GEOLOGY AND GEOCHEMISTRY OF A URANIUM-RICH AREA IN SOUTHWESTERN NEWFOUNDLAND

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GEOLOGY AND GEOCHEMISTRY OF A URANIUM-RICH AREA IN SOUTHWESTERN NEWFOUNDLAND

by

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ABSTRACT

A regional geochemical stream sediment survey in southwestern Newfoundland showed several anomalously high uranium areas. Follow-up soil and rock sampling and geological mapping programs were carried out in one of these anomalous areas -- the Brinex Lake map-area.

The area is underlain by granodiorite, which is possibly of metasomatic origin, schist and gneisses. Pegmatite dykes are numerous and some aplite and basic dykes were also found. Rocks of the Brinex Lake map-area are possibly of Pre-Cambrian age.

No uranium mineralization was found in the rocks although some rocks contained anomalously high uranium values, ranging up to 85 ppm. Uranium in the rocks appears to be associated with biotite-rich lenses in schists and gneisses and in the contact zone between them and the granodiorite. Radioactive inclusions in biotite are believed to be the main source of uranium in these rocks. Red hematite alteration, which is characteristic of known uranium occurrences in other parts of the world, is commonly associated with the biotite lenses. Soil and stream sediment anomalies are closely associated with areas containing abundant biotite lenses.

Comparisons with known uranium provinces suggests that favourable geological environments for the accumulation of uranium into deposits of economic value exist in southwestern Newfoundland. Radioactive occurrences have been reported in similar rocks along the north shore of the St. Lawrence River and in Nova Scotia and New Brunswick.

CHAPTER I

INTRODUCTION

Location and Means of Access

A block of approximately fourteen square miles, near the head-waters of several of the northerly tributaries of Garia Brook in southwestern Newfoundland, is the main area of consideration in this study. This area lies between latitudes 47° 45'N and 48° 00'N and longitudes 58° 15'W and 58° 45'W as shown in Figure I-1, and will be called the Brinex Lake Map-Area.

The area is easily accessible only by helicopter and single engine aircraft. To reach the area on foot would mean a thirty mile walk from either the Trans-Canada Highway to the west or the gravel road along the south coast, between Port aux Basques and Rose Blanche. However, the area is located a distance of only ten miles from the bottom of Garia Bay, which is not accessible by road. A number of hunting lodges in the general vicinity use Bombardier track vehicles to transport men and supplies from Port aux Basques.

Previous Geological Work

Geological mapping in southwestern Newfoundland along the coast between Port aux Basques and Rose Blanche and inland for a distance of thirty to forty miles has been sparce to date. The area has been mapped by the Geological Survey of Canada on a scale of one inch equals four miles (1 in. = 4 mi.), but this work has not yet been published (Gillis, 1965).

Several ill-defined sections along the south coast were mapped by three different authors. In 1946-47 a small part of the area between Cape

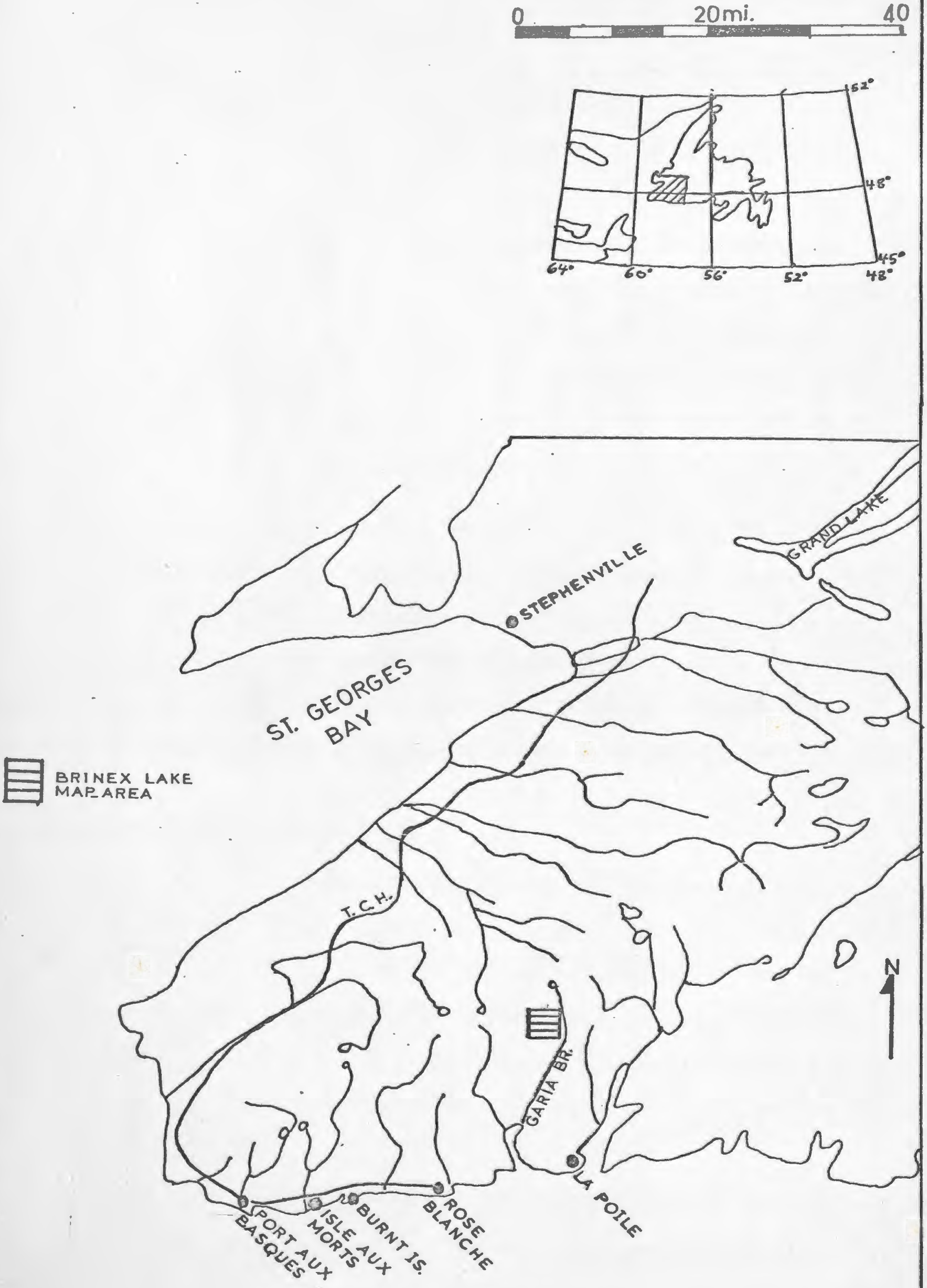

FIGURE I-1:— INDEX MAP

Ray and Port aux Basques was mapped by G. Phair for an unpublished doctoral thesis presented at Princeton University (Phair, 1948). In his report Phair assigned a Paleozoic age to the rocks of the Long Range igneous and metamorphic complex that were originally assigned to the Pre-Cambrian (Murray and Howley, 1881). A small section of the area near Isle aux Morts was mapped by W. Power in 1955 for the Newfoundland Geological Survey (Power, 1955). More recently, in 1965, G. H. Gale carried out an economic assessment of pegmatite between Isle aux Morts and Rose Blanche for the Newfoundland Department of Mines, Agriculture and Resources (Gale, 1965).

The Stephenville and Red Indian Lake map-areas to the north were mapped by G. C. Riley in 1953-55 for the Geological Survey of Canada (Riley, 1962). To the east the La Poile - Cinq Cerf map-area was mapped by J. R. Cooper in 1937-40 for the Geological Survey of Newfoundland. This work was published by the Geological Survey of Canada (Cooper, 1954).

Purpose and Scope of Present Study

The field work connected with this report was carried out during the summer of 1969 while the author was employed by British Newfoundland Exploration Limited (Brinex). The field party consisted of five men who were housed in tents supported by aluminium frames. These special frames were necessary because of the lack of trees of sufficient height for tent poles. Weekly supply flights from Deer Lake were provided by Newfoundland Air Transport Limited.

During the 1968 field season Brinex had carried out a regional geochemical stream sediment sampling program on the whole of their exploration concession in southwestern Newfoundland. Later the same season the regional survey was followed by more detailed sampling of streams that contained anomalous amounts of uranium.

The present investigation concerns one of those anomalous areas. The whole of the area was mapped geologically on a scale of one inch equals one thousand feet (1 in. = 1000 ft.). Soil samples were collected on two grids covering approximately one and a half square miles each. The purpose of this program was to determine the source of the uranium in the stream sediments. It was hoped that the silt anomalies would be related to surface or near surface mineralization, which would in turn lead to uranium deposits of economic significance. However, no such mineralization was found. Indeed, the only mineralization visible in outcrops of the area are a few grains and stringers of pyrite, and, in places, hematitic staining. The object of this investigation then became to provide a plausible explanation of uranium anomalies occurring in rocks, soils and stream sediments in the area.

Physiography and Glaciation

The area can be described as a rolling upland in a youthful stage of dissection by streams. The main stream in the area, Garia Brook, is fed by numerous small tributaries, mainly flowing from the northwest. The headwater streams flow in broad, open valleys in the upland and then drop by a succession of falls and rapids into the narrow, steep-walled valley of Garia Brook.

The upland has been extensively glaciated, as evidenced by the abundance of U-shaped valleys, hanging valleys, roches moutonnées and perched erratics. Most pre-glacial soil has been removed and very little glacial drift has been left behind. The present soil cover, which will be discussed in detail in a later section, is thin and consists mainly of humus and undecayed organic matter.

Extensive weathering has obscured conclusive evidence of glacial movement, but it is generally believed that this part of Newfoundland was over-ridden by a continental ice sheet coming from the north or west. No glacial erratics of rock types different than those which crop out in the map area were observed. This suggests that the distance these boulders travelled was small.

Exposure, in general, is poor. Where outcrops do occur their detail is somewhat obscured by lichen. A large part of the area is covered by scrub spruce, numerous swamps and small ponds.

CHAPTER II

GENERAL GEOLOGY

Regional Setting

The Newfoundland Appalachian System is divided into three major tectono-stratigraphic belts: the Western Platform, the Central Paleozoic Mobile Belt, and the Avalon Platform. Figure II-1 illustrates these divisions and the major structural features of the system. The intensely deformed metamorphic rocks which occur along the western margin of the Mobile Belt are separated from the Western Platform by the Cabot Fault, a major strike-slip fault with sinistral displacement of at least several tens of miles (Williams et al., 1970). Towards the center of the Mobile Belt are less deformed and metamorphosed Ordovician and Silurian sedimentary and volcanic rocks. The eastern margin consists of a belt of granitic gneisses, metasediments, amphibolites and mylonites. This marginal unit extends from Bonavista Bay to Hermitage Bay where it was folded by the Acadian Hermitage Flexure and extends along the south coast of Newfoundland, probably as far as Port aux Basques (Williams et al., 1970).

On the latest geological map southwestern Newfoundland is divided into three main northeasterly-trending belts: a northwestern Carboniferous sedimentary belt, a central belt that is referred to as the Long Range Metamorphic and Igneous Complex, and a southeastern belt of unseparated granite, schists, gneisses and migmatites (Williams, 1967). The Carboniferous belt is separated from the central belt by the Cabot Fault. The central and southeastern belts are separated by a topographic linear feature which has been interpreted as a large wrench fault known as the Cape Ray Fault (Webb, 1969).

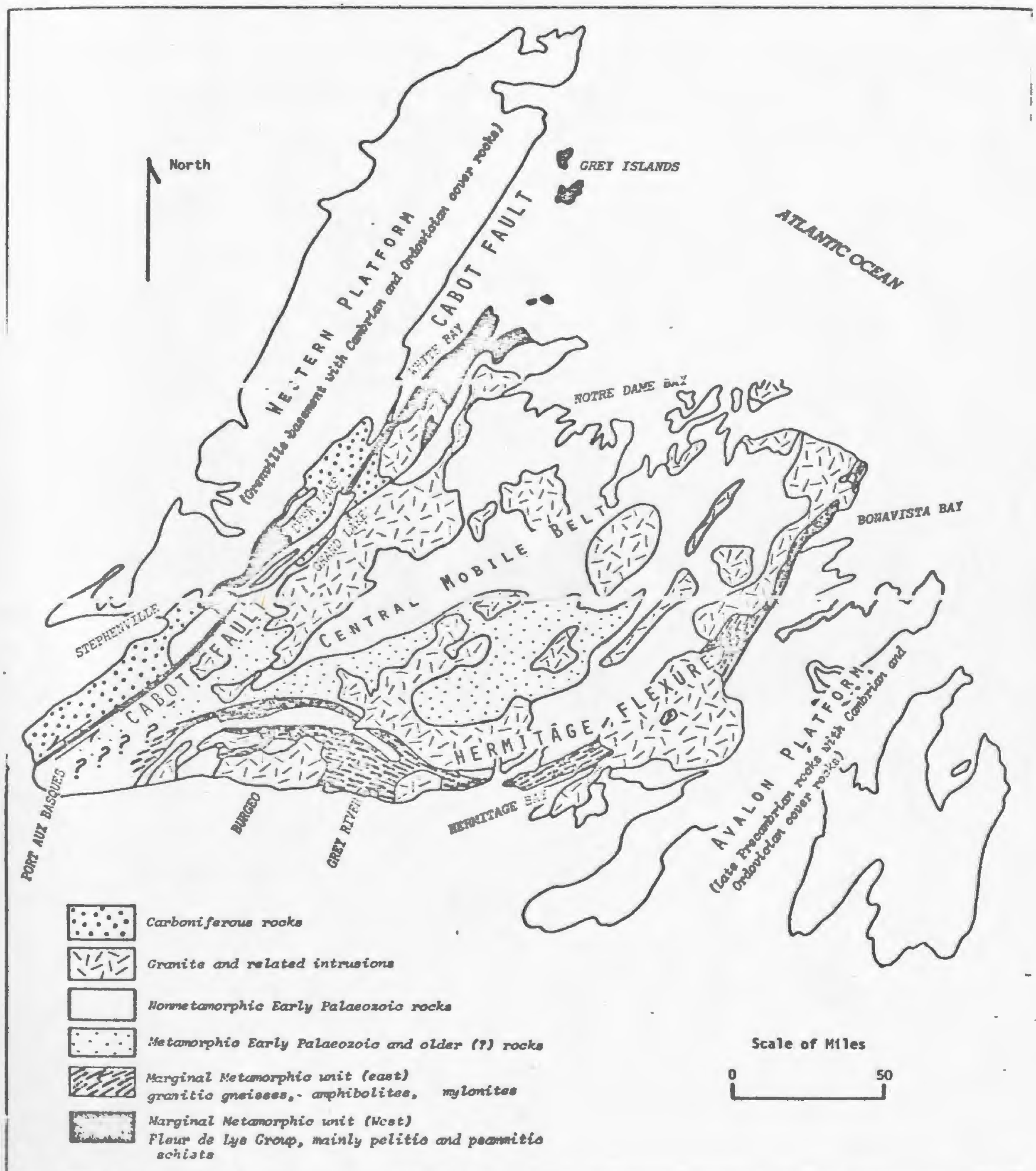

Figure II-1. General geology and major structural subdivisions of the Newfoundland Central Mobile Belt.
(AFTER Williams et al, 1970)

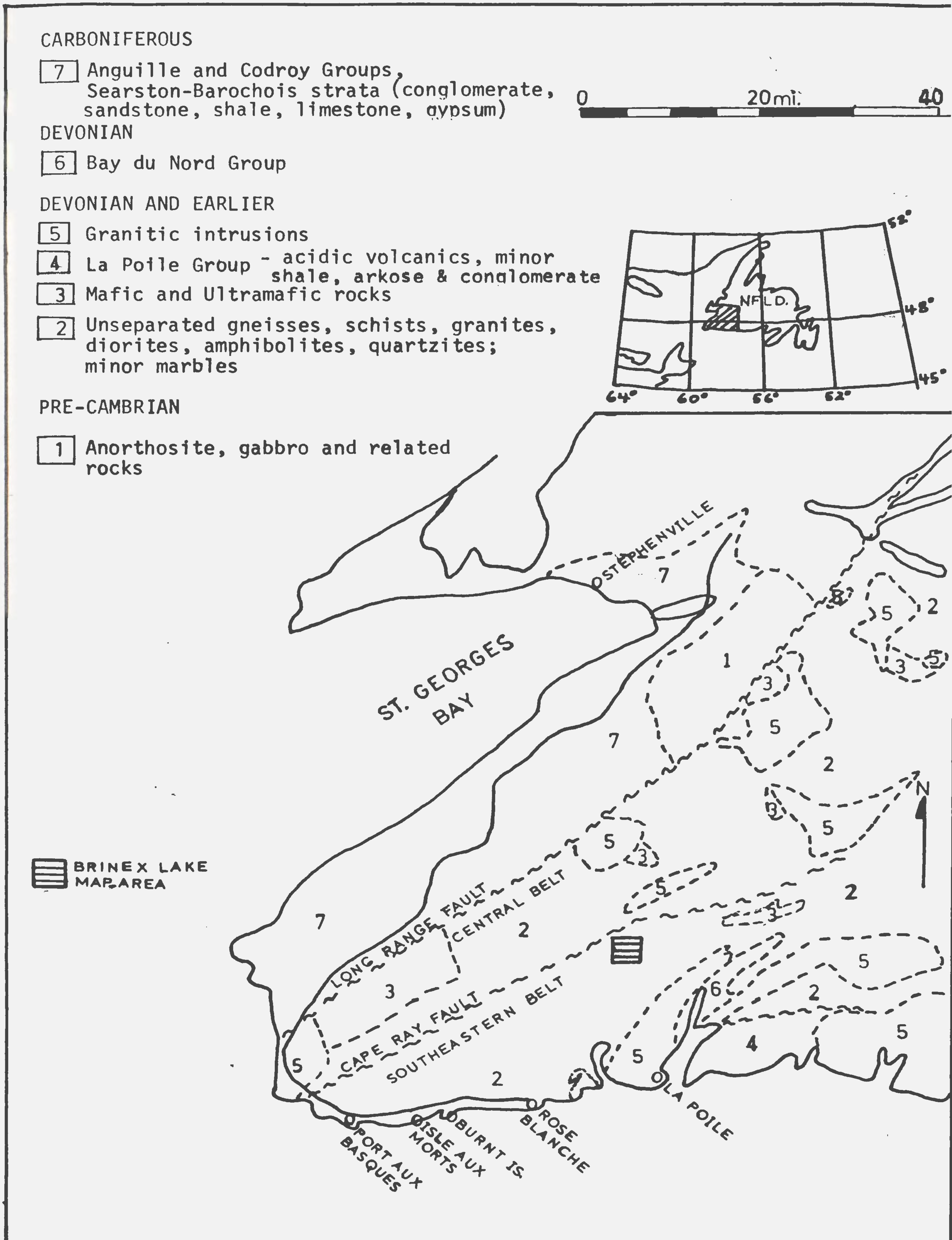

Figure II-2: Regional Geology

The Carboniferous belt has been clearly defined and consists of three stratigraphic units consisting mainly of arenaceous sediments, the Anguille and Codroy groups of Mississippian age and the Barachois - Searston Strata of Mississippian and Pennsylvanian age. Whether the metamorphic belt on the southeast side of the Cape Ray Fault is different from the metamorphic belt on the northwest side has not yet been properly established. Gillis (1965), on his generalized preliminary map, does not distinguish between the two belts nor does he show the Cape Ray Fault. However, Williams (1967) did distinguish between the two belts, showing the central belt as Ordovician, Silurian, Devonian or earlier. More recently it has been suggested that some of the rocks east of the Cabot Fault may be a continuation of the Gander Lake Group, which contains some rocks of Precambrian age (Williams et al., 1970).

Further east in the La Poile - Cinq Cerf map-area Devonian sedimentary and volcanic rocks overlie metamorphic rocks similar to those in the southeastern belt (Cooper, 1954).

History of Geologic Investigation

The lack of regional geological mapping and published information on southwestern Newfoundland makes proper reconstruction of the geologic history of the area difficult. A brief summary of the regional geology of this area based on the available literature is presented below. However, due to the lack of information, only general interpretation can be made. The accompanying map (Figure II-2) is based on the work of Gillis (1965) and the Geological Survey of Canada's Map of Newfoundland (Williams, 1967).

The first geological investigations in southwestern Newfoundland were by Murray and Howley (1881). They assigned a Pre-Cambrian age to the southwestern Long Range Mountains, on the basis of correlations with the crystalline rocks of the Great Northern Peninsula which were in turn correlated with the Laurentian (Grenville) rocks of the Canadian mainland. The association of crystalline limestone with these rocks in parts of western Newfoundland was taken as further evidence of a Pre-Cambrian age, since such limestones are typical of the mainland succession.

In 1948 Phair mapped portions of the three belts in southwestern Newfoundland. He provided the first description of the rocks of the southeastern belt and named them the Cape Ray Cove schists and gneisses. In general, they consist of northeasterly-trending schists, gneisses, amphibolites, migmatites and quartzite intruded by granite, diorite and pegmatite dykes. Phair found crystalline limestones interbedded with gneissic metasediments along the canyon of the south branch of the Grand Codroy River in southwestern Newfoundland. He suggested that these silicated marbles are of early Paleozoic age because of their distribution and the wide variation in their degree of metamorphism (fine-grained phases approaching limestone were found preserved within the section). Farther north Schuchert and Dunbar (1934) found similar marbles in the Bay of Islands region that they considered to be metamorphosed equivalents of the Lower Ordovician St. George's Series. This led Phair to conclude that the metasediments in the whole of the southwestern Long Range Mountains are of Paleozoic age.

Power (1955) mapped a portion of the southeastern belt in the

Isle aux Morts - Burnt Island area (Figure II-2). He described granitic rocks, schists and gneisses with the proportion of gneissic rocks increasing from east to west. Amphibolites and quartzites are present in the area in minor amounts. The quartzites display ghost stratification and the amphibolites occur as narrow, discontinuous bands concordant with the schists and gneisses.

Folding in this area appears to be complex due to the effects of several deformation phases. Power (1955) suggested that the major folds in the area are upright, northeast-trending, anticlinoria and synclinoria that plunge to the southwest near the coast and to the northwest farther inland. Thus he considered the anticlinoria to be elongate domes. However, the validity of this interpretation could be questioned on the basis of a statement made elsewhere in the same publication that the axes of the minor folds in the area nearly all plunge to the northeast. His map also shows the minor folds plunging to the northeast. This leads to the conclusion that the major folds also plunge to the northeast and not to the southwest as he suggested.

The pattern of joints described by Power (1955) in the Isle aux Morts area has considerable significance in this study as will be shown later. On the basis of 193 field measurements he showed that there are two principal joint sets that are vertical and trend S 75°E and due north. The same pattern is followed by streams in the area suggesting that the stream erosion is joint controlled.

Gale (1965) studied pegmatites in the southeastern metamorphic belt between Isle aux Morts and Rose Blanche and he discussed the general geology of the area in his report. He concluded that schists and gneisses are the predominant rocks in the belt. They grade into each other and are interbanded so that division into distinct lithological units is impossible. The contacts are generally gradational and characterized by an increase in the amount of feldspar in passing from schists to gneisses. Both rock types have the same range of mineral constituents, biotite being more abundant than quartz and feldspar in the schists and less abundant in the gneisses. Gale concluded that the metamorphic grade increased westward and northwestward from Rose Blanche. This conclusion was based on a change in rock types from fine-grained biotite-garnet and biotite-muscovite schists in the east to coarser-grained garnet-biotite schists and kyanite schists in the west near Port aux Basques. Like Power (1955), he noted that schist appeared to be more abundant in the east, whereas the reverse appeared to be the case in the western part of the belt.

Gale noted that granitic rocks occur throughout the belt but appear to be most abundant in the east. The composition of these rocks varies from granite to diorite, some containing little or no potash feldspar. The essential minerals of the granites are microcline, plagioclase and quartz, with varying amounts of muscovite and biotite. The accessory minerals include apatite, sphene, magnetite-ilmenite, epidote, allsnite, chlorite, zircon, garnet and tourmaline. Associated with the granites are numerous pegmatite and aplite dykes.

Discontinuous bands of amphibolites occur in this area and Gale concluded that these bands are the result of boudinage acting on original basic volcanic dykes, sills or flows. Hornblende and andesine are the most abundant minerals in the amphibolites, while magnetite-ilmenite, garnet, calcite, epidote, sphene and pyroxene are present in lesser quantities.

The most detailed geologic investigation in southwestern Newfoundland was carried out in La Poile - Cinq Cerf map-area by Cooper (1954). The oldest rocks in this area are a group of orthogneisses and paragneisses which Cooper called the Keepings gneiss. He concluded that the Keepings gneiss is pre-Devonian because of its uniformly high degree of metamorphism, generally coarse texture and difference in structural trend from the Devonian rocks and that it is possibly Pre-Cambrian in age.

The Northern Granite which intrudes the Keepings Gneiss is considered to be younger than the gneiss and older than the earliest Devonian rocks in the area. Cooper based this conclusion on the fact that these rocks have petrographic characteristics which are unlike the Devonian intrusions farther south.

The Keepings gneiss is separated from the Bay du Nord group by a later mafic intrusive body. The Bay du Nord group contains Devonian fossils and Cooper claimed that the fossiliferous Devonian sediments grade laterally into biotite and kyanite grade metamorphic rocks. He believed that the metamorphism is related to granitic intrusions because the metamorphic grade increases near the igneous intrusion at the top and bottom of the section. The author questions this conclusion because the metamorphism described is of the regional type and not the contact metamorphism usually associated with granitic intrusions.

Rocks of the Bay du Nord group are separated from those of the La Poile group by intrusive bodies and by a fault. The La Poile group consists of sedimentary and acid volcanic rocks and is considered to be younger than the Bay du Nord group.

In the La Poile-Cinq Cerf map-area Cooper concluded that the structural trend of the Devonian rocks is northeast in conformity with the trends in the greater Appalachians. He further concluded that little could be said of the structure of the pre-Devonian rocks except that their structural trends are irregular and more nearly north than northeast.

It should be pointed out here that most of the geological work referred to in the preceding section was carried out near the coast and that the Brinex Lake map-area lies approximately thirty miles inland from the coast. It is not known for certain if the same geology extends inland but Gillis' preliminary map indicates that it probably does (Gillis, 1965). The rock types of the Brinex Lake map-area are very similar to some of those described in the coastal areas.

Geology of the Brinex Lake Map Area

The present map-area lies in the northeast corner of the southeastern belt (Figure II-2). The major rock types are granodiorite and undifferentiated schists and gneisses. These rocks are intruded by numerous small pegmatite dykes and some aplite and diabase dykes. The distribution of these rock types is shown on map no. 1 in the folder.

1. Granodiorite

The granodiorite, which underlies about ninety per cent of the map-area, has the following modal composition, based on analyses of two representative samples: albite-oligoclase 45%, quartz 30%, biotite 20%, potash feldspar 2-3%, and accessories 2-3%. The accessory minerals are muscovite, magnetite, epidote, sphene, allanite, chlorite, zircon and apatite.

The plagioclase crystals are subhedral and most have undergone slight alteration. Albite twinning is very common and some of the crystals appear to be zoned. Quartz occurs as anhedral crystals which generally show undulatory or strained extinction. Chlorite always occurs as a replacement of biotite and is fairly abundant in some places. Euhedral allanite occurs as minute crystals commonly surrounded by epidote (Plate II-1). Apatite and zircon occur as minute euhedral inclusions in biotite and some crystals of both have pleochroic haloes (Plates II-2, II-3, II-4, and II-5). Sphene occurs in its characteristic rhombic cross-sectional form in thin section (Plate II-6).

The granodiorite generally contains a distinct foliation defined by preferred orientation of biotite. The rock is medium grained and displays a typically granitic texture.

Several intrusive contacts were noted in the field with the granodiorite cutting across the foliation of the schists and gneisses (Plate II-7). However, most of the contacts with schist and gneiss are gradational over several feet and are characterized by biotite-rich lenses becoming more abundant towards the metamorphic rocks. The biotite lenses vary in width from two inches to two feet and their length varies from two to four feet. The predominance of such gradational contacts suggests that the granodiorite may have resulted from extensive granitization of the

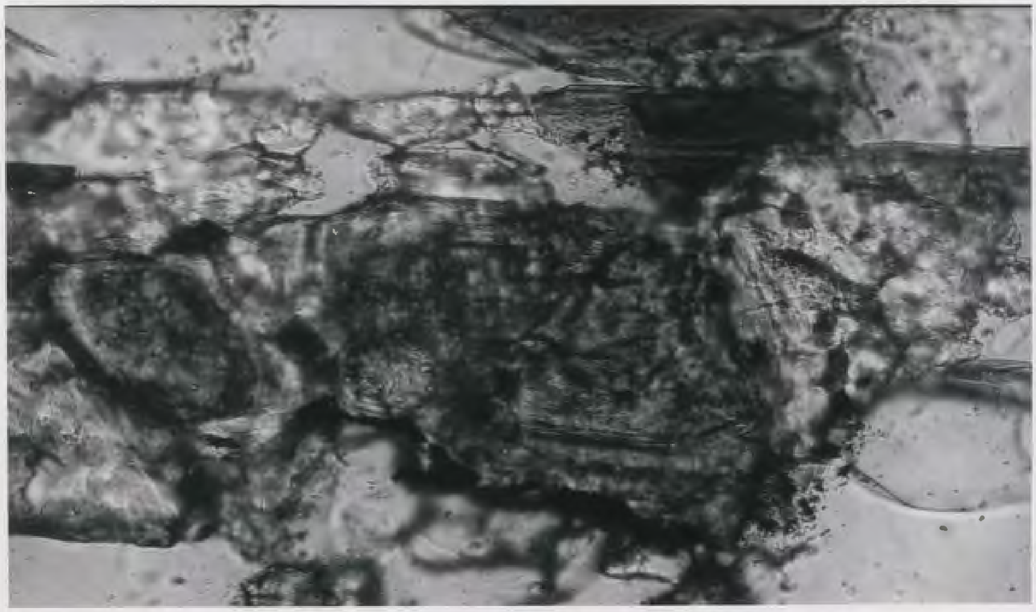

PLATE II-1: (X160, plane polarized light). Allanite crystal (dark grey) surrounded by rim of epidote (light grey).

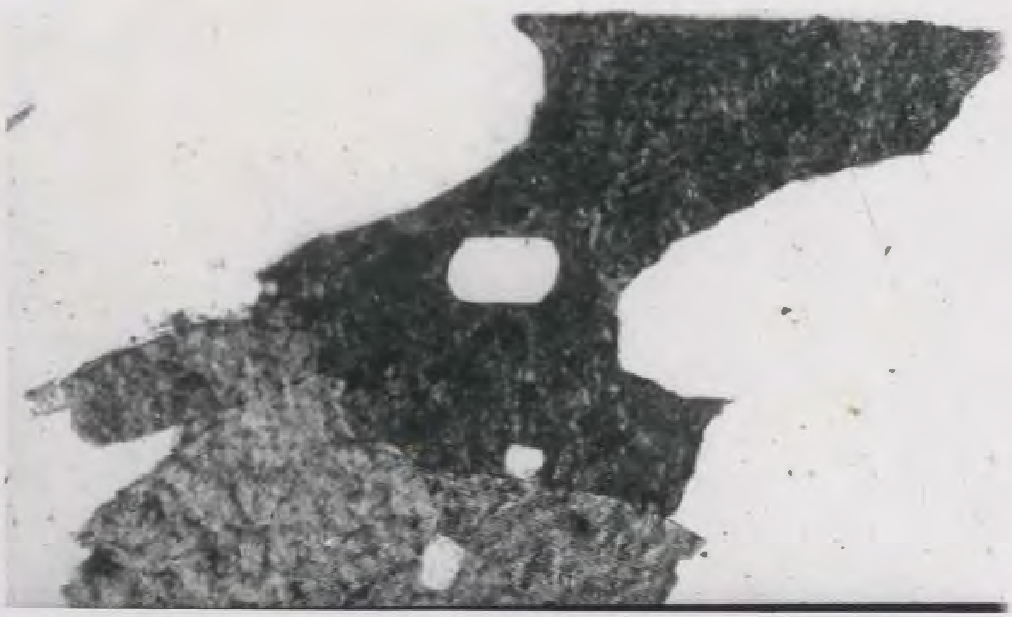

PLATE II-2: (X40, plane polarized light). Apatite inclusions (small white crystals) in biotite.

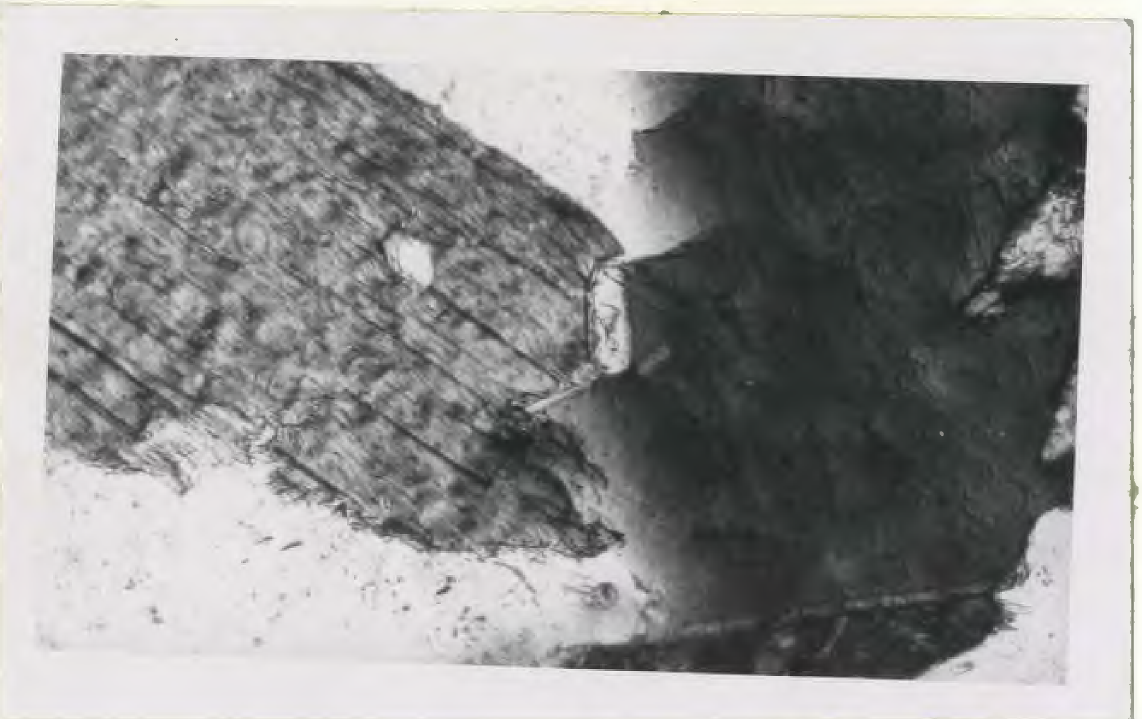

PLATE II-3: (X63, plane polarized light). Zircon inclusions in biotite.

PLATE II-4: (X50, plane polarized light). Pleochroic haloes around minute inclusions of apatite and zircon in biotite.

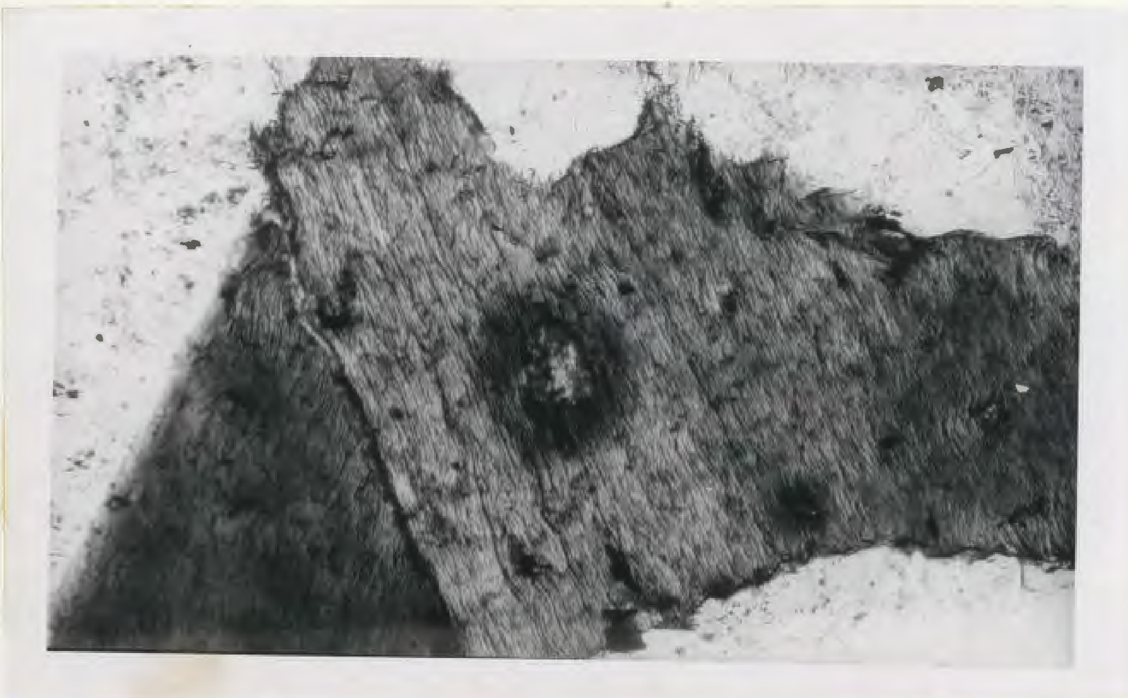

PLATE II-5: (X63, plane polarized light). Pleochroic halo around apatite inclusion in biotite.

PLATE II-6: (X10, plane polarized light). Sphene crystal showing angular rhombic cross section.

PLATE II-7: Intrusive contact between granodiorite (below black line) and gneiss (above black line).

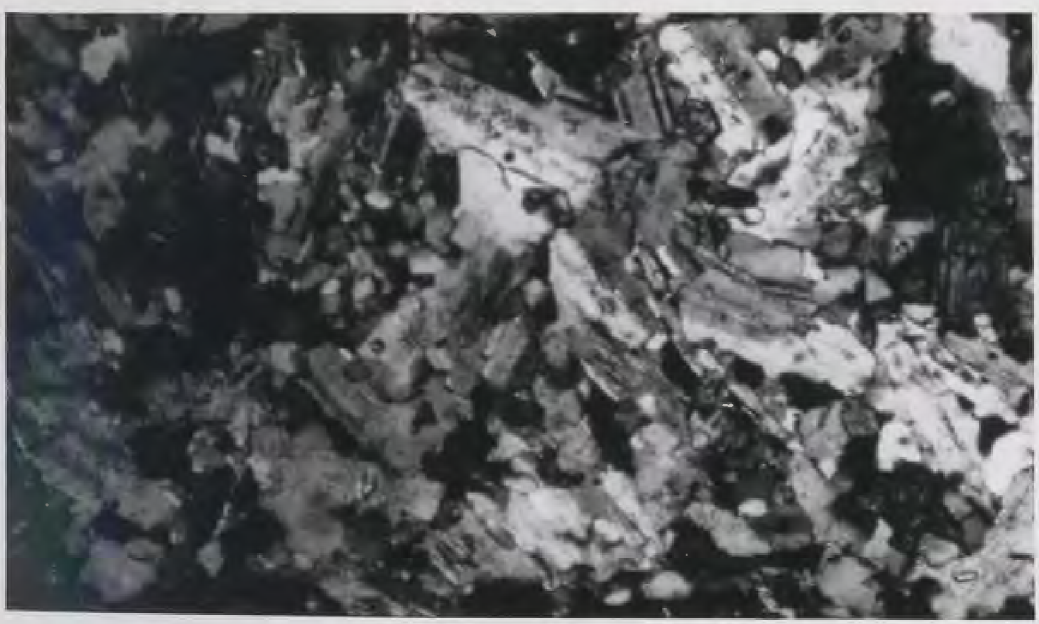

PLATE II-8: (X10, X nicols). Original igneous texture in altered diabase dyke.

schists and gneisses which are considered to be mainly metasediments. However, the presence of some sharply discordant contacts attests to at least some local melting and remobilization. This aspect of the granodiorite will be dealt with later in terms of the rock geochemistry.

2. Schists and Gneisses

This rock unit consists mainly of biotite-muscovite-garnet schists which locally grade into gneisses across-strike the gradation being marked by an increase in the number and thickness of felsic layers relative to mafic layers. Biotite-hornblende schist occurs as discontinuous, concordant lenses within this unit.

The gneisses contain the same minerals and in approximately the same proportions overall as the biotite-muscovite garnet schists. The mafic layers in the gneiss contain mainly biotite, muscovite and garnet and have less quartz and feldspar than the schist. The felsic layers in the gneiss have the following approximate modal composition: albite-oligoclase 50%, quartz 35%, biotite 7%, potash feldspar 5%, and accessories 3%. The accessory minerals are apatite, epidote, allanite, zircon and chlorite. The modal composition was determined from two thin sections of the felsic layers. The crystal habit and mode of occurrence of these minerals is the same as that described for the granodiorite. The mineralogical composition of these metamorphic rocks suggests that most were derived from pelitic sediments.

The biotite-hornblende schist lenses in this unit were found in the north part of the area near Brinex Lake. These lenses vary in thickness from four feet to ten feet and pinch out along strike into boudinage like structures. Their approximate mineralogical composition, based on a visual estimate of one thin section, is as follows: quartz 40%, biotite 20%, hornblende 20%, epidote 5%, magnetite 4%, muscovite 5%, plagioclase 4%, and chlorite 1%. This rock was probably derived from a basic dyke, sill or flow.

In the south part of the map area the metamorphic rocks contain some migmatite zones. These zones contain potash feldspar-rich lenses that are concordant with the gneissic layering. The presence of these lenses suggest either extreme metamorphic differentiation or a type of lit-par-lit injection related to later intrusives.

3. Minor Intrusives

Pegmatite, aplite and diabasic dykes were the only minor intrusives found in the area.

Pegmatite dykes are numerous and they can be found in both the granodiorite and the metamorphic rocks, cross cutting the foliation in both. They are distributed randomly and do not follow any recognized fracture patterns. The maximum width of the pegmatite dykes is two feet and the majority are between six inches and one foot wide. The pegmatites have a simple mineralogy consisting almost entirely of orthoclase, microcline, and quartz, with minor perthite, plagioclase and biotite. The sharp boundaries and well-defined shape of these pegmatite dykes leaves no doubt that their origin is igneous. Since none of these dykes appear to be folded or foliated, it is likely that they are post-deformational.

Two wide aplite dykes are shown on Map No. 1 intruding the granodiorite and the gneisses in the southern part of the map-area. The actual extent of these dykes is not well defined due to the lack of exposure. The aplite is fine-grained and displays the typical sugary texture of aplites in hand specimen. The main minerals are orthoclase, oligoclase, perthite, quartz, biotite and muscovite. The accessory minerals present are garnet, allanite, epidote, apatite, chlorite and magnetite.

Several diabase dykes, two to four feet wide, also occur in the map-area. They intrude both the granodiorite and the gneisses, and although they have to some extent been affected by metamorphism, they have not been strongly deformed for they still retain their original igneous texture (Plate II-8). The most abundant minerals are andesine, quartz, biotite and hornblende. Epidote-allanite and potash feldspar are fairly abundant. Chlorite, muscovite and magnetite are present as accessories. Epidote and allanite are always associated with one another and in most cases the grains contain allanite cores surrounded by epidote rims.

4. Rock Alteration and Mineralization

The abundance of red hematite alteration in the area has a particular significance in terms of uranium mineralization and this will be dealt with later. It is sufficient to say here that the hematite alteration is most prominent along fractured zones and in the biotite-rich lenses in the contact zone between the granodiorite and the metamorphic rocks. Minor silicification and chloritization were also noted in the area.

Geiger counter readings showed that the radioactivity in the area is most commonly associated with the biotite-rich lenses mentioned above. However, no uranium or thorium minerals except allanite were identified in thin section. The distribution of uranium in these rocks will also be discussed later. Some pyrite, in the form of pods and stringers, was also found in the biotite-rich lenses.

5. Structural Geology

The poor outcrop exposure and the difficulty of measuring the attitudes of the faint foliation in the granodiorite, which constitutes most of the rocks in the map-area, makes structural interpretation difficult. Where the schists and gneisses are exposed, the outcrops are small and lichen-coated so that the recognition of minor structures is difficult. The rocks are extensively recrystallized and thus metamorphic textures, which might provide clues to the deformation history of the area, have been obliterated.

In the south part of the area the attitudes of the gneissosity in the metasediments indicates a synform as shown on Map No. 1. This synform appears to close towards the southwest and this is probably plunging towards the northeast. No minor folds were observed in the metasedimentary rocks on either limb of the fold. The axial plane of the synform trends approximately northeast and appears to be curved. The curved axial plane is likely the result of superimposed folding. The granodiorite is faintly foliated in most places. In general this foliation is parallel to the gneissic banding in the metasediments and also indicates a synform in the south part of the map-area.

The whole area has probably gone through a minimum of four deformation phases. It usually takes at least two deformations to produce a compositional banding such as that present in the gneisses. This banding is itself folded into a synform and the axial plane of the synform was then warped by a fourth deformation. This interpretation is highly speculative, however, since the data available is not sufficient to properly establish the deformational history or link it with the metamorphic and igneous histories.

Several areas of faulting are shown on Map No. 1. These fault zones are characterized by topographic depressions, gouge and brecciation. The nature of the displacement on these faults is not known because no marker horizons could be traced across them. Joints are common in the area. The joint spacing is irregular but is in the order of two to three hundred feet. The joints appear to be continuous over several tens of feet or more, but their true continuity is not known due to the lack of exposure. In general, there appear to be two joint sets, one trending N 60-70°W and another trending roughly north. This is a similar pattern to that worked out by Power in the Isle aux Morts area to the south (Power, 1955).

Summary and Conclusions

Rocks of the Brinex Lake map-area are very similar to those described by other authors along the coast between Port aux Basques and Rose Blanche. The metamorphic rocks are comparable to the Cape Ray Cove schists and gneisses described by Phair (1948) and to the metamorphic rocks described by Power (1955) and Gale (1965). The Keepings gneiss and the Devonian (?) metamorphic rocks described by Cooper are also similar to these rocks. Similar granitic rocks occur in the coastal areas and they have associated with them numerous pegmatite and aplite dykes. Also, amphibolites similar to the biotite-hornblende schists in the present map-area have been reported in the coastal region.

While the age of the rocks of the Brinex Lake map-area has not been established, several general statements can be made about those rocks in southwestern Newfoundland which lie east of the Cabot Fault. The original assignment of a Precambrian age to these rocks by Murray and Howley appears more likely than some of the conclusions made since that time. In the author's opinion, Phair's assignment of a Paleozoic age to these rocks is based on insufficient evidence.

Cooper's assignment of a pre-Devonian (possible Precambrian) age to the Keepings gneiss appears to be feasible. However, his conclusion that the metamorphic rocks which he assigned to the Bay du Nord group are of Devonian age is doubtful. It is highly unlikely that plant-bearing arenaceous sediments grade laterally into kyanite grade metamorphics. It is more likely that these metamorphic rocks are pre-Devonian and are unconformably overlain by Devonian sediments. Given the similarity of the Keepings gneiss and the metamorphic rocks of the Bay du Nord group to the rocks of the Brinex Lake map-area, the author concludes that these rocks too are pre-Devonian and possibly Precambrian in age.

The major structures of the Brinex Lake map-area appear to trend northeast. This is parallel to the trend of the structures in the Devonian (?) metamorphic rocks in the La Poile - Cinq Cerf area and to that described by Power in the Isle aux Morts area.

In the author's opinion any firm conclusions about the age of structures, metamorphism, etc. in the Brinex Lake map-area would be unwise at this time.

CHAPTER III

GEOCHEMISTRY

Sample Collection and Preparation

The stream sediment samples used in this study were collected during the summer of 1968 by Brinex. A regional survey of all the streams in the company's mineral exploration concession in southwestern Newfoundland showed anomalously high uranium in the sediments of the northwest tributaries of Garia Brook. These results were followed up by more detailed sampling of the tributaries at approximately 500 foot intervals. The samples were then dried and sieved and the -80 mesh portion analyzed.

As a part of the follow-up program, soil samples were collected during the summer of 1969 under the supervision of the author. The samples were collected with a grub hoe at fifty to one hundred foot intervals along grid lines spaced two hundred feet apart. These samples were also dried, sieved and the -80 mesh portion analyzed.

Rock samples were collected by the author. They consist of specimens of different rock types from outcrops, grab samples from trenches and core samples from three packsack drill holes to depths of forty feet. These samples were crushed, pulverized and the -200 mesh portion analyzed.

All sample preparation and analyses were carried out at the Brinex Geochemical Laboratory near Springdale, Newfoundland.

Analytical Methods

Stream sediment and soil samples were analyzed for Cu, Pb, Zn, Ni, CO, Ag, Mo, U, and Ba. Rock samples were analyzed for these and Fe and Mn as well. Uranium determinations were carried out using fluorimetric methods while the remainder of the elements were determined by atomic absorption spectroscopy. The analytical procedures are outlined in Appendix No. 1.

Rock Chemistry

A total of sixty-three rock samples were analyzed; fifty were schists or gneisses and thirteen were granodiorite. The results are listed in Appendix No. 2. Table III-1 shows the ranges and averages of the elements analyzed for in each rock type as well as their crustal abundances in common rock types. When available, both crustal averages and ranges of each element are given but in most cases only one or the other of these is reported in the literature. Visual comparison of the data presented in Table III-1 leads to the following conclusions:

(1) The Cu and Zn contents of the metamorphic rocks and the granodiorite are similar.

(2) With the exception of Cu and Zn the minor and trace element contents of the metamorphic rocks are considerably higher than those of the granodiorite.

(3) The minor and trace element contents of the metamorphic rocks can in most cases be correlated with reported values in clay-rich sediments either shales, black shales or deep-sea clays, but not with values reported for sandstones.

(4) Average Co, Ni, and Fe contents in the granodiorite match averages reported for felsic igneous rocks; they also lie part way between the values for sandstone and shale so therefore they are similar to the values one would expect in an argillaceous sandstone.

TABLE III-1

	Rock Types	Cu ppm	Pb ppm	Zn ppm	Ni ppm	Co ppm	Ba ppm	Mn ppm	Fe %	U ppm	Ag ppm
Range	Metamorphic Rocks	10 to 1200	5 to 95	40 to 350	0 to 200	0 to 90	200 to 2300	100 to 5000	1.4 to 16.5	0 to 85	0.3 to 2.4
	Granodiorite	30 to 800	0 to 30	55 to 200	0 to 25	0 to 25	200 to 800	100 to 600	1.0 to 5.2	0 to 25.5	0.2 to 0.5
Average	Metamorphic Rocks	163	23	148	41	28	1163	950	6.7	9.6	1.25
	Granodiorite	143	13	148	9	4	455	371	2.6	2.6	0.3
Crustal Averages and Ranges*	Felsic Igneous Rocks	30	48	60	8	5	830	600	2.7	3.5	0.15
	Shales	45 (30-150)	20	95 (5-300)	68 (20-100)	19 (10-50)	(300-600)	850	4.7	3.7	0.7
	Sandstones	(10-40)	7 (10-40)	16 (5-20)	2 (2-10)	0.3 (1-10)	(100-500)	385	3.1	0.45	0.4
	Black Shales	(20-300)	(20-400)	(100-1000)	(20-300)	(5-50)	(450-700)			(2-300)	(5-50)
	Deep Sea Clays	250	80	165	225	74	6	6700	6.5	1.3	0.11

* Averages for felsic igneous rocks and ranges in brackets from Hawkes & Webb (1962); remainder from Turekian and Wedepohl (1961).

(5) Cu, Pb, Zn, Ba, Mn, U and Ag concentrations in the granodiorite are not similar to those reported for felsic igneous rocks, but they are, in a general way, similar to values reported for sedimentary rocks, especially values for shales and sandstones.

It could be postulated from the above evidence that the granodiorite was derived from granitization of sedimentary rocks. However, in the author's opinion the amount of data presented is not sufficient to make such a conclusion on geochemical grounds alone.

The uranium content of the rocks from the Brinex Lake map area ranges from 0-85 ppm. The samples showing the highest uranium content were collected from biotite-rich lenses, ranging from two inches to ten feet thick, in the metamorphic rocks and in the contact zone between the metamorphic rocks and the granodiorite. The biotite in these samples contains minute inclusions of apatite and zircon that are surrounded by pleochroic haloes. These pleochroic haloes are believed to be due to the presence of radioactive elements in the mineral lattices (Kerr, 1959). While pleochroic haloes are present in other rocks in the area, they generally are more abundant in the uranium rich rocks.

Uranium commonly occurs as a trace constituent in rock forming minerals and accessories in igneous and metamorphic rocks. Table III-2 summarizes the abundances of uranium in some of these minerals (Wedepohl et al., 1969).

All of the minerals in Table III-2 are present in either the granodiorite or the metamorphic rocks and it is reasonable to assume that any one or several of them could have contributed most of the uranium present

TABLE III-2

Minerals	U in ppm
Quartz	1.7 (0.1 -10)
Feldspar	2.7 (0.1-10)
Biotite	8.1 (1 - 60)
Muscovite	(2 - 8)
Allanite	200 (30-1000)
Apatite	65 (10-100)
Epidote	43 (20-200)
Garnet	(6 - 30)
Magnetite	(1 - 30)
Sphene	280 (10-700)
Zircon	1330 (100-6000)

in the rock samples. A material balance on several of the samples confirmed this assumption. The close association of the high uranium values with the biotite-rich lenses strongly suggests that the biotite and its minute inclusions of apatite and zircon contain most of the uranium in these samples. Examples of uranium concentrated in biotite in uraniferous gneisses and schists have been reported in other areas, such as the Charlebois Lake District of Saskatchewan (Mawdsley, 1958).

An attempt was made to study the distribution of radioactivity in thin sections of these samples by autoradiographic methods. However, the technique could not be perfected in the time available for this study.

It should be pointed out that rock sample No. 69-TR-68, which contained 46.5 ppm. U, was taken from a radioactive boulder. This boulder was, in fact, a gneissic rock similar to other gneisses in the map-area.

Geochemical Stream Sediment Survey

The stream sediment survey was carried out during the 1968 field season in two stages, a regional survey and follow-up detailed sampling of the Garia Brook tributary system. The data and statistical analysis presented here were provided by W. T. Meyer of Brinex. Figure III-1 shows the results of a rolling mean analysis of uranium values obtained from the regional survey superimposed on the drainage pattern. Figure III-2 shows the same results superimposed on the regional geology. Map No. 2 (in folder) shows the anomalous zones outlined by the detailed survey.

The high uranium areas in Figure III-2 show no consistent spatial relationship with geological units or structures. However, some of the high areas appear to lie over or close to granitic intrusives. The anomalous zone in the southeast corner of Figure III-2 was sampled in detail.

The results of the detailed stream sediment survey of the tributary systems of Garia Brook are shown on Map No. 2. Only the anomalies of the northernmost tributary system (the Brinex Lake map-area)

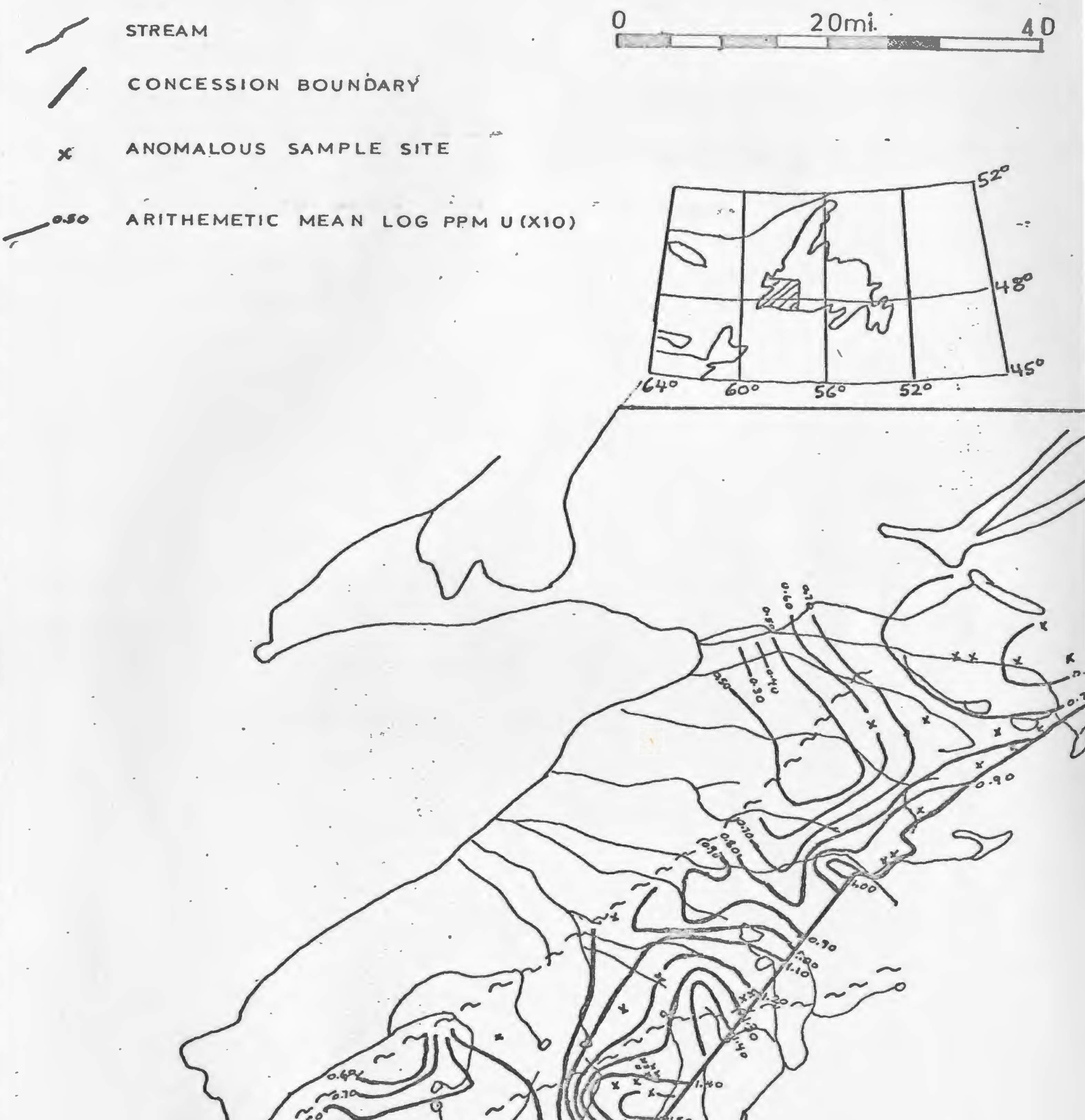

FIGURE III-1: ROLLING MEAN ANALYSIS OF REGIONAL STREAM SEDIMENT DATA AND DRAINAGE

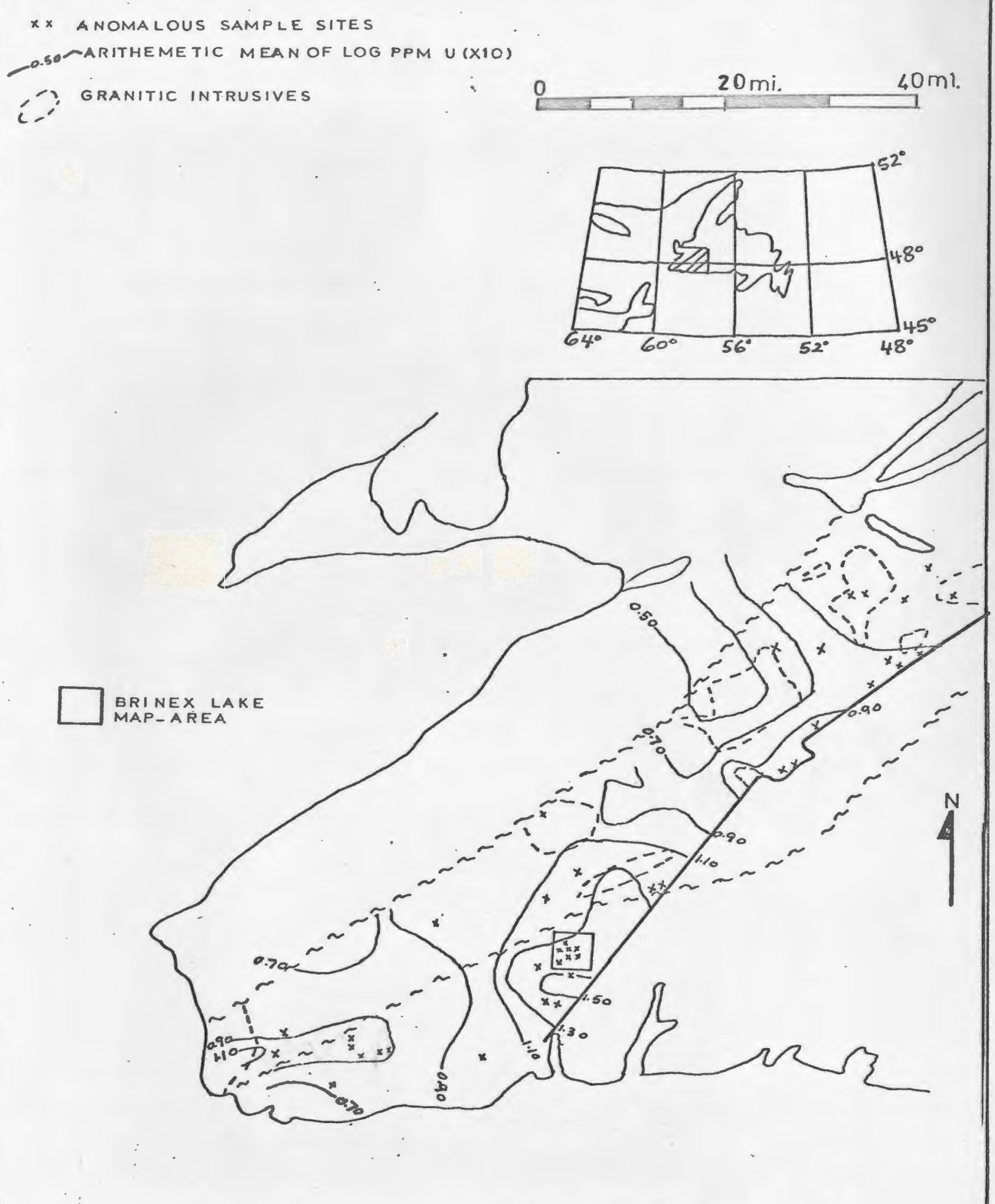

FIGURE III-2 : ROLLING MEAN ANALYSIS OF REGIONAL STREAM SEDIMENT DATA AND GEOLOGY concentrated along joints, possibly as leakage halos from uranium mineralization at depth. However, a comparison of Maps No. 1 and 2 shows that the uranium anomalies in the stream sediments are closely associated with areas of biotite-rich schists and gneisses in the Brinex Lake map-area. A brief reconnaissance trip to the anomalous zones south of the area showed that they are also associated with these types of rocks.

The high uranium values in the rocks in the Brinex Lake map-area are associated with biotite-rich lenses and the abundant inclusions of apatite and zircon in the biotite are believed to be the source of this uranium. These same minerals could be the source of uranium in the stream sediments. Unfortunately, analysis of the stream sediment samples was not possible because of the amount of samples remaining after chemical analysis was insufficient. The uranium in the stream sediments could also be present as metallo-organic complexes or absorbed onto clay minerals or sesquioxides. The possibility that uranium, which could give rise to such concentrations, is released to the surface waters from the biotite-rich zones by weathering is discussed later in relation to the soil anomalies.

Geochemical Soil Survey

Two soil sampling grids were laid out as shown on Map No. 1. The northern grid did not show any significant uranium anomalies and will not be discussed further. The south grid did show significant uranium anomalies and the results are presented both as a data map (Map No. 3, in folder) and an interpretation map (Map No. 4, in folder). The data map shows the relationship of soil analyses to geological boundaries, swamps and drainage patterns. The interpretation map consists of geochemical contours, or lines of equal concentrations. Since uranium is the only one of the eight elements determined that showed above background concentrations it will be the only element dealt with in this discussion. A visual comparison between the concentrations of Cu, Pb, Zn, Ni, Co, Ag and Mo in the soil shows no obvious correlation between these elements and uranium.

1. Physiography and Origin of the Soil Profile

The regional physiography of the map-area is that of a gently rolling upland with broad stream valleys and abundant swamps (Plate III-1). Locally some of the streams have cut steep sided gulleys down to 30 or 40 feet below the top of the stream bank (Plate III-2). In the area covered by the south soil grid variations in topographic relief are small as shown by the topographic contours on Map No. 1. The land slopes gently upward from east to west in the direction of the base line (N 70°E) from an elevation of 1250 feet at line 8E to 1500 feet at line 4W. The topographic variations consist of small depressions, which are generally swamps, and slightly higher outcrop areas.

The surface drainage in the area is approximately from west to east. The vegetation consists of dense scrub spruce on the valley slopes, grass in

PLATE III-1: Gently rolling hills in Brinex Lake map-area.

PLATE III-2: Steep-walled stream valley at eastern end of the southern soil grid.

the swampy areas and moss and lichen on the higher outcrop areas. Perched glacial erratics are common. There has been little or no glacial till deposited in the area and the present soil cover is believed to be residual in origin.

A residual origin for the soil is favoured because of its physical nature. It consists mostly of organic material with a thin layer of weathered parent material at the bottom. The thickness of the soil cover varies from 2-6 inches except in swampy areas where it is up to 2 feet thick in places. The soil profile is poorly developed and distinct horizons are difficult to distinguish. However, in general, the soil profile can be separated into three horizons that have transitional zones between them (Figure III-3). It was never possible to sample all three horizons shown in Figure III-3 at any given sample site and in most cases the sample consisted of a mixture of all three components of the profile. Where possible an attempt was made to collect mainly humus because this was the most persistent component of the soil profile.

2. The Distribution of Uranium in the Soil

Since there were no known deposits of uranium in the area, a proper orientation survey could not be carried out. However, an attempt was made at the beginning of the survey to sample different parts of the soil profile. Two samples were taken at each of 30 sampling stations, one from the top layers of intermixed humus and organic matter and another from the bottom layers of intermixed humus and parent material.

The uranium contents of these samples are shown in Table III-3. At sixteen of the sampling stations the sample from the top zone contained

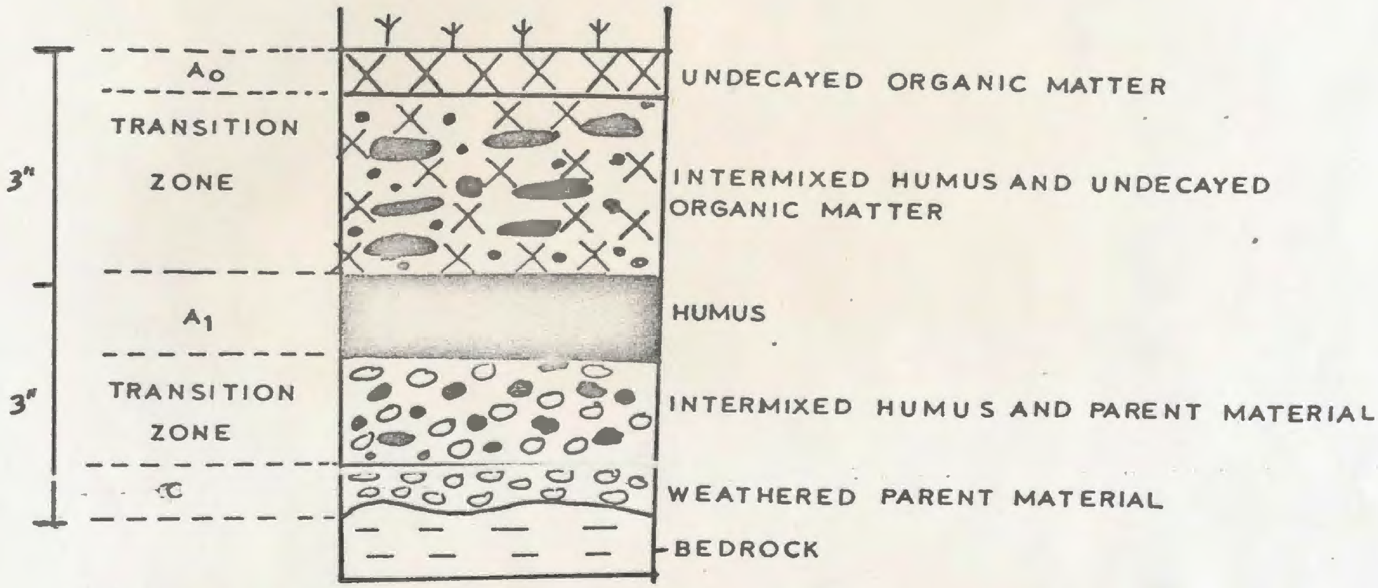

FIGURE III_3: GENERALIZED MODEL OF SOIL PROFILE

TABLE III-3: Uranium Distribution in Soil Profile

Sample Site Line	Station	Humus + Organic (U in ppm)	Humus + Parent (U in ppm)
Base Line	0+00	1.8	1.1
" "	1+00W	0.2	0.1
" "	2+00W	0.4	0.3
" "	4+00W	4.1	10.0
" "	5+00W	2.0	1.4
" "	7+00W	1.5	0.3
" "	9+00W	4.0	2.6
" "	10+00W	2.4	0.7
	13+00W	2.5	2.0
	18+00W	0.2	0.1
	19+00W	0.4	0.3
	20+00W	0.4	0.4
	21+00W	0.7	0.5
	23+00W	0.0	1.5
	24+00W	0.6	1.6
	26+00W	0.0	0.1
	27+00W	0.0	0.1
	29+00W	0.3	0.3
	30+00W	0.2	0.2
	31+00W	0.1	0.1
	32+00W	0.3	0.4
	34+00W	0.3	0.8
4+00W	0+50S	3.0	18.5
4+00W	4+00S	0.7	2.8
2+00W	4+00S	0.2	1.0
2+00W	2+00S	5.5	4.6
2+00W	1+00S	6.8	3.0
2+00W	0+50S	4.5	2.6
24+00W	0+50S	64.3	0.8
0+00	9+00N	15.2	11.3

a higher concentration of uranium than the lower zone, while at ten stations this situation was reversed, and at four stations both samples contained equal amounts. This indicates that the uranium is randomly distributed throughout the soil profile.

3. Background and Threshold Calculations

The statistical distribution of uranium in the soil samples is shown by the histogram plots in Figure III-4a & b. Figure III-4a shows the frequency distribution of ninety per cent of the data plotted as the frequency of occurrence of the values within intervals of 0.1 ppm, on normal graph paper. The values less than 2 ppm approach a normal distribution but are highly skewed to the left. Figure III-4b shows the frequency distribution of eighty per cent of the data plotted as the frequency of occurrence within intervals of log 0.2 ppm on semi-logarithmic graph paper. In this case the values less than 2 ppm show a fairly symmetrical distribution about a geometric mean suggesting that the data is lognormally distributed.

Applying the method suggested by Hawkes and Webb (1962) for calculating the threshold, one would calculate the mean and standard deviation of the data and take the threshold, or upper limit of background, to be the mean plus twice the standard deviation. In this case the arithmetic mean of the whole data is 2.1 ppm and the standard deviation is 4.9, giving a threshold value of 11.9 ppm. Figure III-4a shows clearly that the data is not distributed symmetrically about the arithmetic mean and therefore the above threshold value is not statistically valid. Figure III-4b, on the other hand, shows that the logarithms of the uranium values

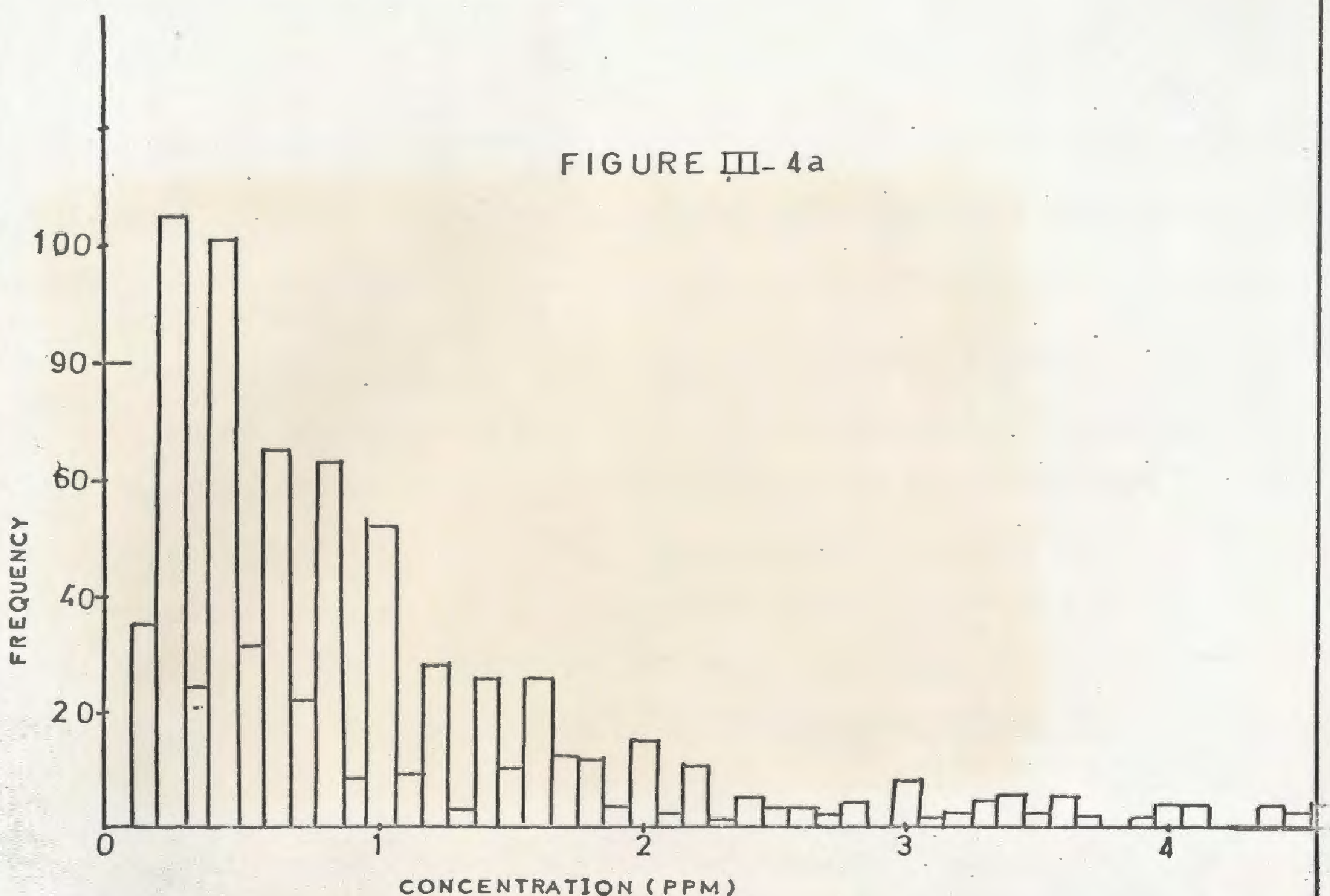
FIGURE III-4a
100
90
60
40
20
0
1
2
3
4
FREQUENCY
CONCENTRATION (PPM)

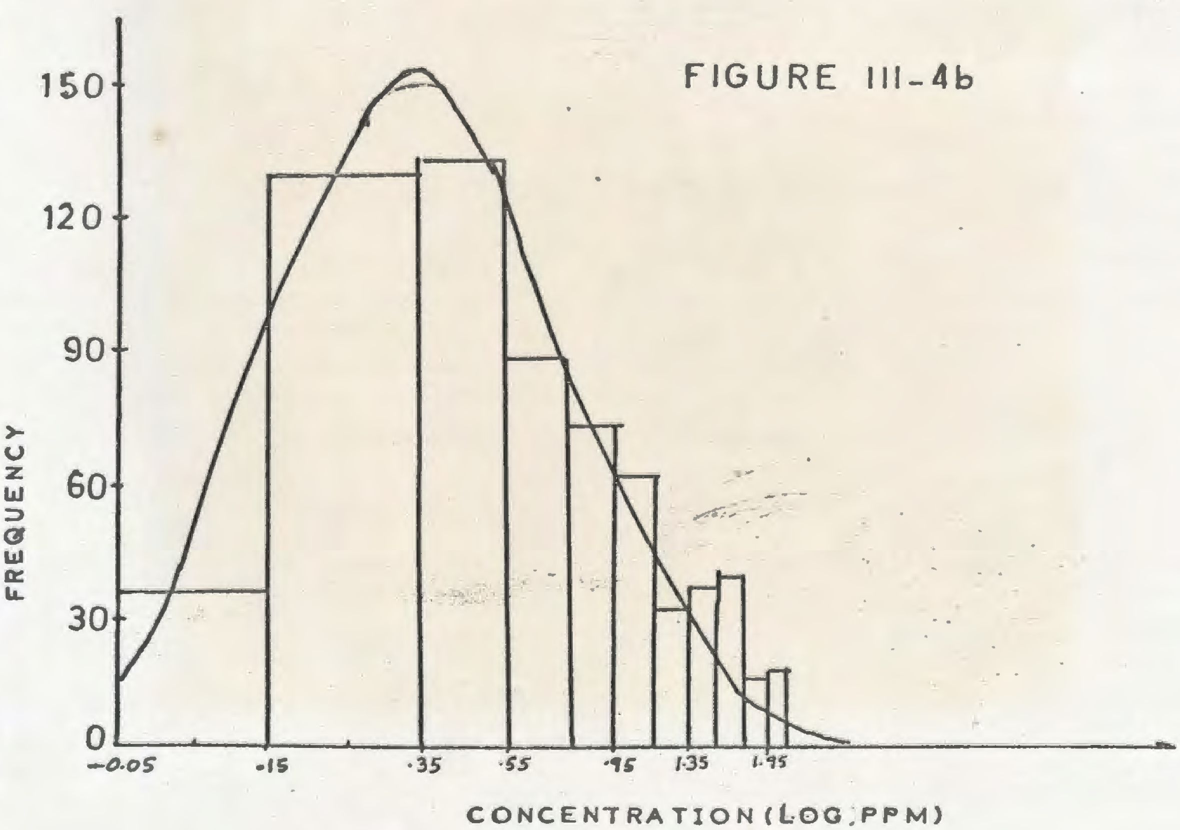
FIGURE III-4b
150
120
90
60
30
0
-0.05
·15
·35
·55
·95
1·35
1·95
FREQUENCY
CONCENTRATION (LOG.PPM)

tend to be symmetrically distributed about a geometric mean of 0.35 ppm. The standard deviation for this population would then be 0.2, giving a threshold value of 0.75 ppm.

The above distributions include the effects of laboratory and field sampling errors and these may be of considerable relative magnitude in the lower concentration range. Therefore, there is little point in applying rigid statistical laws to this data in order to establish background and threshold values. Based on a visual survey of the data, as well as consideration of the statistical treatment presented above, the author has decided to group the data in the following categories:

0 - 1 ppm	background
1 - 2 ppm	possibly anomalous
2 - 5 ppm	probably anomalous
5 - 10 ppm	anomalous
10 ppm	highly anomalous

Maps No. 3 and 4 show the relationships of these different zones to drainage patterns and bedrock geology.

4. Relationship of Uranium Anomalies in the Soil to Topography and Geology

The interpretation map (Map No. 4) shows that the anomalous zones are generally elongated in a westerly or southwesterly direction. As stated earlier the land slopes gently upward in this direction and the drainage channels are also parallel to this direction. This suggests that the drainage of surface waters in the area is the controlling factor in the dispersion of uranium in the soil. The soil anomalies can be correlated with the schists and gneisses in many cases but they are generally elongated in a direction that is at an angle of 30° to the strike of these rocks.

Hawkes and Webb (1962) noted that true groundwater tables may not exist in areas of crystalline or metamorphic rocks which have a thin soil cover. They further suggested that surface waters flowing along channels in the surface of the bedrock are largely responsible for the secondary dispersion of elements in such areas. Thus it seems feasible that in this area the uranium anomalies in the soil are related to the secondary dispersion of uranium by surface waters.

Assuming that surface waters are the medium of dispersion, one must now attempt to explain the origin of the uranium present in the surface waters. By comparing Maps No.3 and 4, it can be seen that the uranium anomalies in the soil generally lie either directly above the metamorphic rocks or above the contact zone between them and the granodiorite. The above correlation plus the fact that biotite-rich lenses, some of which are known to contain anomalous amounts of uranium, occur abundantly within the metamorphics and in the contact zone strongly suggests that the uraniferous biotite lenses are the source of the uranium in the soil. The biotite in these lenses commonly contains radioactive inclusions, and it has been suggested that uranium can be released from such inclusions by weathering (Roubault and Coppens, 1958). The weathering process responsible for this migration of uranium was outlined as follows:

1. Oxidation of biotite and other Fe-bearing minerals and the appearance of Fe in the Fe^{++} form;

2. Oxidation and destruction of radioactive inclusions with the liberation of uranium;

3. Reduction of U^{+6} and U^{+4} by Fe^{++} and adsorption of this

uranium by oxides of Fe;

4. Uranium remains temporarily in the altered minerals and later is released to surface waters.

In the present area it was noted that the biotite-rich lenses were highly weathered and hematitic staining in these lenses is very common. It appears that the surface waters could easily seep down between the mica plates and remove the uranium tied up in the biotite or in radioactive inclusions by the process outlined above. The depth of weathering is only several inches and therefore the uranium bearing surface waters would be in close proximity to the soil above, into which they are likely to rise periodically by capillary action and during winter soil freezing. In the soils the uranium is probably removed from the waters by the organic phases. The humus content of the soil is quite high. A direct correlation between the uranium and humus contents of soils has been well established in other areas (Szalay, 1958; Armonds, 1967). Szalay and Armonds concluded that the enrichment coefficient for uranium in humus was 9,000 and 10,000 respectively.

The present author has concluded that the source of the uranium anomalies in the soils are the biotite-rich lenses. Soil anomalies are epigenetic,hydromorphic,essentially superjacent,although slightly offset and elongated due to surface water flow. In the rocks uranium was only detected in biotite lenses and it is not present in commercial quantities in these lenses. Therefore the soil anomalies do not reflect uranium mineralization of economic significance.

CHAPTER IV

URANIUM PROSPECTING IN SOUTHWESTERN NEWFOUNDLAND

Introduction

Geochemical uranium anomalies in stream sediments, soils and rocks of the Brinex Lake map-area have been discussed in detail and similar anomalies in the stream sediments and rocks farther south along the Garia Brook tributary system have been briefly compared with them. An attempt will be made here to expand the discussion to include a synthesis of all the information available on uranium geochemical anomalies and known radioactive occurrences in southwestern Newfoundland and to thereby suggest geological environments within this area favourable for the formation of uranium deposits. In order to evaluate the significance of this information in terms of the probability of finding uranium deposits of economic importance, one must first consider the types of uranium deposits found in other parts of the world and the geologic characteristics of uranium metallogenic provinces. A number of uranium occurrences have been reported in eastern Canada and the possibility of this region being considered a uranium province will be discussed.

A genetic classification of Canadian radioactive deposits has been provided by Lang et al. (1962) and is shown in Table IV-1. This classification cannot be applied rigidly because some deposits are borderline cases that show characteristics of several of the categories outlined. However, it is the most useful classification proposed to date and it is presented here to establish the terminology that will be used in this discussion.

Table IV-1
Genetic Classification of Canadian Radioactive Deposits

	Types		Characteristic Elements	Characteristic Uraniferous Minerals	Other Characteristic Minerals
IGNEOUS AND RELATED TYPES	Granite, Syenite (including pegmatitic facies)		Th U Zr Si (Ce Fe P F)	Uraninite, uranothorite, thorite, zircon, monazite	Magnetite, sphene, allanite, fluorite
	Pegmatite		U Th Nb Ta (Zr Si Ce P Fe F Ti Mo C)	Uraninite, pyrochlore, betafite, euxenite, samarskite, thucholite, brannerite	Molybdenite, biotite, magnetite, allanite
	Metasomatic	General	U Th Ce P Si (F Mo Fe S)	Uraninite, thorianite, thorite, monazite, rare earth silicates	Biotite, apatite, pyrite, fluorite, molybdenite, magnetite
		Fenites	U Th Nb (Ta Ce P F Ti Fe S)	Pyrochlore, betafite, perovskite	Calcite, soda pyroxene and amphibole, apatite, biotite, magnetite
	Hydrothermal	With simple mineral associations	U C Fe	Pitchblende, 'thucholite'	Hematite, quartz, calcite
		With complex mineral associations	U C Fe (Cu Co Pb Se V Ni As Au Pt)	Pitchblende, 'thucholite'	Hematite, quartz, calcite, chlorite, chalcopyrite, galena, pyrite, arsenides, selenides, nolanite
SEDIMENTARY	Placer		Th U Ce P Zr Fe (Nb Ta Ti W Sn)	Monazite, uraninite, pyrochlore, zircon	Magnetite, garnet, ilmenite, pyrite, etc.
	Conglomerate		U Th Ti Ce P Fe (Cr Zr C)	Brannerite, uraninite, monazite, uranothorite, zircon	Pyrite, anatase, chromite, traces of common sulphides, hydrocarbon, etc.
	Sandstone		U Ca P	Autunite, phosphuranylite	Hematite
	Dolomite		Th U Fe	Monazite	Hematite, zircon
	Phosphate rock[1]		U Ca P C	Unknown	Collophanite, bitumen
	Carbonaceous		U C H	Unknown	Bitumen, lignite
SUPERGENE	Cappings		Fe U Si Se V As S Al Mn (Pb Cu Co Ni)	Uranophane, liebigite, zippeite, gummite, etc.	Limonite, erythrite, malachite, etc.
	Formed by percolating water		U Si S	Uranophane, secondary (?) pitchblende, 'thucholite' (?)	Barite, gypsum

Types now in production are underlined.

[1] Only known examples in amounts below 0.05% U_3O_8 or ThO_2.

After Lang et al. (1962).

Uranium Metallogenic Provinces

Uranium deposits, like those of other metals, tend to be most abundant within large ill-defined areas known as metallogenic provinces. Klepper and Wyant (1956) summarized world-wide data on uranium deposits and defined a uranium province as "a broad and generally indefinitely bounded area in which uranium deposits and uranium-rich rocks are relatively abundant". They listed the following provinces: the broad belt in and adjacent to the Rocky Mountains, from New Mexico and Arizona to the Dakotas and Montana; the western and southern part of the Canadian Shield; the northeastern part of the South African shield; parts of the Australian shield; and the Erzgebirge and vicinity in central Europe.

Lang et al. (1962) concluded that uranium occurrences in the Canadian Shield area are sufficiently segregated to suggest that distinct areas are characterized by vein, conglomeratic or pegmatite deposits, and that these areas correspond to a large degree with geological divisions or sub-divisions of the Shield. They further concluded that the pattern in the Shield suggests that pegmatite occurrences are found mainly in the deeply eroded remnants of primary mountains, such as the Grenville Province, and vein and conglomeratic occurrences mainly in belts of secondary orogen such as the Timiskaming sub-province. The significance of these patterns in terms of uranium prospecting in southwestern Newfoundland will be discussed later.

In applying the concept of uranium provinces to prospecting, Klepper and Wyant (1956) considered that the only positive indicator of a province is the presence of a variety of types of abnormal uranium concentrations, although the presence of a single epigenetic deposit is sufficient to suggest that a province may exist. They further suggested that if an area is known or suspected to be a province every possible setting in which uranium might be localized should be investigated. They listed the following geological settings as favourable for the location of uranium deposits:

1. Acidic and alkalic igneous rocks and mineralized structures in the vicinity of such rocks
2. Placers or sites where placers might occur
3. Sequences of continental sandstone and shale
4. Lignite and coal
5. Metamorphosed black shales
6. Conglomerate bearing sequences deposited on a crystalline basement.

They concluded that if abnormally radioactive igneous rocks and a few vein deposits are known to occur in an orogenic belt one might expect to find more vein deposits in favourable structural settings and also placer deposits. Furthermore, in areas of erosional debris within and marginal to this belt one should look for deposits of uraniferous sandstone, uraniferous lignite or coal, uraniferous petroleum residues and perhaps placer deposits. They suggested that in ancient shield regions vein deposits and uraniferous rocks are most likely to occur in strongly deformed and metamorphosed areas while uraniferous conglomerates may occur in less strongly deformed rocks on the periphery of these areas. In some areas that are geologically similar to known uranium provinces no important deposits have been found to date; for example, the Appalachian region and the Brazilian Shield.

Uranium Occurrences in Eastern Canada

A number of small uranium occurrences have been reported in the Canadian Appalachian region (Gross, 1957; Lang et al. 1962). Four small occurrences have been reported on the north shore of the Gulf of St. Lawrence in the Grenville Province (Baldwin, 1970). Figure IV-1 shows their distribution and also shows areas of uranium geochemical anomalies in southwestern Newfoundland. None of the deposits in eastern Canada have been mined to date.

Gross (1957) noted that the uranium occurrences in Gaspé, New Brunswick and Nova Scotia are of particular geological interest because they represent many distinctly different types of deposits; and that some of these types are mined in other parts of the world. He listed the following types of known occurrences in the region:

1. Pegmatite dykes
2. High temperature quartz veins and greisen in granite
3. Veins containing galena and pitchblende
4. Radioactive minerals associated with purple fluorite in shear and breccia zones and in rhyolite and volcanic breccia
5. Uranium bearing hydrocarbon or mixtures of uranium oxides and hydrocarbons in small nodules or veinlets in felsite dykes
6. Radioactive hydrocarbon in fault zones
7. Radioactive minerals associated with fossil carbon, chalcocite, pyrite, hematite or malachite in sedimentary rocks.

Baldwin (1970) noted that the north shore of the Gulf of St. Lawrence is a uranium-thorium metallogenic province. He described three areas of pegmatitic occurrences and another area of more complex mineralogy containing uranium mineralization associated with migmatites, pegmatites, granite and gneisses.

On the island of Newfoundland four uranium occurrences have been reported. Of these, two are known to occur in pegmatite dykes; one reported by Heyl and Ronan (1954) and the other by Gale (1965). These are shown as occurrences 1 and 2 respectively in Figure IV-1. The remaining two were reported by Lang et al. (1962) but no details were given as to the type of occurrence.

Because of the variety of deposits present, eastern Canada can be considered a uranium province in which no deposits of economic value have yet been found. Lang et al. (1962) saw fit to designate the Appalachian region as a favourable area for uranium prospecting. Klepper and Wyant (1956) noted that the main geologic features of the Appalachian region are similar in many respects to those of the uranium-rich Erzgebirge and Rocky Mountain region. They stated that "each of these areas is a strongly deformed geosynclinal belt, intruded by granitic plutons of various types; each is flanked and in part covered by erosional debris from orogenic mountains". Thus the Canadian Appalachian region can be considered a favourable area for the localization of uranium deposits. Southwestern Newfoundland is part of the Appalachian region and also contains some rocks which are similar to the Grenville rocks on the north shore of the Gulf of St. Lawrence.

Favourable Geological Environments for Uranium Prospecting in Southwestern Newfoundland

As stated earlier, the Long Range Mountains in southwestern Newfoundland can be divided into two belts of igneous and metamorphic rocks separated by the Cape Ray Fault (Figure II-1). The central belt is in fault contact with the Carboniferous sedimentary rocks to the northwest and the southeast belt is overlain by Devonian sedimentary and volcanic rocks to the east.

The metamorphic rocks of the Long Range Mountains may be of Pre-Cambrian age and therefore represent deeply eroded remnants of primary mountains. Thus one might expect to find pegmatitic uranium occurrences similar to those found in the Grenville Province (Lang 1962). Occurrences 1 and 2 in Figure IV-1 are examples of known pegmatite occurrences in southwestern Newfoundland. One might also expect to find vein type deposits in favourable structural settings such as the Cape Ray fault zone.

In the less deformed sedimentary and volcanic rocks of southwestern Newfoundland, namely the Carboniferous strata in the northwest and the Devonian rocks in the southeast, there are a number of favourable geological settings for the localization of uranium. In the Carboniferous strata one might expect to find uraniferous conglomerates, sandstones, or coal beds. Two uranium occurrences have been reported in the Carboniferous rocks but the type of occurrence is not known (Figure X, Nos. 3 & 4). In the Devonian rocks in the southeast Cooper (1954) has described slightly metamorphosed black shale containing abundant carbonaceous material, quartzite, and conglomerate in the Bay du Nord group, and a basal conglomerate unit deposited unconformably on a crystalline basement in the La Poile group. All of these types of rocks are considered favourable geological settings for the location of uranium deposits (Klepper and Wyant, 1956).

The reported pegmatitic occurrences (Figure IV-1, No. 1) in the Pre-Cambrian Indian Head Range intrusive complex might have counterparts in similar Pre-Cambrian rocks elsewhere in western and northwestern Newfoundland. One might also expect to find deposits of sedimentary type in the peripheral less strongly deformed sedimentary rocks.

From the above evidence it is obvious that many favourable areas for uranium prospecting exist in southwestern Newfoundland. Very little uranium exploration has been carried out in this area and what has been done has produced encouraging results in terms of the possible existence of a uranium province. Recommendations for future exploration and research will be presented in the next chapter.

CHAPTER V

SUMMARY AND CONCLUSIONS

The Brinex Lake map-area lies in a regional belt of unseparated granites, schists, gneisses and migmatites. Some of the rocks in this belt are possibly of pre-Cambrian age. The major rock types in the map-area are granodiorite, schist and gneiss. These rocks are intruded by numerous small pegmatite dykes and some aplite and basic dykes.

The origin of the granodiorite has not been firmly established but metasomatic origin is favoured. The schist and gneiss are believed to have been derived from pelitic sediments with minor intercalated basic volcanics. The pegmatite and aplite dykes are obviously of igneous origin. A proper evaluation of the structural geology of the map-area was not possible due to poor exposure. However, the information available suggests that the deformation has been polyphase.

Rock samples were analyzed for the following elements: Cu, Pb, Zn, Ni, Co, Ba, Mn, Fe, U and Ag. The minor and trace element contents of the granodiorite suggests that it was derived from sedimentary rocks by granitization. The uranium content of the rocks ranges from 0-85 ppm. This uranium is believed to be contained mostly in radioactive inclusions in biotite.

Uranium geochemical anomalies in stream sediments and soils in the map-area are closely associated with areas containing abundant biotite-rich lenses. The soils in the area are believed to be residual. The uranium anomalies in the soil are epigenetic, hydromorphic and essentially superjacent. Uranium was not present in commercial quantities in the rocks and therefore the soil anomalies do not reflect uranium mineralization of economic significance.

The geology of southwestern Newfoundland is similar to that in other parts of eastern Canada where a number of small uranium deposits have been reported. Comparisons between the geologic features of eastern Canada and those of known uranium metallogenic provinces suggests that a uranium province may exist in this region. It has been established that the north shore of the Gulf of St. Lawrence is a uranium-thorium province. Therefore, the author has concluded that southwestern Newfoundland is a favourable area for further uranium prospecting. Many geologically favourable environments for the accumulation of uranium deposits exist in southwestern Newfoundland and each of these areas should be thoroughly investigated using the most modern geochemical and geophysical techniques.

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APPENDIX NO. 1 - ANALYTICAL PROCEDURES

Uranium Determination - Soil and Silt Samples

1. Weigh a 0.5 gm. sample into a test tube.
2. Digest in sand bath with 2 ml. of 1:1 $HNO_3:H_2O$.
3. Remove, cool, add 5 ml. $Al(NO_3)_3\ 9H_2O$ plus 5 ml. ethyl acetate.
4. Shake in shaker for 20 mins.
5. Remove and let settle for 5 mins.
6. Wash platinum covers with H_2O. Add 1 ml. of 1% NaF solution & evaporate to dryness.
7. Add 1 ml. of sample and evaporate to dryness.
8. Remove from pan and add 2 gm. of flux.
9. Place dishes in muffle furnace & fuse for 10 mins.
10. Let cool for 10 mins. Remove & read on instrument.

CALCULATIONS:

$$\frac{\text{Sample-Blank}}{\text{Standard-Blank}} \quad X \quad \text{Factor} \quad = \quad \text{U ppm}$$

Sample: 0.5 gm. 5 ml. acetate 1 ml. = 0.1 gm.

Standard: 1 ml. 10 /ml U 5 ml. acetate = 2 /ml. U
0.2 ml. = 0.4 /ml.

FACTOR: $\frac{0.4}{0.1} = 4$ ppm

INSTRUMENT OPERATION:

1. Set back ground to 0.
2. Set blank to 10.
3. Take Standard reading and record.
4. Read sample and record.

CALCULATIONS:

$$\frac{\text{Sample - Blank}}{\text{Standard - Blank}} \quad X \quad \text{Factor} \quad X\ 1.181 \quad = \quad \%\ U_3O_8$$

Factor (Sample): 1 gm. 100 ml. .01 gm/ml 5ml. acetate = .002 gm/ml 0.2 ml. = .0004 gm/ml.

(Standard): 1 ml. 10 /ml. U 5 ml. acetate = 2 /ml U 0.2 ml. = 0.4 /ml.

$$* \text{ Factor} = \frac{0.4}{0.0004} = 1000 \text{ ppm} = 0.1\%$$

DIGESTION METHOD FOR

Cu Pb Zn Ni Co Ba Mn Fe Ag Mo

1. Weigh a 1 gram sample into a 250 ml. beaker. Add 5 ml. H_2O and 10 ml. HCl plus 2 to 3 ml. HF (where necessary). Boil for 3 mins.

2. Remove from hot-plate and add 10 ml. HNO_3 plus 4 ml. $HClO_4$. Digest on hot-plate until digestion of all dark material is complete.

3. Remove from plate, cool, and pour contents into a 100 ml. volumetric flask. Stopper and shake well.

4. Let solids settle and run for the various elements on the AA instrument.

APPENDIX NO. 2 - RESULTS OF ROCK ANALYSES (ppm)

Sample No.	Cu	Pb	Zn	Ni	Co	Ba	Mn	% Fe	Ag	Mo	U
69-TR-3	50	10	110	45	20	1000	700	6.0	1.2	1	0.2
TR-4	400	95	95	25	20	1250	900	9.0	2.0	4	0.2
TR-6	100	10	90	10	ND	200	600	3.5		ND	ND
-8	275	10	120	30	30	1700	850	10.0	1.5	3	0.5
9	170	40	350	80	60	1400	5000	14.5		ND	ND
12	130	20	150	10	ND	500	500	3.4		ND	ND
13	230	15	115	20	18	1900	1350	11.0	2.0	0	0.3
14	175	15	120	40	30	2000	1800	10.5	1.8	6	0.7
16	105	5	80	35	20	1500	600	16.5	1.0	8	0.8
18	95	5	120	40	25	1200	1000	7.5	1.2	1	1.0
20	80	10	105	50	35	1400	2200	9.0	1.5	1	0.9
22	90	10	190	30	ND	300	600	3.7		ND	ND
24	90	10	160	10	ND	600	500	3.7		ND	ND
25	120	10	145	30	25	1800	1200	11.0	1.7	90	1.0
26	95	30	155	90	40				0.6	ND	0.7
27	92	25	70	20	20				0.6	ND	0.2
28	20	35	255	110	45				0.5	ND	1.0
30	35	30	200	70	40				1.4	ND	0.7
31	120	40	260	60	65				1.0	ND	0.8
35	100	20	60	10	15				1.2	ND	0.2
37	120	45	350	200	90				1.8	ND	2.8
38	1200	25	52	20	25				1.0	38	0.2
39	85	35	95	20	15				0.8	ND	0.6
40	375	45	240	90	70				2.4	ND	0.4
41	125	25	190	30	30				1.4	ND	0.2
43	450	25	240	60	40				1.4	ND	0.6
44	72	20	350	90	50				1.2	ND	0.4
45	35	15	260	100	65				0.7	ND	0.3
46	40	20	280	10	40	900	1400	8.0		ND	ND
47	140	60	55	20	15				1.0	ND	0.2
48	30	230	30	100	40				1.7	ND	0.8

Sample No.	Cu	Pb	Zn	Ni	Co	Ba	Mn	% Fe	Ag	Mo	U
69-TR-49	78	145	45	35	25				1.2	ND	0.4
TR-53	160	52	10	20	15		400	4.5	0.3	6	ND
54	210	60	8	10	15		480	3.8	0.3	0	ND
56	140	120	18	45	30		3500	12.0	1.5	3	ND
57	500	190	20	80	40		800	15.0	1.6	5	ND
58											34.0
63	60	180	10	ND	ND	600	300	1.4		ND	ND
64	90	140	30	ND	ND	600	100	1.5		ND	
65	30	160	20	90	50	1800	600	8.0		ND	ND
66											34.0
67	10	70	20	20	20	800	500	3.4		ND	25.5
68	130	100	20	40	20	1600	600	4.2		ND	46.5
69	470	160	20	50	40	2100	1000	9.5		ND	46.5
70A	80	50	20	ND	10	1000	300	2.9		ND	46.5
70B	40	90	30	10	20	1000	400	3.9		ND	85.0
71	240	130	20	40	30	2300	1200	7.5		ND	8.5
72	40	40	20	ND	ND	800	100	1.5		ND	25.5
73	240	50	10	10	10	1000	300	3.0		ND	25.5
74	80	50	10	20	10	900	300	3.2		ND	25.5
75	130	50	20	10	10	600	300	3.0		ND	25.5
-103											25.5
TR-5	130	10	55	25	25	700	450	5.2	0.5	1	1.5
TR-50	40	20	60	15	10				0.2	ND	0.5
52	800	10	65	10	18		500	4.5	0.3	ND	8.5
7	50	10	150	ND	ND	300	200	1.0		ND	ND
10	50	30	160	ND	ND	300	200	1.9		ND	ND
11	60	20	180	10	ND	600	500	2.8		ND	ND
17	40	20	170	ND	ND	200	500	2.4		ND	ND
29	70	10	190	10	ND	700	600	3.3		ND	ND
32	120	10	140	10	ND	300	100	1.5		ND	ND
33	60	10	190	20	ND	200	500	2.3		ND	ND
34	290	ND	200	20	ND	800	500	2.9		ND	ND
36	120	10	170	ND	ND	700	200	2.0		ND	ND
42	30	10	160	ND	ND	200	200	1.4		ND	ND

Appendix No. 2 Continued --

In the above table of rock analyses the samples can be classified as follows:

Biotite Schist

Samples No. 3, 4, 8, 13, 14, 16, 18, 20, 25, 26, 27, 28, 35, 37, 40, 43, 48, 49, 58, 65, 66, 67, 69, 70A, 71, 72, 73, 74, 75.

Gneiss

Samples No. 6, 9, 12, 24, 30, 31, 38, 39, 41, 44, 45, 47, 53, 54, 56, 57, 63, 70B, 103.

Biotite-hornblende schist

Samples No. 22 and 46.

Granodiorite

Samples No. 5, 7, 11, 17, 29, 33, 34, 36, 42, 50, 52, 59.

Pegmatite

Samples No. 10 and 32.

Aplite

Sample No. 64.