annapolis, Torbrook	-	-	x	x	stream	x	stream well	-	Mag(a) VLF(a)	air
103.	21A/15C 54-A-17(02) (432836)	1981	Shell	Annapolis, Torbrook	-	-	-	-	-	-	stream well	-	-	-
103.	21A/15C 54-A-17(03) (433228)	1981	Shell	Annapolis, Torbrook	-	-	x	x	-	x	-	-	Mag(g) VLF(g) track etch	air ground
104.	21A/15C 54-K-29(01) (433280)	1981	Shell	Kings, Cloud lake	-	x	x	x	-	x	-	-	Mag(g) VLF(g) track etch logs	ground air
105.	21A/15D 54-K-25(01) (433027)	1980	Esso	Kings, Gaspereau Lake	-	-	x	x	lake	x	lake	radon	VLF(g) track etch	ground air
106.	21A/15D 54-K-25(02) (433221)	1980	Esso	Kings, Gaspereau Lake	-	-	-	x	-	-	-	-	-	-
107.	21A/15D 54-K-25(03) (433225)	1981	Esso	Kings, Gaspereau Lake	-	x	x	x	-	-	-	-	track etch	-
108.	21A/16B 54-I-64(01) (432958)	1980	Aquitaine	Hants, Millet Brook	x	-	-	x	-	-	-	radon	-	ground
108.	21A/16B 54-I-64(02) (432959)	1981	Aquitaine	Hants, Millet Brook	x	x	-	x	-	x	-	radon	VLF(g)	ground
108.	21A/16B 54-I-64(03) (433275)	1981	Aquitaine	Hants, Millet Brook	-	-	-	-	-	-	-	-	Res(g)	-
109.	21A/16B 54-I-64(04) (433276)	1981	Aquitaine	Hants, Millet Brook	-	-	-	-	-	-	-	-	EM(a) VLF(a) Mag(a) Res(a)	-
110.	21A/16B 54-I-65(01) (433119)	1980	Riddell, J.E.	Hants, Leminster	-	-	x	-	-	-	-	-	-	ground air
110.	21A/16B 54-I-65(02) (433120)	1980	Riddell, J.E.	Hants, Leminster	-	-	x	-	-	-	-	-	-	ground air

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111.	21A/16B 54-L-19(00) (431307)	1950	G.S.C.	Lunenburg, New Ross	-	-	-	-	x	-	-	-	-	on rock sample
112.	21A/16B 54-L-35(01) (433118)	1980	Riddell, J.E.	Lunenburg, Card Lake	-	-	-	-	-	-	-	-	-	ground air
113.	21A/16B 54-L-37(02) (433272)	1981	Norcen	Lunenburg, Harris Lake	-	x	-	x	-	-	bog	radon helium	-	-
114.	21A/16B 54-L-38(01) (433042)	1981	Esso	Lunenburg, Walluback Lake	-	-	x	-	lake	-	lake	-	-	ground air
115.	21A/16C 54-I-70(01) (433127)	1980	Saarberg	Hants, French Mill Brook	-	-	x	-	-	-	-	-	-	ground
116.	21A/16C 54-K-26(01) (433216)	1981	Esso	Kings, Black River Lake	-	-	x	x	-	-	-	-	track etch	ground
117.	21A/16D 54-I-22(01) (433125)	1980	Saarberg	Hants, Martock	-	-	x	-	-	-	-	-	Mag(g)	ground
117.	21A/16D 54-I-57(01) (433132)	1980	Saarberg	Hants, Windsor	-	-	x	-	-	-	-	-	-	ground
117.	21A/16D 54-I-57(02) (433134)	1980	Saarberg	Hants, Windsor	-	-	-	x	stream	-	well stream	radon	-	ground
118.	21A/16D 54-I-57(03) (433239)	1981	Saarberg	Hants, Windsor	-	x	x	-	-	-	-	-	logs	-
119.	21A/16D 54-I-57(04) (433240)	1981	Saarberg	Hants, Windsor	x	x	x	x	stream	x	well stream	radon	-	ground
120.	21A/16D 54-I-69(01) (433124)	1981	Saarberg	Hants, West Avon River	x	-	x	-	-	-	-	-	-	ground
121.	21A/16D 54-I-70(01) (433126)	1980	Saarberg	Hants, French Mill Brook	-	-	x	-	-	-	-	-	-	ground
122.	21H/01A 54-I-71(01) (433128)	1980	Saarberg	Hants, Halfway River	-	-	x	-	-	-	-	-	-	ground
123.	21H/01A 54-I-72(01) (433129)	1980	Saarberg	Hants, Shey Lake	-	-	x	-	-	-	-	-	-	ground
124.	21H/01B 54-K-11(02) (432822)	1979	Getty	Kings, Kentville	-	-	x	-	stream	x	stream well spring	-	-	ground
125.	21H/01C 54-K-04(02) (432824)	1979	Getty	Kings, Blomidon	-	x	x	-	stream	x	stream well spring	-	-	ground
126.	21H/01C 54-K-24(01) (432826)	1979	Getty	Kings, Sheffield	-	x	x	-	stream	x	stream well spring	-	-	ground
127.	21H/01D 54-I-05(01) (433133)	1980	Saarberg	Hants, Cheverie	-	-	x	-	stream	-	well	radon	-	ground
129, 127.	21H/01D 54-I-05(04) (433135)	1980	Saarberg	Hants, Cheverie	-	-	-	x	stream	-	[illegible]	[illegible]	-	ground
127.	21H/01D 54-I-05(06) (433242)	1981	Saarberg	Hants, Cheverie	-	-	-	-	-	-	-	radon	-	ground
128.	21H/01D 54-I-05(02) (433130)	1980	Saarberg	Hants, Cheverie	-	-	x	-	-	-	-	-	-	ground
129.	21H/01D 54-I-05(03) (433131)	1980	Saarberg	Hants, Cheverie	-	-	x	-	-	-	-	-	-	ground
129, 127.	21H/01D 54-I-05(04) (433135)	1980	Saarberg	Hants, Cheverie	-	-	-	x	stream	-	well stream	radon	-	ground
130.	21H/01D 54-I-05(05) (433241)	1981	Saarberg	Hants, Cheverie	-	x	-	-	-	-	-	-	logs	-
131.	21H/02A 54-K-05(02) (432830)	1979	Getty	Kings, Berwick	-	x	x	-	stream	x	stream well	-	logs	ground
132.	21H/02B 54-K-01(02) (432821)	1979	Getty	Kings, Auburn	-	x	x	-	stream	x	stream well	-	logs	ground

No.	Map Sheet/ Report Number	Open	Company	County/Place	Trench.	Drill.	Geol.	Geochemistry					Geophysics	Radiometric
								Soil	Sed.	Rock	Water	Vapour		
133.	21H/02B 54-K-20(01) (432899)	1979	Getty	Kings, N.Kingston	-	x	x	-	-	x	ground/ water	radon	logs	-
134.	21H/08D 54-D-19(01) (432898)	1979	Gulf	Colchester, Five Islands	-	x	x	-	stream	x	well	-	logs	air
135.	21H/09D 54-E-41(01) (434057)	1981	Cominco	Cumberland, Springhill	-	x	x	x	-	x	-	-	VLF(g) logs	-
135.	21H/09D 54-E-41(02) (434058)	1981	Cominco	Cumberland, Springhill	-	x	x	x	stream	-	-	radon	logs	-

APPENDIX III

Item 1.	Compilation of Confidential Uranium Exploration Assessment Reports Submitted During 1980 and 1981.
Item 2. (In Pocket)	Index Map to Confidential Reports Submitted for Areas Explored for Uranium during 1980 and 1981.

COMPILATION OF URANIUM EXPLORATION ACTIVITIES IN NOVA SCOTIA DURING 1980 AND 1981

The information in the following Table and accompanying Index Map has been compiled from all the confidential (i.e. not publically available), uranium exploration assessment reports submitted during 1980 and 1981 to the NSDME. The Mineral Resources Act states that exploration assessment reports submitted to the NSDME must remain confidential for a period of two years after the date of their submission. Once the two-year confidentiality period is over, the reports are released and become publically available.

The following Table shows what information is available or what types of exploration surveys (geological, geochemical, geophysical) were conducted on specific areas of the province. Thus, the accompanying Index Map shows the actual areas of ground on which exploration activities conducted. A detailed explanation of the contents of the Table is provided below.

EXPLANATION OF TABLE

x means that information exists in a particular category for a specific assessment report.

– means that no information exists in a particular category for a specific assessment report.

No. refers to a numbered block of land on the Index Map. This block of land represents an area of ground on which some type of exploration activity has been conducted.

Map Sheet/Report Number the map sheet (e.g. 11D/12C) refers to the NSDME Claim Reference map on which the exploration activity was conducted. The report number (e.g. 54-H-84(01)) is an alpha-numeric code that classifies all assessment reports on the basis of commodity (54 = Uranium), county (H = Halifax), location (84 = Pogwa Lake) and successive report number (01 = first report on Pogwa Lake). The bracketed, six-digit number (e.g. 433006) is a unique number assigned to each assessment report for storage in a computerized database.

Open refers to the year in which a particular assessment report became non-confidential. The Mineral Resources Act states that assessment reports submitted to the NSDME must be held confidential for a period of two years after the date of receipt of the assessment report.

Company refers to the company or person who held the uranium exploration licence(s) on which the assessment report was submitted.

County/Place refers to a specific location (e.g. Pogwa Lake) in a county (e.g. Halifax) of Nova Scotia, which lies within or near the area of the exploration activity.

Trench. refers to information on trenching.

Drill. refers to information on drilling.

Geol. refers to information on geological survey.

Soil refers to information on a single or multi-element, soil geochemical survey. Biog. refers to a biogeochemical survey.

Sed. refers to information on a single or multi-element, stream or lake-bottom sediment geochemical survey.

Rock refers to information on a single or multi-element, analyses of rock outcrop samples, float or drill core samples.

Water refers to information on a single or multi-element, analyses of water from springs, streams, lakes, swamps or wells.

Vapour refers to information on geochemical surveys for radon or helium gas, generally in soil or water.

Geophysics refers to information on various types of ground(g) or airborne(a) geophysical surveys, such as magnetic(=Mag), electromagnetic(=EM) very low frequency electromagnetic(=VLF), induced polarization(=IP), resistivity(=Res) or track etch. Logs refers to down-hole radiometric probing of drillholes.

Radiometric refers to information on ground or airborne radiometric surveys.

No.	Map Sheet/ Report Number	Open	Company	County/Place	Trench.	Drill.	Geol.	Geochemistry Soil	Sed.	Rock	Water	Vapour	Geophysics	Radiometric
136.	11D/13B 54-I-67(01) (434037)	1982	M.E.X.	Hants, Big Indian Lake	–	–	x	–	–	–	–	–	–	ground
137.	11D/13B 54-I-76(01) (434067)	1982	Shell	Hants, Kehoe Hill	–	x	x	–	–	x	–	–	–	ground
138.	11E/02A 54-H-85(01) (434202)	1983	Aquitaine	Halifax, Lake Mulgrave	–	–	x	x	stream	–	–	–	–	ground
139.	11E/02A 54-H-88(01) (434203)	1983	Aquitaine	Halifax, West River Sheet Harbour	–	–	x	x	stream	–	–	–	–	ground air
140.	11E/02D 54-G-62(01) (434201)	1983	Aquitaine	Guysborough, First Rocky Lake	–	–	x	x	stream	–	–	–	–	ground
141.	11E/04A 54-I-41(01) (434101)	1982	Saarberg	Hants, Roulston Corner	x	–	x	x	stream	–	well	radon	VLF(g) Mag(g)	ground
142.	11E/04H 54-I-21(01) (434257)	1983	Saarberg	Hants, McKay Settlement	–	x	x	–	–	–	–	–	logs	–
143.	11E/04B 54-I-33(01) (434102)	1982	Saarberg	Hants, Central Rawdon	x	–	x	x	stream	–	well	radon	VLF(g)	ground
144.	11E/04B 54-I-34(01) (434196)	1983	Saarberg	Hants, Rawdon Gold Mines	–	x	–	–	–	–	–	–	logs	–
145.	11E/10A 54-M-19(01) (434012)	1982	Noranda	Pictou, New Glasgow	–	–	x	–	stream	–	well	–	–	ground
146.	11E/11A 54-D-70(01) (434056)	1982	Cominco	Colchester, N. Earltown	–	x	x	–	–	–	–	–	VLF(g) Mag(g) track etch	–

No.	Map Sheet/ Report Number	Open	Company	County/Place	Trench.	Drill.	Geol.	Soil	Geochemistry Sed.	Rock	Water	Vapour	Geophysics	Radiometric
146.	11E/11A 54-D-70(02) (434160)	1982	Cominco	Colchester, N. Earltown	–	x	x	–	–	–	–	–	VLF(g) Mag(g) logs	–
147.	11E/11B 54-D-16(04) (434106)	1982	Gulf	Colchester, East New Annan	–	x	x	–	–	x	–	–	logs	ground
147.	11E/11B 54-D-16(05) (434268)	1983	Gulf	Colchester, East New Annan	–	–	x	–	–	x	–	–	EM(g)	ground
148.	11E/11C 54-D-45(16) (434161)	1982	Cominco	Colchester, Tatamagouche	–	–	x	x	stream	x	well	–	–	ground
149.	11E/11D 54-D-71(01) (434059)	1982	Cominco	Colchester, Keble	–	–	x	x	stream	x	well	–	–	ground
150.	11E/11D 54-M-40(01) (434125)	1983	Lacana	Pictou, Louisville	–	x	–	–	–	x	–	–	logs	–
151.	11E/12A 54-E-64(03) (434033)	1982	Cominco	Cumberland, Westchester	–	x	–	–	–	–	–	–	logs	–
152.	11E/12A 54-E-64(04) (434034)	1983	Cominco	Cumberland, Westchester	–	x	–	–	–	–	–	–	logs	–
153.	11E/12A 54-E-64(05) (434035)	1982	Cominco	Cumberland, Westchester	–	x	–	–	–	–	–	–	logs	–
154.	11E/12A 54-E-64(06) (434055)	1982	Cominco	Cumberland, Westchester	–	x	x	–	–	x	–	–	logs	ground
155.	11E/12B 54-D-64(04) (434007)	1982	Gulf	Colchester, Cobequid Mountains	–	–	–	x	–	–	–	–	–	–
156.	11E/12B 54-E-65(01) (434036)	1982	Cominco	Cumberland, Williamsdale East	–	x	–	–	–	–	–	–	logs	–
157.	11E/12D 54-E-52(04) (434094)	1982	Gulf	Cumberland, Wentworth	x	x	x	x	–	x	–	–	logs	ground
157.	11E/12D 54-E-52(05) (434253)	1983	Gulf	Cumberland, Wentworth	–	x	x	–	–	x	–	–	logs	–
158.	11F/03C 54-G-24(03) (434107)	1982	St.Joe.	Guysborough, Larrys River	–	–	x	x	–	–	–	–	VLF(g)	ground
159.	11K/02A 54-C-103(01) (434096)	1982	Uranerz	Cape Breton Indian Brook	–	–	x	–	–	x	–	–	–	ground
160.	11K/02C 54-Q-46(01) (434097)	1982	Uranerz	Victoria, Peters Brook	–	–	x	–	stream	x	–	–	–	ground
161.	11K/07B 54-J-76(02) (434002)	1982	Lacana	Inverness, NE Margaree River	–	–	x	x	stream	x	stream	–	Mag(g)	–
162.	20P/13C 54-R-29(02) (434087)	1982	E and B	Yarmouth, Peter Lake	–	–	x	x	–	–	–	radon	VLF(g)	ground
163.	20P/13C 54-R-29(03) (434171)	1983	E and B	Yarmouth, Peter Lake	–	–	–	x	–	–	–	–	–	ground
164.	21A/NE 54-I-77(01) (434276)	1983	Saarberg	Hants, Lunenburg, Halifax, South Mountain	–	–	x	x	stream	x	–	–	VLF(g,a) Mag(g,a)	ground airborne
165.	21A/NW 54-A-25(02) (434128)	1983	Shell	Annapolis, South Mountain	–	–	x	x	x	–	–	–	–	ground
166.	21A/03C 54-P-10(01) (434148)	1983	Shell	Shelburne, Mink Lake	–	–	x	x	–	x	–	–	–	ground
167.	21A/03C 54-R-32(02) (434112)	1982	E and B	Yarmouth, Whitecap Lake	–	–	x	x	–	x	–	radon	–	ground
168.	21A/04A 54-R-25(06) (434005)	1982	Lacana	Yarmouth, East Kemptville	–	x	–	–	stream lake	x	–	–	VLF(g) Mag(g,a) EM(g)	ground
169.	21A/06D 54-A-26(01) (434113)	1982	Shell	Annapolis, Twin Lakes	x	–	x	x	–	x	–	–	–	ground

No.	Map Sheet/ Report Number	Open	Company	County/Place	Trench.	Drill.	Geol.	Geochemistry					Geophysics	Radiometric
								Soil	Sed.	Rock	Water	Vapour		
170.	21A/09B 54-L-11(01) (434051)	1982	Eldorado	Lunenburg, Henry Lake	-	-	x	x	-	-	-	-	Mag(g)	ground
171.	21A/09C 54-L-19(03) (434018)	1982	Can. 14	Lunenburg, New Ross	-	-	x	-	stream	-	-	-	-	ground
172.	21A/09C 54-L-19(04) (434064)	1982	Shell	Lunenburg, New Ross	-	-	x	x	-	x	-	-	-	ground
173.	21A/09C 54-L-19(05) (434089)	1982	E and B	Lunenburg, New Ross	x	x	x	x	-	x	-	radon	VLF(g) Mag(g) logs	ground
173.	21A/09C 54-L-19(06) (434173)	1983	E and B	Lunenburg. New Ross	-	x	x	x	-	x	-	radon	Mag(g,a) VLF(g) logs	ground air
174.	21A/09C 54-L-34(02) (434039)	1982	E and B	Lunenburg, Middle River	-	-	x	x	-	x	-	radon	VLF(g)	ground
174.	21A/09C 54-L-34(03) (434174)	1983	E and B	Lunenburg, Middle River	-	-	x	-	-	x	-	radon	-	ground
175.	21A/09D 54-H-82(02) (434025)	1982	E and B	Halifax, Hubbards River	-	-	x	x	-	-	-	-	VLF(g)	ground
176.	21A/10C 54-A-20(05) (434050)	1982	Esso	Annapolis, Dalhousie East	-	x	-	x	-	x	-	-	track etch logs	ground
177.	21A/10C 54-A-23(02) (434088)	1982	E and B	Annapolis, Falkland Ridge	-	-	x	x	-	x	-	-	VLF(g) Mag(g)	ground
177.	21A/10C 54-A-23(04) (434172)	1983	E and B	Annapolis, Falkland Ridge	-	-	x	x	-	x	-	-	VLF(g)	ground
178.	21A/10C 54-A-23(03) (434149)	1983	Shell	Annapolis, Falkland Ridge	-	-	x	x	-	-	-	-	-	-
179.	21A-10D 54-K-28(02) (434120)	1982	E and B	Kings, East Dalhousie	-	-	x	x	-	-	-	-	-	ground
180.	21A/10D 54-L-31(02) (434021)	1982	Esso	Lunenburg, Sherbrooke Lake	-	x	x	-	-	x	-	-	logs	ground
181.	21A/10D 54-L-31(03) (434062)	1982	Eldorado	Lunenburg, Sherbrooke Lake	-	-	x	x	-	-	-	-	-	ground
182.	21A/11C 54-A-24(03) (434090)	1982	Shell	Annapolis, Lambs Lake	x	x	x	x	-	-	-	-	-	ground
183.	21A/12A 54-F-07(01) (434132)	1983	Shell	Digby, Lansdowne	x	x	x	x	-	x	-	-	IP(g) Res(g)	ground air
184.	21A/15C 54-A-17(04) (434013)	1982	Shell	Annapolis, Torbrook	-	x	x	x	-	x	-	radon	VLF(g) Mag(g) logs	ground air
185.	21A/15C 54-A-17(05) (434080)	1982	Shell	Annapolis, Torbrook	-	-	x	x	stream	-	-	-	Mag(g)	ground
186.	21A/15C 54-A-17(06) (434141)	1983	Shell	Annapolis, Torbrook	-	x	x	x	stream	x	-	-	Mag(g)	ground
187.	21A/15C 54-A-29(02) (434133)	1983	Shell	Annapolis, Cloud Lake	x	-	x	x	-	x	stream	radon	-	ground
188.	21A/15D 54-K-25(04) (434008)	1982	Shell	Kings, Gaspereau Lake	-	-	x	x	stream	x	-	-	Mag(g) VLF(g)	ground
188.	21A/15D 54-K-25(05) (434134)	1982	Shell	Kings, Gaspereau Lake	-	x	x	x	-	x	stream	-	IP(g)	ground
189.	21A/16C 54-K-30(01) (434060)	1982	Shell	Kings, Little River Lake	-	-	x	-	stream	x	-	-	-	ground
189.	21A/15D 54-K-25(06) (434189)	1983	Shell	Kings, Gaspereau Lake	-	-	x	x	-	x	-	-	-	-
190.	21A/16B 54-I-64(05) (434023)	1982	Aquitaine	Hants, Millet Brook	x	x	x	-	lake	x	-	-	VLF(a,g) Res(a,g) Mag(a) EM(a)	ground air

No.	Map Sheet/ Report Number	Open	Company	County/Place	Trench.	Drill.	Geol.	Geochemistry Soil	Sed.	Rock	Water	Vapour	Geophysics	Radiometric
191.	21A/16B 54-I-64(06) (434187)	1983	Aquitaine	Hants, Millet Brook	x	x	x	biog. x	-	x	-	-	Res(g) logs	ground air
192.	21A/16B 54-I-64(07) (434188)	1983	Aquitaine	Hants, Millet Brook	x	x	x	-	-	x	-	-	-	-
193.	21A/16B 54-L-37(03) (434121)	1982	Norcen	Lunenburg, Harris Lake	-	x	x	x	-	x	stream	-	Mag(g)	-
194.	21A/16B 54-L-37(04) (434158)	1983	Norcen	Lunenburg, Harris Lake	-	-	x	x	-	-	-	-	-	ground
193.	21A/16B 54-L-37(05) (434248)	1983	Norcen	Lunenburg, Harris Lake	-	x	x	-	-	-	-	-	Ip(g) Res(g) VLF(g) Mag(g)	-
195.	21A/16C 54-K-26(02) (434038)	1982	M.E.X.	Kings, Black River Lake	-	-	x	-	-	x	-	-	-	ground
196.	21A/16D 54-I-57(05) (434066)	1982	Saarberg	Hants, Windsor	x	x	x	x	stream	-	Well	radon	VLF(g) logs	ground air
197.	21A/16D 54-I-57(06) (434122)	1982	Saarberg	Hants, Windsor	-	x	x	-	-	x	-	-	VLF(g) logs	ground
198.	21A/16D 54-I-57(07) (434176)	1983	Saarberg	Hants, Windsor	-	x	-	-	-	-	-	-	logs	-
199.	21A/16D 54-I-57(08) (434191)	1983	Saarberg	Hants, Windsor	-	x	x	-	-	x	-	-	logs	-
200.	21A/16D 54-I-57(09) (434258)	1983	Saarberg	Hants, Windsor	-	x	x	-	-	-	-	-	logs	-
201.	21H/01D 54-I-05(07) (434123)	1982	Saarberg	Hants, Cheverie	-	-	x	-	stream	-	Well	radon	-	ground
202.	21H/02A 54-K-31(01) (434091)	1982	Shell	Kings Prospect	-	-	x	-	-	-	-	-	-	ground
203.	21H/09A 54-E-42(01) (434024)	1982	Brinex	Cumberland, Springhill South	-	-	x	-	stream	x	-	-	-	-

APPENDIX IV

Item 1. Letter dated May 15, 1975 from the Minister of Mines to the Registrar of Mineral Rights informing that coal, uranium, salt and potash have been placed in special licence category by Order of Governor in Council.

Item 2. Letter sent on June 16, 1980 to all exploration interests in the Province regarding:
(1) NSDME policy toward areas of overlap of general and special licence.
(2) Mineral Resources Act regulations regarding trespass on private and Crown lands.
(3) Notification of intention of formulating guidelines for uranium exploration.

Item 3. Notice to Landowners placed in regional newspapers throughout the Province on June 16, 1980.

MINISTER OF MINES

PROVINCE OF NOVA SCOTIA

May 15, 1975

Mr. R. Slater, P. Eng.
Mining Engineer & Supervisor of Mineral Rights
Department of Mines
Province of Nova Scotia
Halifax, Nova Scotia

Dear Sir:

Re: Withdrawal of coal, uranium, salt and potash from application under Exploration License

This is to confirm that in accordance with Section 24 of Chapter 12, The Mineral Resources Act 1975, all lands in the Province are withdrawn from application for an Exploration License for coal, uranium, salt and potash.

Lands withdrawn from application may be worked, licensed or leased under an agreement or arrangement with the Crown (Special License) in such manner and upon such terms and conditions as may be provided by order of the Governor-in-Council.

Sincerely,

Leonard L. Pace

NOVA SCOTIA
DEPARTMENT OF MINES AND ENERGY
P.O. BOX 1087 · HALIFAX · NOVA SCOTIA · B3J 2X1

June 16, 1980.

This letter is an attempt to clarify certain aspects related to mineral exploration in Nova Scotia that have been raised recently by both mineral licensees and the general public.

OVERLAP OF GENERAL AND SPECIAL EXPLORATION LICENCES

1. This Department has terminated the issuing of overlapping general (base metal) and special (uranium; salt and potash) licences held by different licensees. It must be understood that some overlaps will continue to exist with licences previously so issued and being renewed.

2. Applications may be made separately for general or special licences, or combined. There is no restriction on the subsequent issuing of overlapping licences to the same party. If general licences are held initially, special licences must be applied for when specific uranium or salt and potash exploration programs are anticipated.

3. Special licence applications require approval by Order-in-Council and must be accompanied by an acceptable work proposal document.

URANIUM EXPLORATION GUIDELINES

1. This Department is presently investigating environmental and safety concerns related to uranium exploration, with the intention of establishing meaningful general guidelines.

2. To this end, personnel from the Mineral Resources Division are attempting to contact all field staff conducting uranium exploration over the summer, to discuss programs and effective management of this resource.

ENTRY UPON PRIVATE AND CROWN LAND

1. All minerals are reserved to the Crown excepting only limestone, gypsum and building materials (Mineral Resources Act, 3).

2. A mineral licence entitles the holder to search and prospect for minerals only within the claim or tract to which the licence applies (Mineral Resources Act, 23).

3. No licensee shall enter upon or prospect any private lands included in his mineral licence except with the consent of the owner or tenant or occupant or under special licence from the Minister (Mineral Resources Act, 66).

4. Crown lands whether ungranted or under timber licence or lease may be entered upon and prospected only with the consent of the Minister of Lands and Forests, or person designated, and upon such terms and conditions as may be prescribed (Mineral Resources Act, 67).

5. A licensee who is unable to make an agreement with the owner, tenant or occupant of private lands for the right to enter and prospect the lands covered by his licence or any part thereof may apply to the Minister, after notice to the owner, tenant or occupant, for a special licence to enter and prospect upon such lands (Mineral Resources Act, 68(1)).

6. The Minister, after hearing the parties, may grant such special licence upon such terms and conditions as the Minister may think proper, and may determine the amount of any compensation to be paid to such owner, tenant or occupant (Mineral Resources Act, 68(3)).

(The attached Notice to Landowners regarding this entry problem is being placed in most regional newspapers in the Province.)

It would be appreciated if copies of this letter could be distributed to field personnel.

This summary is meant only to document existing regulations and current procedures. The industry has been and will continue to be encouraged to actively participate in the review of all elements of the Mineral Resources Act now in progress.

J A Garnett.

J. A. Garnett, Ph.D., P. Eng.
Director, Mineral Resources

JAG*ss

NOTICE TO LANDOWNERS

This notification outlines the Rights of Landowners in respect to entry upon mineral lands by mining companies or individuals:

All minerals are reserved to the Crown excepting certain limestone and all gypsum and building materials.

No Mineral Exploration licensee (mining company or individual) shall enter upon or prospect any private lands included in such licence except with the consent of the owner or tenant or occupant or under special licence from the Minister.

A licensee who is unable to make an agreement with the owner, tenant or occupant of private lands for the right to enter and prospect the lands covered by his licence may apply to the Minister, after notice to the owner, tenant or occupant, for a special licence.

The Minister, after hearing the parties, may grant such special licence upon such terms and conditions as the Minister may think proper.

Further information may be obtained from: –

Nova Scotia Department of Mines and Energy
P.O. Box 1087, Halifax, Nova Scotia B3J 2X1
Hon. Ron Barkhouse, Minister of Mines and Energy

APPENDIX V

First Draft of Guidelines for Uranium Exploration in Nova Scotia.

Nova Scotia
Department of Mines and Energy
P.O. BOX 1087 · HALIFAX · NOVA SCOTIA · B3J 2X1

GUIDELINES FOR URANIUM EXPLORATION IN NOVA SCOTIA

As indicated to all exploration licencees in a letter dated June 16, 1980, this Department has been developing guidelines for uranium exploration over this field season.

A preliminary outline of these guidelines has now been formulated, and a copy is attached for your comments. The guidelines have been developed in consultation with staff of the Nova Scotia Department of the Environment, following discussions with company personnel and evaluation of regulations existing in other jurisdictions.

It is our intention to establish formal regulations for uranium exploration in Nova Scotia to be in place by next spring. We would therefore urge your study of this outline and invite constructive comments at your earliest convenience.

J. A. Garnett, Ph.D., P. Eng.
Director, Mineral Resources

1980 09 23

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DRAFT OUTLINE

GUIDELINES FOR URANIUM EXPLORATION IN NOVA SCOTIA

LEVEL ONE - REGIONAL EXPLORATION

Collection of exploration data of a reconnaissance nature including:

(a) airborne and ground geophysical surveys;
(b) geological mapping;
(c) sediment, soil, rock and water sampling.

Exploration at this level may be conducted under the terms and conditions of a general exploration licence, namely, the submission of a summary work proposal accompanying the application, and submission of yearly assessment reports.

LEVEL TWO - DETAILED GROUND EXPLORATION

Exploration programs designed to evaluate local areas where uranium mineralization has been determined.

Level Two is defined as beginning when specific uranium and/or uranium decay related minerals have been documented as occurring in either consolidated or unconsolidated material. Programs may include:

(a) localized ground geophysical and geochemical surveys;
(b) road building, stripping, test-pitting, trenching;
(c) diamond and/or percussion drilling;
(d) bulk surface sampling of soil and/or bedrock.

Level Two approval procedures involve both the Nova Scotia Department of Mines and Energy and the Nova Scotia Department of the Environment. The Mineral Resources Division of the Nova Scotia Department of Mines and Energy will act as the initial contact and coordinating agency for all programs requiring the Nova Scotia Department of the Environment approval.

Prior to commencement of Level Two activity, the general exploration licencee must apply for a Special Uranium Exploration Licence. This licence is designed to officially register the commencement of detailed ground exploration for uranium, and initiate regulations related to such activity. Special uranium licences will only be issued to holders of valid general exploration licences and only over the same ground.

GUIDELINES FOR LEVEL TWO:
DETAILED EXPLORATION ON URANIUM PROPERTIES

I Program Information Requirements

An information report must accompany the special uranium licence application, including a detailed description of the proposed exploration program; approximate time span of exploration activity; land uses in the immediate vicinity of the exploration property; location of surface water courses and water wells in the area; site access; location and size of surface excavations; location and expected depth of drillholes; location and design of core storage facilities. Maps at appropriate scales should be included showing the specific location of the above activities.

II Environmental Baseline Study

Prior to initiating detailed ground exploration, the outline of a geochemical sampling program must be submitted through the Nova Scotia Department of Mines and Energy for approval by the Nova Scotia Department of the Environment. The program should be designed to provide sufficient baseline data to define the environmental characteristics of the site, including information on ground and surface water, air and terrestrial radionuclide levels before, during and after the exploration work.

III Road Building

Road construction may result in altering the surface drainage regime. Details on intended road building must be submitted through the Nova Scotia Department of Mines and Energy for approval by the Nova Scotia Department of the Environment. Removal of cover material during construction of access roads to uranium exploration sites may result in increased exposure of radioactive materials. Consequently, such roads should be surveyed radiometrically and results provided to the Nova Scotia Department of Mines and Energy as soon as is feasible. Where high radioactivity is identified, the Nova Scotia Department of the Environment may require burial, redesign or relocation.

IV Stripping, Trenching and Test Pitting (including Blasting)

Stripping, trenching and test pitting may result in increased exposure of radioactive materials, as well as the possibility of altering the surface drainage regime. Therefore, the following constraints must be adhered to:

1. All exploration surface excavations should be monitored prior to opening and backfilled as soon as mapping and sampling is completed. In backfilling, the most radioactive material should be replaced first. Following reclamation, a scintillometer survey should be undertaken to ensure that radiation levels do not significantly exceed those present prior to the disturbance.

2. Where it is anticipated that excavated material will not be replaced within three months, this material shall be stabilized to minimize erosion.

3. Excavated material shall not be placed in or adjacent to surface water courses.

4. No water pumped for surface excavations should be discharged directly into a surface water course. Any discharge should be directed through a sump located at least 15 m away from the nearest water course.

V Drilling

1. Specific information on drilling programs must be submitted for approval prior to commencement. The Nova Scotia Department of the Environment will be notified in order that holes may be selected for the installation of piezometers for groundwater monitoring purposes.

2. Throughout the test drilling program, an effort should be made to recycle water used for drilling purposes.

3. Return water from drillholes should not be discharged directly into a surface water course, but through a sump located at least 15 metres away from the nearest water body.

4. Upon being abandoned, all drillholes not approved by the Nova Scotia Department of the Environment for monitoring purposes should be properly cement grouted from bottom to top.

5. Upon completion of a drillhole, an identification number, date and name of the exploration company must be posted at the drillhole site in a permanent manner.

6. The area surrounding test holes should be cleared of debris and material (cuttings, drilling mud, etc.) used in the drilling operation.

VI On-Site Core and Sample Storage

Where radioactive cores and/or samples are being stored, premises designed for this storage should be clearly posted, well ventilated and secured to prevent unauthorized entry.

VII General

A full report on all geological investigations conducted on the property, including levels of radioactivity recorded at drill sites and from surface rock or core storage areas, should be submitted to the Nova Scotia Department of Mines and Energy on an annual basis.

Any changes in exploration programs and any new information involving increasing levels of uranium mineralization and/or high levels of radioactivity should be reported to the Nova Scotia Department of Mines and Energy as soon as is feasible.

Details on exploration programs, reports and specific data will be maintained in confidential files for a period of two years from date of submission. General information derived from this monitoring process will be distributed so that appropriate agencies may be kept informed of the current status of uranium exploration.

APPENDIX VI

Second Draft of Guidelines for Uranium Exploration in Nova Scotia.

Nova Scotia
Department of Mines and Energy
P.O. BOX 1087 · HALIFAX · NOVA SCOTIA · B3J 2X1

GUIDELINES FOR URANIUM EXPLORATION IN NOVA SCOTIA

The attached second draft of proposed Guidelines for Uranium Exploration in Nova Scotia has been prepared after considerable consultation with the Nova Scotia Department of the Environment, and constructive comments from numerous exploration companies and environmental groups.

The objective of these guidelines is to provide clearly stated terms and conditions under which exploration for uranium can be conducted in Nova Scotia. The procedures outlined incorporate all elements necessary to protect the environment and provide government agencies with all relevant information regarding such activity. They also provide for notification to appropriate agencies where potential health and environmental impacts are determined. General information derived from the licencing and monitoring process will be made available on open file to the public.

These guidelines are intended to address the exploration stage of mineral investigation. The development and production stages of the mining cycle involve additional provincial and federal inter-agency monitoring and approvals.

It is the intention of the Department of Mines and Energy to recommend that the guidelines be established as Regulations. In the interim, companies conducting detailed ground exploration for uranium are complying with the outlined procedures.

JAGarnett

J. A. Garnett, Ph.D., P. Eng.
Director, Mineral Resources

JAG*ss

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GUIDELINES FOR URANIUM EXPLORATION IN NOVA SCOTIA

JURISDICTION

The issuing and renewing of mineral exploration licences and the monitoring and approving of work done on mineral lands is the responsibility of the Nova Scotia Department of Mines and Energy through the Mineral Resources Act. The pollution control of mineral exploration activities is the responsibility of the Nova Scotia Department of the Environment through the Environmental Protection Act and the Water Act.

The Mineral Resources Division of the Nova Scotia Department of Mines and Energy will act as the initial coordinating agency for all mineral exploration programs.

REGIONAL EXPLORATION: All Minerals

Collecting of exploration data of a reconnaissance nature including:

(a) airborne surveys;
(b) prospecting and geological mapping;
(c) ground geophysical and geochemical surveys;
and (d) regional drilling for geological information: may be conducted under the terms and conditions of a general exploration licence. Regional Geologist monitor all such activity on a regular basis and assessment reports, documenting work performed, are required on an annual basis. General information collected during regional exploration relating to anomalous distribution of uranium or its daughter products must be brought to the attention of Departmental staff as soon as is feasible and specific data must be included in assessment reports.

DETAILED GROUND EXPLORATION - Uranium

When major ground disturbance is planned, as part of a detailed exploration program to evaluate local areas where uranium mineralization has been determined, the general exploration licencee must apply to the Nova Scotia Department of Mines and Energy for a Special Uranium Exploration Licence. This licence is designed to officially register the commencement of specific detailed ground exploration for uranium, and initiate procedures related to such activity. Special Uranium Exploration Licences will only be issued to holders of valid general exploration licences and only over the same ground. This special uranium licence will have the same anniversary date as the general licence.

Major localized ground disturbance includes:
(a) road building, stripping, test-pitting, trenching;
(b) detailed diamond and/or percussion drilling;
and (c) bulk surface sampling of soil and/or bedrock.

I Program Information Requirements

A An information report must accompany the special uranium licence application, including a description of the proposed exploration program; approximate time span of exploration activity; land uses in the immediate vicinity of the exploration property; location of surface water courses and water wells in the area; site access; approximate location and expected size of surface excavations; approximate location and expected depth of drillholes; location and design of core storage. Index maps at appropriate scales should be included.

B A full report on all geological investigations conducted on the property, including levels of radioactivity recorded at all areas of ground disturbance, should be submitted to the Nova Scotia Department of Mines and Energy on an annual basis.

In addition, any changes in exploration programs and any new information involving uranium mineralization and/or high levels of radioactivity should be reported to the Nova Scotia Department of Mines and Energy as soon as is feasible.

Details on exploration programs, reports and specific data will be maintained in confidential files for a period of two years from date of submission. General information derived from the monitoring process will be distributed so that government agencies and the public may be kept informed of the current status of uranium exploration.

Where information is received documenting potential health and environmental impact, the appropriate agencies will be notified in order that action can be taken.

II Preliminary Environmental Surveys

Geochemical and radiometric surveys taken as part of the normal exploration program must be submitted to the Nova Scotia Department of Mines and Energy as quantification of the natural levels of uranium in water and soil prior to commencement of and during the conducting of major ground disturbance programs.

These surveys should provide sufficient baseline date to define the geochemical characteristics of the site before, during and after major ground disturbance. Baseline data will be directed to the Department of the Environment for evaluation.

III Road Building

Details on intended road building must be submitted through the Nova Scotia Department of Mines and Energy for approval by the Nova Scotia Department of the Environment. Access roads to exploration sites should be surveyed radiometrically and results provided as soon as is feasible. Where high radioactivity is identified, the Nova Scotia Department of the Environment may require burial, redesign or relocation. Alteration of natural water courses will require a Water Rights Permit.

IV Stripping, Trenching and Test Pitting

Where stripping, trenching and test pitting are done, the following constraints must be adhered to:

1. All surface excavations should be monitored prior to opening and backfilled as soon as mapping and sampling are completed. In backfilling, the most radioactive material should be replaced first. Following reclamation, a scintillometer survey should be undertaken to ensure that radiation levels do not significantly exceed those present prior to the disturbance.

2. Where it is anticipated that excavated material will not be replaced within three months, this material shall be stabilized to minimize erosion.

3. Excavated material shall not be placed in or adjacent to surface water courses.

4. No water pumped from surface excavations should be discharged directly into a surface water course. Any discharge should be directed through a sump located at least 15 metres away from the nearest water course.

V DRILLING

A Specific information on drilling programs must be submitted to the Nova Scotia Department of Mines and Energy prior to commencement. The Nova Scotia Department of the Environment will be notified in order that holes may be selected for the installation of piezometers for groundwater monitoring purposes.

B Return water from drillholes should not be discharged directly into a surface water course, but through a sump located at least 15 metres away from the nearest water body.

C On abandonment, all mineralized drillholes not approved by the Nova Scotia Department of the Environment for groundwater monitoring purposes should be properly cemented from bottom to top. All unmineralized holes should be cemented from the collar into bedrock. Cement caps in all cases should be at least 20 feet in thickness.

D The area surrounding test holes should be cleared of debris and material used in the drilling operation.

E Upon completion of a drillhole, an identification number, indexed to submitted documents, and the date and name of the exploration company must be posted at the drillhole site in a permanent manner.

VI On-Site Core and Sample Storage

Where radioactive cores and/or samples are being stored, storage facilities should be clearly posted and well ventilated. Upon completion of detailed drilling programs, all core not retained by the licencee for further study must be turned over to the Nova Scotia Department of Mines and Energy.

APPENDIX VII

Terms and Conditions Governing Special Uranium Exploration Licences in Nova Scotia.

TERMS AND CONDITIONS
GOVERNING SPECIAL URANIUM EXPLORATION LICENCES
IN NOVA SCOTIA

JURDISDICTION

The issuing and renewing of mineral exploration licences and the monitoring and approving of work done on mineral lands is the responsibility of the Nova Scotia Department of Mines and Energy through the Mineral Resources Act. With respect to uranium, the Minister of Mines and Energy has withdrawn all lands in the Province from application for general exploration licences. Specific detailed uranium exploration is conducted under special licence and upon terms and conditions as provided by order of the Governor in Council.

The pollution control of all mineral exploration activities is the responsibility of the Nova Scotia Department of the Environment through the Environmental Protection Act and the Water Act.

The Mineral Resources Division of the Nova Scotia Department of Mines and Energy acts as the initial coordinating agency for all mineral exploration programs.

REGIONAL EXPLORATION: All Minerals

Collecting of exploration data of a reconnaissance nature including:

(a) airborne surveys;
(b) prospecting and geological mapping;
(c) ground geophysical and geochemical surveys;
and (d) regional drilling for geological information; may be donducted under the terms and conditions of a general exploration licence. Regional Geologists monitor all such activity on a regular basis and assessment reports, documenting work performed, are required on an annual basis. General information collected during regional exploration relating to anomalous distribution of uranium or its daughter products must be brought to the attention of Departmental staff as soon as is feasible and specific data must be included in assessment reports.

DETAILED GROUND EXPLORATION - Uranium

When major ground disturbance is planned, as part of a detailed exploration program to evaluate local areas where uranium mineralization has been determined, the general exploration licencee must apply through the Nova Scotia Department of Mines and Energy for a Special Uranium Exploration Licence. This licence is designed to officially register the commencement of specific detailed ground exploration for uranium, and initiate procedures related to such activity. Special Uranium Exploration Licences will only be issued to holders of valid general exploration licences and only over the same ground. This special uranium licence will have the same anniversary date as the general licence.

Major localized ground disturbance included:

(a) road building, stripping, test-pitting, trenching;
(b) detailed diamond and/or percussion drilling;
and (c) bulk surface sampling of soil and/or bedrock.

I Program Information Requirements

A An information report must accompany the special uranium licence application, including a description of the proposed exploration program; approximate time span of exploration activity; land uses in the immediate vicinity of the exploration property; location of surface water courses and water wells in the area; site access; approximate location and expected size of surface excavations; approximate location and expected depth of drillholes; location and design of core storage. Index maps at appropriate scales must be included.

B A full report on all geological investigations conducted on the property, including levels of radioactivity recorded at all areas of ground disturbance, must be submitted to the Nova Scotia Department of Mines and Energy on an annual basis.

In addition, any changes in exploration programs and any new information involving uranium mineralization and/or high levels of radioactivity must be reported to the Nova Scotia Department of Mines and Energy as soon as is feasible.

Details on exploration programs, reports and specific data will be maintained in confidential files for a period of two years from date of submission. General information derived from the monitoring process will be distributed so that government agencies and the public may be kept informed of the current status of uranium exploration.

Where information is received documenting potential health and environmental impact, the appropriate agencies will be notified in order that action can be taken.

II Preliminary Environmental Surveys

Geochemical and radiometric surveys taken as part of the normal exploration program must be submitted to the Nova Scotia Department of Mines and Energy as quantification of the natural levels of uranium in water and soil prior to commencement of and during the conducting of major ground disturbance programs.

These surveys should provide sufficient baseline data to define the geochemical characteristics of the site before, during and after major ground disturbance. Baseline data will be directed to the Department of the Environment for evaluation.

III Road Building

Details on intended road building must be submitted through the Nova Scotia Department of Mines and Energy for approval by the Nova Scotia Department of the Environment. Access roads to exploration sites must be surveyed radiometrically and results provided as soon as is feasible. Where high radioactivity is identified, the Nova Scotia Department of the Environment may require burial, redesign or relocation. Alteration of natural water courses will require a Water Rights Permit.

IV Stripping, Trenching and Test Pitting

Where stripping, trenching and test pitting are done, the following constraints must be adhered to:

1. All surface excavations must be monitored prior to opening and backfilled as soon as mapping and sampling are completed. In backfilling, the most radioactive material should be replaced first. Following reclamation, a scintillometer survey must be undertaken to ensure that radiation levels do not significantly exceed those present prior to the disturbance.

2. Where it is anticipated that excavated material will not be replaced within three months, this material must be stabilized to minimize erosion.

3. Excavated material must not be placed in or adjacent to surface water courses.

4. Water pumped from surface excavations must not be discharged directly into a surface water course. Any discharge must be directed through a sump located at least 15 metres away from the nearest water course.

V Drilling

A Specific information on drilling programs must be submitted to the Nova Scotia Department of Mines and Energy prior to commencement. The Nova Scotia Department of the Environment will be notified in order that holes may be selected for the installation of piezometers for groundwater monitoring purposes.

B Return water from drillholes must not be discharged directly into a surface water course, but through a sump located at least 15 metres away from the nearest water body.

C On abandonment, all mineralized drillholes not approved by the Nova Scotia Department of the Environment for groundwater monitoring purposes must be properly sealed from bottom to top. All unmineralized holes must be sealed from the collar into bedrock. Impermeable caps in all cases must be at least 20 feet in thickness.

D The area surrounding test holes must be cleared of debris and material used in the drilling operation.

E Upon completion of a drillhole, an identification number, indexed to submitted documents, and the date and name of the exploration company must be posted at the drillhole site in a permanent manner.

VI On-Site Core and Sample Storage

Where radioactive cores and/or samples are being stored, storage facilities must be clearly posted and well ventilated. Upon completion of detailed drilling programs, all core not retained by the licencee for further study must be turned over to the Nova Scotia Department of Mines and Energy.

APPENDIX VIII

Item 1. Policy Statement Regarding Exploration for Uranium in Nova Scotia.

Item 2. Information Directive regarding mineral land access to Municipal Water Supply Lands.

MINISTER OF MINES AND ENERGY
PROVINCE OF NOVA SCOTIA

1982 02 02

POLICY REGARDING EXPLORATION FOR URANIUM

This will serve as official notification of this Department's policy regarding exploration for uranium.

No new Special Uranium Exploration Licences will be issued by Cabinet, existing Special Licences for uranium will not be renewed, and no further uranium exploration will be permitted, pending the findings of the inquiry to investigate environmental and health impacts associated with uranium exploration and mining.

Companies or individuals wishing to retain uranium rights in areas previously held under either General Exploration or Special Licences must submit a request for a Special Uranium Exploration Licence to the Registrar of Mineral Rights. The area will then be withdrawn from further exploration for all minerals, and the request held on file until Cabinet decides what action is to be taken on this issue.

Yours truly,

Ron Barkhouse

November 17, 1981.

FOR THE INFOMATION OF
ALL HOLDERS OF EXPLORATION LICENCES
UNDER THE MINERAL RESOURCES ACT

Access to Municipal Watersupply Land*

All licence holder receiving an Exploration Licence over ground designated as a Municipal Watersupply Watershed area shall be notified concerning that part of the licence which falls within the Watershed area.

Access to mineral lands in Nova Scotia which fall within designated Municipal Watersupply lands will be governed by the following guidelines:

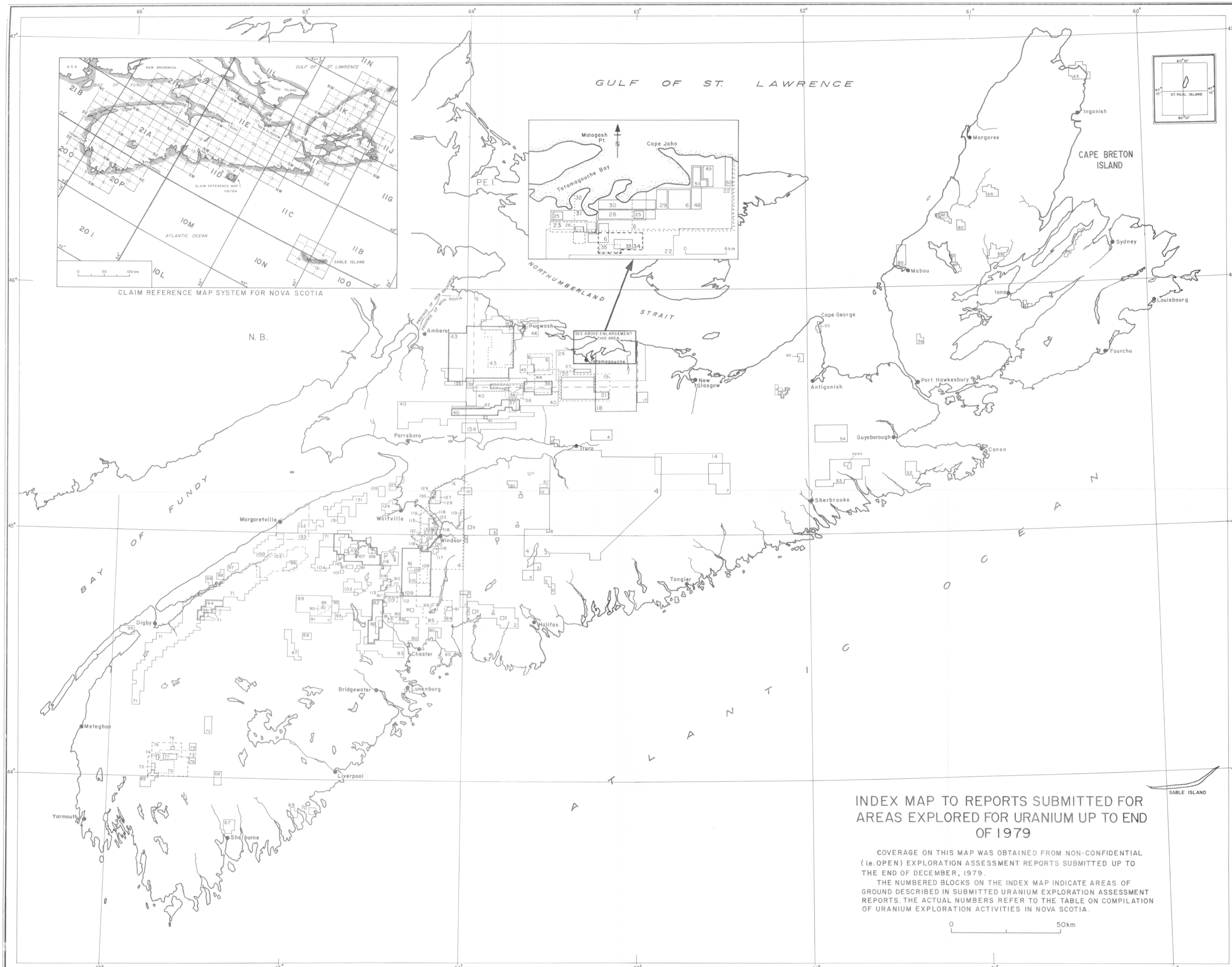
I Regional Exploration

exploration activities that cause no surface damage require only notification to the Nova Scotia Department of Mines and Energy of entry and completion dates. Such activities are airborne surveys, prospecting, geological mapping, geochemical and geophysical surveys;

II Detailed Ground Exploration

exploration activities involving surface damage require approval from the Minister of the Nova Scotia Department of the Environment. Such activities include drilling, blasting, test pitting, trenching, stripping, road construction and water course alterations. Contact person in the Department of the Environment is John Jones, Director of Water Planning & Management Division.

*These constraints are over and above any constraints set forth by the property owners.


INDEX MAP TO REPORTS SUBMITTED FOR AREAS EXPLORED FOR URANIUM UP TO END OF 1979
COVERAGE ON THIS MAP WAS OBTAINED FROM NON-CONFIDENTIAL (ie. OPEN) EXPLORATION ASSESSMENT REPORTS SUBMITTED UP TO THE END OF DECEMBER, 1979.
THE NUMBERED BLOCKS ON THE INDEX MAP INDICATE AREAS OF GROUND DESCRIBED IN SUBMITTED URANIUM EXPLORATION ASSESSMENT REPORTS. THE ACTUAL NUMBERS REFER TO THE TABLE ON COMPILATION OF URANIUM EXPLORATION ACTIVITIES IN NOVA SCOTIA.
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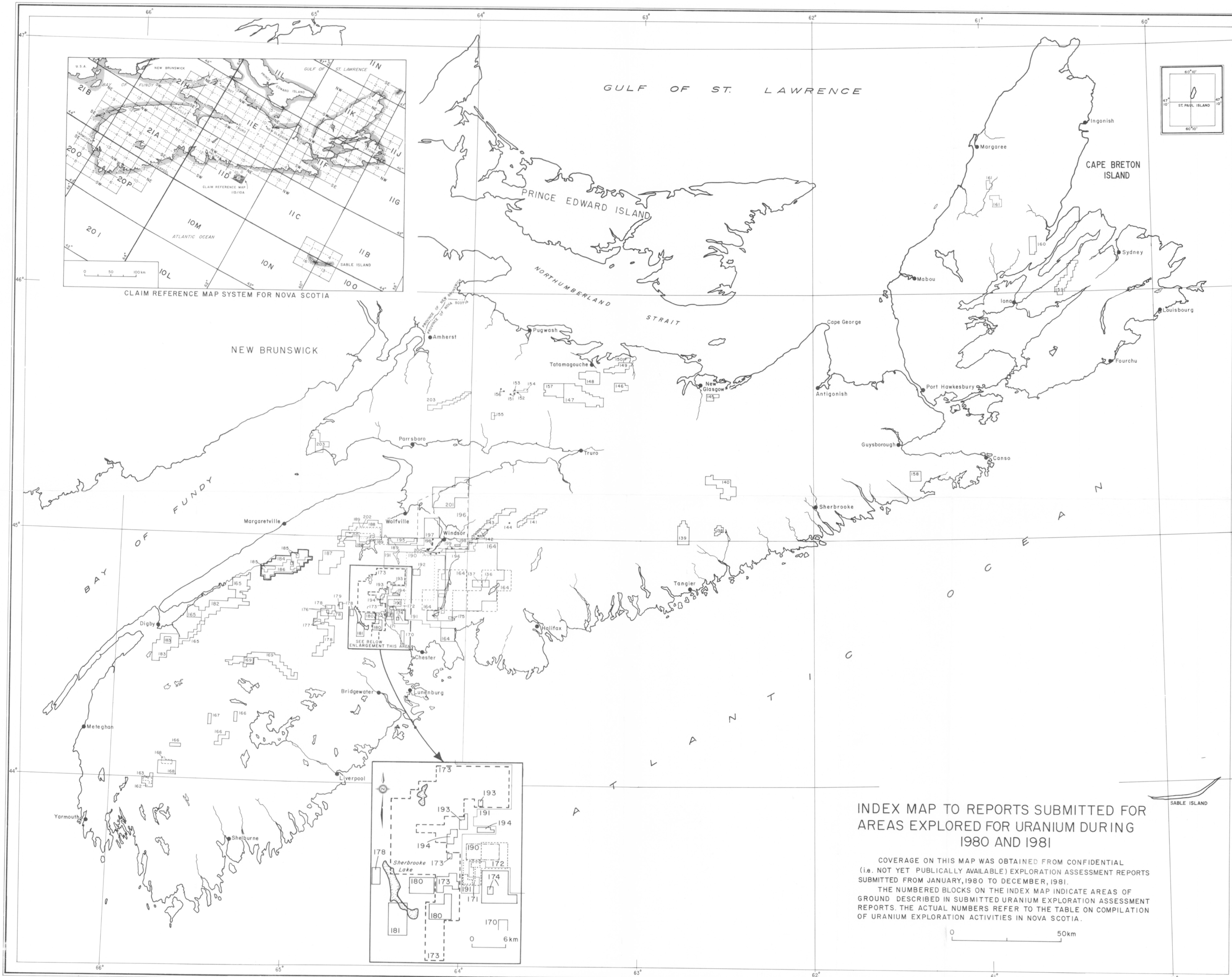
CLAIM REFERENCE MAP SYSTEM FOR NOVA SCOTIA
GULF OF ST. LAWRENCE
NORTHUMBERLAND STRAIT
BAY OF FUNDY
ATLANTIC OCEAN
CAPE BRETON ISLAND
SABLE ISLAND
ST. PAUL ISLAND
N.B.
P.E.I.
SEE ABOVE ENLARGEMENT THIS AREA
Malagash Pt.
Cape John
Tatamagouche Bay
Amherst
Pugwash
Tatamagouche
New Glasgow
Truro
Parrsboro
Wolfville
Windsor
Margaretville
Digby
Chester
Halifax
Lunenburg
Bridgewater
Liverpool
Meteghan
Yarmouth
Shelburne
Tangier
Sherbrooke
Antigonish
Cape George
Guysborough
Canso
Port Hawkesbury
Mabou
Margaree
Ingonish
Sydney
Iona
Louisbourg
Fourchu



INDEX MAP TO REPORTS SUBMITTED FOR AREAS EXPLORED FOR URANIUM DURING 1980 AND 1981

COVERAGE ON THIS MAP WAS OBTAINED FROM CONFIDENTIAL (i.e. NOT YET PUBLICALLY AVAILABLE) EXPLORATION ASSESSMENT REPORTS SUBMITTED FROM JANUARY, 1980 TO DECEMBER, 1981.

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