GEOLOGICAL SURVEY OF CANADA

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GEOLOGICAL, GEOCHEMICAL AND GEOPHYSICAL FAVOURABILITIES FOR POLYMETALLIC VEIN-TYPE URANIUM MINERALIZATION IN THE LONG LAKE AREA AND IN THE MIRAMICHI ANTICLINORIUM, NEW BRUNSWICK

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Energy, Mines and
Resources Canada

Énergie, Mines et
Ressources Canada

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ABSTRACT

Polymetallic vein-type U deposits of the Long Lake area occur in hydrothermally altered highly brecciated, northwesterly-trending fractures, cross-cutting post-Acadian granites of the Lower Devonian North Pole Pluton. The U deposits are commonly formed in chalcedony (jasperoid) veins and associated with economically significant amounts of other elements such as Cu, Pb, Zn, Mo, W, Sn, Ag and Au. The centre of the mineralization occurs in an area of the pluton that is associated with a coincident high airborne radiometric eU, eTh and K anomalies and a strong negative (less than-48 mgals) Bouguer gravity anomaly.

The high-level, post-tectonic, peraluminous North Pole Pluton that hosts the deposits was emplaced discordantly, in a seismically active area of the Miramichi Anticlinorium metallogenic domain. Petrologically, the North Pole Pluton consists of three, probably comagmatic phases; biotite granite (older phase); biotite-muscovite granite and quartz-feldspar porphyry granite (younger phase). The U is most probably derived predominantly from the two youngest phases of the pluton.

Existing petrochemical data for the North Pole Pluton suggest that it is an 'S-type' and to a lesser extent an 'A-type' granite. It has geological, geochemical and geophysical characteristics which are similar to those S-type and A-type granites that host economic U-Sn-W-Mo deposits elsewhere, such as the Hercynian granites of Massif Central of France, Hercynian granites of

southwest England and the Millet Brook granites (South Mountain Batholith) of Nova Scotia.

A conceptual geological model is proposed to describe the polymetallic vein-type U deposits in the North Pole Pluton. The model illustrates that U and associated metals are deposited as a result of interaction of hypogene and supergene processes.

Certain geological characteristics favourable for vein-type U deposits, and established for the North Pole Pluton, were used to identify other favourable granitic plutons in the Miramichi Anticlinorium. Three Sn-Mo-W-bearing granitic plutons (Burnt Hill, Trout Brook and Dungarvon) were recognized as the most favourable plutons in the Miramichi Anticlinorium for vein-type U mineralization. These plutons are highly radioactive and coincide with strong negative gravity anomalies.

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SECTION ONE

INTRODUCTION

1.1.0 Scope and Objectives of the Project

In order to evaluate the uranium potential in the Province of New Brunswick several reconnaissance and detailed geochemical and geophysical surveys were conducted during the last ten years by exploration companies. Results of the surveys indicate, in general, that the geological environment of the Miramichi Anticlinorium is suitable for polymetallic vein-type uranium mineralization and is typical of certain environments hosting economic uranium deposits elsewhere.

The available data suggest that the Long Lake area is the most favourable site within the Miramichi metallogenic domain for polymetallic vein-type uranium deposits. Here, uranium and associated metals (Cu, Pb, Zn, Mo, Sn, W, Ag, Sb and Au) occur as fracture-filling veins trending northwesterly and intersecting the post-Acadian Lower Devonian granites of the North Pole Pluton. For this reason and because of the abundance of the geological, geochemical and geophysical data available for Long Lake area relative to other areas in the Anticlinorium, the Long Lake area was selected as a pilot site for detailed investigation of polymetallic uranium deposits in the province.

The objectives of this project are the following:

1. to review and integrate geological, geochemical and geophysical data over the Long Lake area in order to

delineate favourable areas and hence potential sources for uranium and associated metals,

2. to examine the relationships between uranium and associated metals in different geological environments and lithological units in order to define pathfinder elements which aid in uranium exploration in the Miramichi Anticlinorium,

3. to examine the relationships of uranium and associated metals in the host granites of the Lower Devonian North Pole Pluton to tectonic setting, magmatic evolution and post-magmatic processes,

4. to propose a geological model which embodies the different geological processes leading to uranium and associated metals mineralization in the Long Lake area,

5. to define favourable geological, geochemical and geophysical signatures for polymetallic vein-type uranium deposits that maybe used to search for similar type of deposits elsewhere in the Miramichi Anticlinorium.

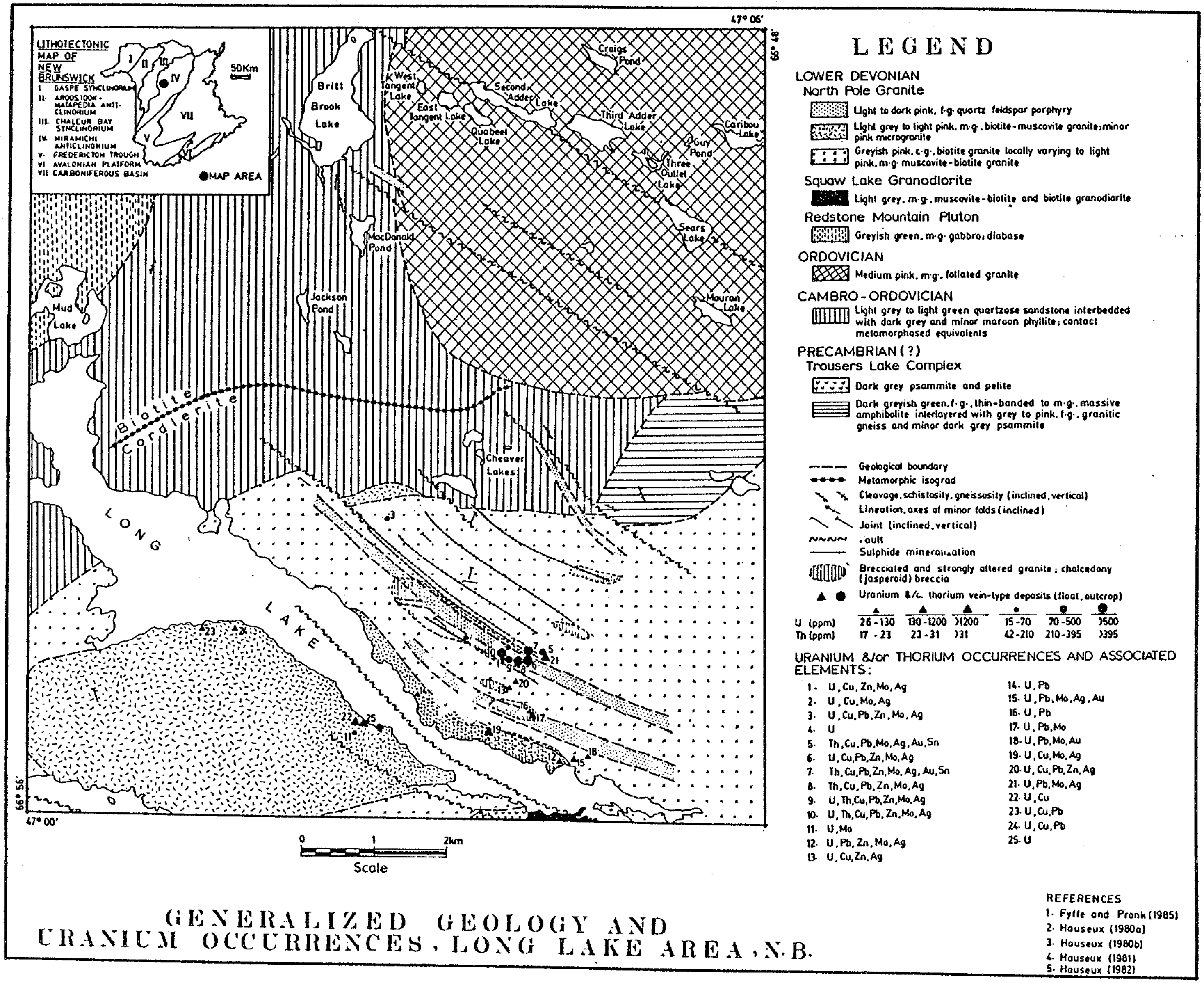
1.2.0 Area of Study

The Long Lake area is located in north-central New Brunswick within the Miramichi Anticlinorium (Fig. 1). The area is accessible by logging roads off the Plaster Rock-Renous Highway (No. 109) and it is covered by numerous streams, lakes and ponds. Most of the area is covered with glacial till which has been deposited by ice flowing east-southeast during Late Wisconsin time (Fyffe and Pronk, 1985).

1.3.0 Methods of Investigations

Published and unpublished geolcgical, geochemical and geophysical data released by the New Brunswick Department of Natural Resources and Energy, the Geological Survey of Canada and by exploration companies were compiled and investigated for the Long Lake area and the Miramichi Anticlinorium. These compiled data were used as a basis for the present study.

The present work is divided into two parts. The first part deals with the detailed investigation of uranium metallogenesis in the Long Lake area. In the second part the results of investigations obtained in the Long Lake area are used to locate other favourable sites for uranium mineralization in the Miramichi Anticlinorium. Favourable targets for uranium exploration delineated in this study are to be examined in detail by means of field and laboratory investigation in the coming year (April 1987 - March 1988).



GENERALIZED GEOLOGY AND URANIUM OCCURRENCES, LONG LAKE AREA, N.B.

Figure 1

1.4.0 Previous Investigations

Exploration in the Long Lake area dates back to 1956, when Anthonian Mining Corporation carried out a detailed geological, geochemical and geophysical survey following the discovery of anomalous base metals in water of the area. These surveys included soil and stream sediment analyses along with self-potential, resistivity, electromagnetic and magnetic coverage. Several favourable targets were outlined and thirty-two holes were drilled. Disseminated and fracture-filling sulphides (Cu-Pb-Zn-Ag-Fe) were located in the Lower Devonian granitic rocks of the North Pole Pluton and in the Cambro-Ordovician metasedimentary rocks.

In 1963, soil sampling and electromagnetic surveys were conducted by Consolidated Mining and Smelting Company. These surveys were followed by drilling of three holes (Shewman, 1964a,b), and were also successful in locating disseminated and stringers of sulphides similar to those above.

In 1971, C.F. Gleeson and Associates Ltd., ran a stream sediment sampling program on the eastern side of Long Lake on behalf of the Canadian Occidental Petroleum Company. The samples were analysed for Cu, Mo, Zn and Ag. As a result of the detection of positive base metal anomalies in the area, the Canadian Occidental Petroleum Co. staked claims between Cheaver Lakes and Long Lake (Fig. 1). Soil surveys were conducted and samples collected were analysed for Cu, Mo and Ag contents. This survey detected Cu-Mo-Ag and Mn anomalies south of Cronin Brook in an area underlain by granitic rocks of the North Pole Pluton. An induced polarization survey was conducted over these anomalies in June, 1973 (Glackmeyer, 1973). Two holes were drilled later in October 1973 (Saracoglü, 1974). These holes intersected stringers and fracture-fillings of pyrite associated with silicified and fractured granites.

In 1979, the Canadian Occidental Petroleum carried out additional stream sediment, water, heavy mineral, soil and rock sampling along with ground scintillometer and induced polarization surveys (Robertson, 1980). In these surveys the presence of widespread U, Cu, Pb, Zn and Ag anomalies located in previous surveys was confirmed.

In the summer of 1980, five holes were drilled by Canadian Occidental to test certain combinations of geochemical and geophysical anomalies delineated by geological mapping, trenching, soil sampling, rock sampling, ground scintillometer, magnetometer, induced polarization and electromagnetic surveys (Hauseux, 1980a,b).

In the summer of 1981, an induced polarization survey followed by trenching and drilling was carried out to investigate the sulphide veins on the eastern side of Long Lake. The results of these surveys were very encouraging (Hauseux, 1981).

During the winter of 1981, Long Lake was explored by lake bottom sediment geochemistry, and very-low frequency (VLF) electromagnetic and magnetic surveys to trace the mineralized float discovered on the shores. Nine holes were drilled to test the geochemical and geophysical anomalies during the winter of 1982 (Hauseux, 1982). The drilling indicated that the induced

Table 1. Best overall analytical results for all elements in different types of samples (after Hauseux, 1982).

Elements	Concentration/Thickness	Samples Type and Locations
U	8,800 ppm	Float, eastern Long Lake
Cu	40,000 ppm/0.30 m	Hole 81-9
Pb	25,000 ppm/0.09 m	Hole 82-19
Zn	153,000 ppm/0.30 m	Hole 80-3
Ag	86,ppm/0.30 m	Hole 81-9
Mo	120,000 ppm	Float, eastern Long Lake
Au	30,000 ppb	Vein, trench 80-15,
Sn	2,868 ppm	Float, trench 80-4, eastern Long Lake
As	8,095 ppm	Vein, trench 80-15, eastern Long Lake
Bi	1,980 ppm	Vein, trench 81-25, eastern Long Lake
Cd	44 ppm/0.53 m	Hole 81-10, eastern Long Lake
Hg	280 ppm/0.08 m	Hole 81-9, eastern Long Lake
In	134 ppm/0.30 m	Hole 81-9, eastern Long Lake
Sb	96 ppm/1.30 m	Hole 81-7, eastern Long Lake

polarization anomalies are, in general, caused by mineralized veins and mineralized breccia.

A summary of best results obtained by Canadian Occidental Petroleum during its surveys of the Long Lake area is shown in Table 1.

The Long Lake area has been mapped by Crouse (1977) and more recently by Fyffe and Pronk (1985). Fyffe and Pronk have also carried out a till sampling program in order to test the geochemical response in the vicinity of the mineralized areas.

Ruzicka and LeCheminant (1986) have investigated briefly the Long Lake uranium occurrences and suggested that there is some similarity between the geological environment of the recently discovered Swanson deposit in Pittsylvania County, Virginia, U.S.A. and the uranium polymetallic deposits at Long Lake.

Hassan *et al*. (in press) have proposed a magmatic-hydrothermal conceptual model to describe the source, mechanism of transportation and environment of deposition of uranium and associated metals in the Long Lake area.

SECTION TWO

GENERAL GEOLOGY OF MIRAMICHI ANTICLINORIUM

2.1.0 Introduction

The Miramichi Anticlinorium (Fig. 2) is underlain by polydeformed Cambro-Ordovician metasedimentary and metavolcanic rocks which are intruded by a series of deformed (pre-Acadian) and massive (post-Acadian), mostly felsic plutons.

The Cambro-Ordovician metasedimentary rocks in the Miramichi Anticlinorium (Fig. 2) are referred to as the Tetagouche Group. The Group comprises a thick sequence of quartz wacke, quartzite and slate (Lower Tetagouche Group) followed conformably by a thin layer of Lower Ordovician calcareous slate (Fyffe et al., 1981).

In the southern part of the Miramichi Anticlinorium, the Lower Ordovician calcareous slate is overlain by Fe- and Mn-bearing slate, black slate and a thick upper unit of greywacke (Poole, 1963). Minor volcanic rocks (mainly felsic) occur below the greywacke (Davies et al., 1983).

In the northern part of the Miramichi Anticlinorium, the Lower Ordovician greywacke and slate is overlain by a thick sequence of felsic volcanic rocks, and relatively younger mafic volcanic rocks and greywacke (Helmstaedt, 1971). The felsic volcanic rocks in the sequence form a broad circular mass, representing a large caldera complex (Davies, 1966 and Harley, 1979). Wilson (1966) has related

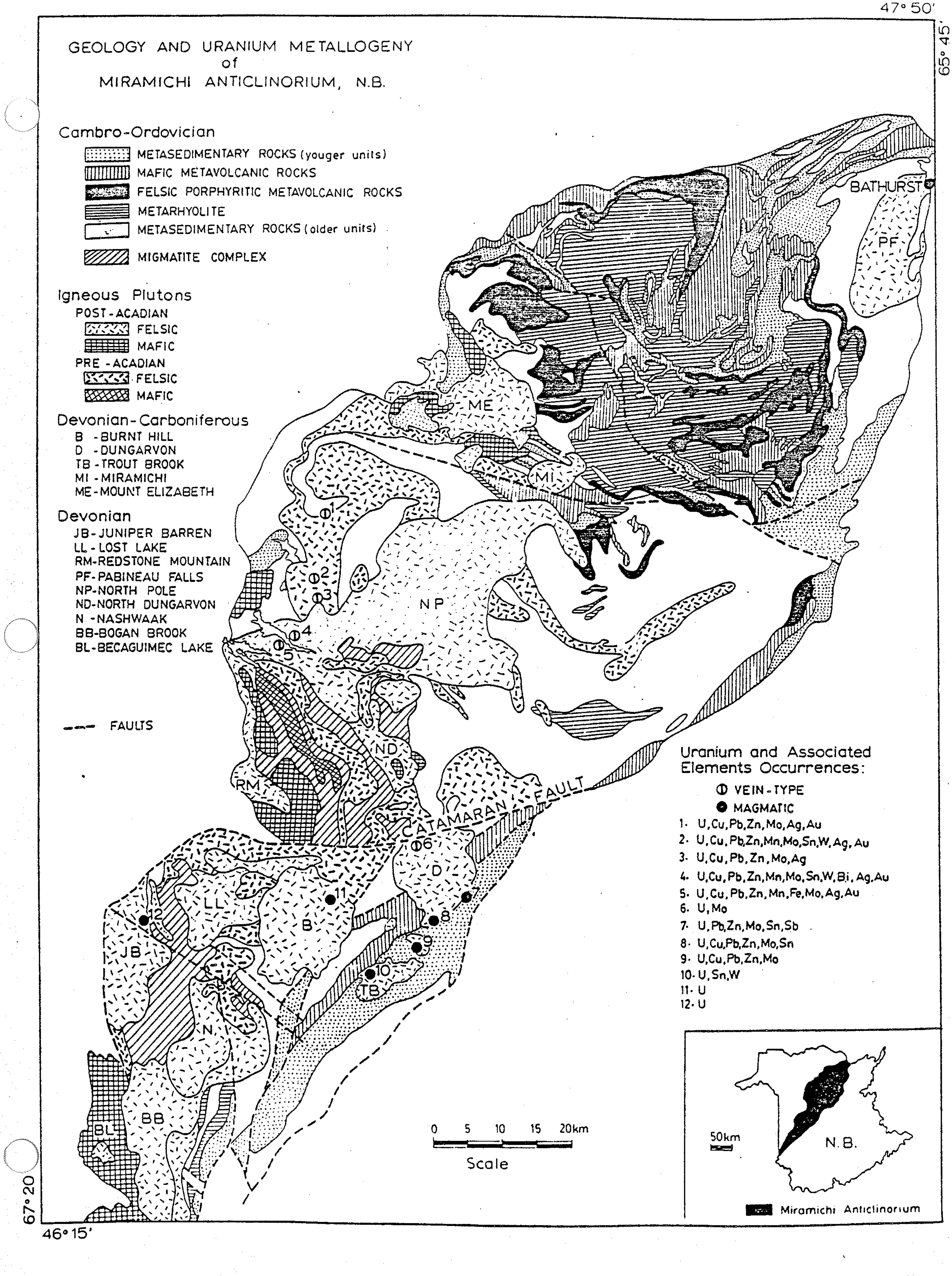

47° 50'
65° 45'
GEOLOGY AND URANIUM METALLOGENY of MIRAMICHI ANTICLINORIUM, N.B.
Cambro-Ordovician
METASEDIMENTARY ROCKS (youger units)
MAFIC METAVOLCANIC ROCKS
FELSIC PORPHYRITIC METAVOLCANIC ROCKS
METARHYOLITE
METASEDIMENTARY ROCKS (older units)
MIGMATITE COMPLEX
Igneous Plutons
POST-ACADIAN
FELSIC
MAFIC
PRE-ACADIAN
FELSIC
MAFIC
Devonian-Carboniferous
B - BURNT HILL
D - DUNGARVON
TB - TROUT BROOK
MI - MIRAMICHI
ME - MOUNT ELIZABETH
Devonian
JB - JUNIPER BARREN
LL - LOST LAKE
RM - REDSTONE MOUNTAIN
PF - PABINEAU FALLS
NP - NORTH POLE
ND - NORTH DUNGARVON
N - NASHWAAK
BB - BOGAN BROOK
BL - BECAGUIMEC LAKE
FAULTS
BATHURST
CATAMARAN FAULT
Uranium and Associated Elements Occurrences:
VEIN-TYPE
MAGMATIC
1. U,Cu,Pb,Zn,Mo,Ag,Au
2. U,Cu,Pb,Zn,Mn,Mo,Sn,W,Ag,Au
3. U,Cu,Pb,Zn,Mo,Ag
4. U,Cu,Pb,Zn,Mn,Mo,Sn,W,Bi,Ag,Au
5. U,Cu,Pb,Zn,Mn,Fe,Mo,Ag,Au
6. U,Mo
7. U,Pb,Zn,Mo,Sn,Sb
8. U,Cu,Pb,Zn,Mo,Sn
9. U,Cu,Pb,Zn,Mo
10. U,Sn,W
11. U
12. U
0 5 10 15 20km
Scale
50km
N.B.
Miramichi Anticlinorium
67° 20'
46° 15'

Figure 2

this volcanism to island arc development during the Taconian Orogeny and its related events.

2.2.0 Tectonic Setting

The Miramichi Anticlinorium represents a distinctive lithotectonic unit in the Appalachian Orogen (Poole, 1967). The Cambro- Ordovician metasedimentary rocks of the anticlinorium were subjected to at least two orogenic movements (Rast, 1983): the Taconian (480 Ma) and the Acadian (400 Ma). The Taconian Orogeny took place during Ordovician time. According to Williams (1979) and Fyffe (1982), the Taconian Orogeny generated as a result of the closing of the Iapetus Ocean and the destruction of the ancient continental margin of North America (e.g., continent-continent collision). The Acadian Orogeny took place during late Lower to Middle Devonian and produced the major anticlinoriums and synclinoriums in the Appalachians including the Miramichi Anticlinorium (St. Julien and Beland, 1982). McKerrow and Ziegler (1971) and Keppie (1977) related the Acadian Orogeny to the final stages of the closure of the Iapetus Ocean.

The Cambro-Ordovician metasedimentary rocks have been subjected to a complex deformational history. At least three major phases of deformations have been identified by most workers in the area, including Helmstaedt (1970), McBride (1976a), Irrinki (1979) and Van Staal (1985), along with other related less intense deformations. A summary of various phases of deformation identified by these investigators is given in Table 2.

Table 2. **Deformation history of the Cambro-Ordovician metasedimentary rocks of the Miramichi Anticlinorium (after Van Staal, 1985)**

Types of Deformations Produced	Van Staal (1985)	Irrinki (1979)	Helmstaedt south part (1971)	Helmstaedt north part (1971)	McBride (1976a)
Isoclinal folding asymmetric northwards recumbent folds, thrusts	F_1a F_1b D_1	D_1 D_2	D_1 D_2	D_1	F_1
Upright folds parallel to trend of Appalachian Orogen	F_2	D_3	D_3		F_2
Open to tight folds or kinks NE-SW, E-W trend, widely spaced crenulation cleavage	F_3			D_2	F_3
Assymmetrical kinkbands NW-SE trend	F_4	D_4		D_3	F_5
Kinkbands, kinks and open folds with horizontal to shallow dipping axial planes	F_5			F_4	F_4

Major northeasterly and northwesterly trending faults are common in the Miramichi Anticlinorium. The most prominent of these faults is the east-northeast trending Catamaran Fault (Fig. 2), which has a right lateral slip with an approximate displacement of 7.2 km (Anderson, 1972). The fault displaces a granite pluton dated as 315±7 Ma (Fyffe, 1982).

2.3.0 Metamorphism

The rocks of the Miramichi Anticlinorium have undergone both regional and thermal metamorphism. The regional metamorphism in areas lacking plutonic rocks varies from sub-greenschist (in the north) to amphibolite grade (in the centre).

In the vicinity of the igneous plutons the country rocks were thermally metamorphosed (within 1 km aureoles) into the following assemblages of index minerals: chlorite, biotite, cordierite, andalusite and sillimanite. Prehnite-pumpellyite grade metamorphism is reported in the southwestern area of the Anticlinorium (Ruitenberg *et al*., (1977).

2.4.0 Igneous Intrusions

Two groups of igneous intrusive rocks, mainly felsic, were intruded in the Miramichi Anticlinorium (Fig. 2). The first group (older granitoids) were emplaced during the Taconian Orogeny and are generally deformed. Rocks of the second group are massive (undeformed) and emplaced mainly during the waning stages of the Acadian Orogeny, extending into Lower Carboniferous time.

Table 3. Geology of selected granitic plutons in the Miramichi Anticlinorium.

Relative Ages	Plutons	No. of Phases	Lithology	Absolute Age	References
DEVONIAN-CARBONIFEROUS	Burnt Hill	3	1. Quartz feldspar porphyry 2 Granitic porphyry 3. Biotite granite	351 ± 8 Ma (Rb-Sr)	Crouse (1981)
	Dungarvon	2	1. Red aplite and pink quartz feldspar porphyry 2. Pink to red biotite granite		
	Trout Brook	1	1. Two-mica adamellite and adamellite		
	Miramichi	1	1. Biotite granite, adamellite and granodiorite	395 ± 15 Ma (K-Ar)	Tupper and Hart (1961)
	Mount Elizabeth	1	1. Biotite adamellite and granite		
DEVONIAN	Juniper Barren	2	1. Biotite granite, minor two-mica granite and quartz feldspar porphyry 2. Biotite granite, minor two-mica granite, minor aplite and pegmatite		St. Peter (1982)
	Lost Lake	2	1. Two-mica granite with minor pegmatite 2. Cataclastic, biotite monzo-granite and granodiorite, two-mica granite and minor muscovite pegmatite	386 ± 18 Ma (K-Ar, biotite) 356 ± 16 Ma (k-Ar, muscovite)	Poole (1980) Wanless et al. (1973)
	Redstone Mountain	1	Quartz feldspar porphyry	409 ± 25 Ma (Rb-Sr)	Fyffe and Cormier (1979)
	North Pole	3	1. Quartz feldspar porphyry 2. Two-mica granite 3. Biotite granite	378 ± 7 Ma (Rb-Sr)	Fyffe and Pronk (1985)
Ordovician ?	Older Granites	1	1. Foliated biotite granite	432 ± 6 Ma (Rb-Sr) and 479 ± 14 Ma (Rb-Sr)	Fyffe et al. (1981)

Geological features of the major plutonic rocks emplaced in the Miramichi Anticlinorium are summarized in Table 3.

2.5.0 Mineralization

The Miramichi Anticlinorium is considered a metallogenic subprovince, because of its high potential for metal deposits. Hassan *et al.* (in press) have suggested the term 'uraniferous metallogenic domain' for the anticlinorium, because significant concentrations of uranium of mainly magmatic and magmatic-related vein-type deposits were located within it (Fig. 2).

Several massive sulphide deposits also have been discovered within the anticlinorium. The majority of these deposits are within the Cambro- Ordovician rocks of the Tetagouche Group. Only one of these deposits is currently in production: Brunswick Mining and Smelting Corporation No. 12 Mine. Metals recoverable from these deposits are Zn, Pb, Cu, Ag and other minor by-products.

The origin of massive sulphide deposits was attributed to a primary precipitation of metals in a sedimentary-volcanogenic environment (McAllister, 1960). These deposits are comparable with the Kuroko massive sulphide deposits of Japan (McBride, 1976b); which are typical sedimentary- volcanogenic deposits (Sato, 1974).

Sn, W, Mo, Sb, Au and U occurrences also have been discovered in several localities in the Miramichi Anticlinorium (Ruitenberg and Fyffe, 1982). These occurences are, in general, quartz and greisen veins and stringers, associated spatially and temporally with the post-Acadian granitic rocks.

SECTION THREE

GENERAL GEOLOGY OF LONG LAKE AREA

3.1.0 Introduction

The Long Lake area (Fig. 1) is underlain by polydeformed Cambro-Ordovician metasedimentary rocks intruded by post-Acadian Lower Devonian felsic and mafic plutons and a pre-Acadian Ordovician felsic pluton. The Lower Devonian granitic rocks occupy a small portion of the 800 km^2 underlain by a pluton known as the North Pole Pluton.

The stratified rocks in the Long Lake area have been subjected to lower greenschist grade regional metamorphism. In a zone up to 2 km wide around their contact with the North Pole Pluton, they have been thermally metamorphosed to an alkali feldspar-cordierite-andalusite-biotite-muscovite hornfels (Fyffe and Pronk, 1985).

The older rocks (Precambrian?) exposed in the Long Lake area belong to the Trousers Lake Complex (Fig. 1). Two units were identified by Fyffe and Pronk (1985) in this complex. The younger unit crops out in the southwestern part of the map area (Fig. 1) and is composed in general of psammite and interbedded pelite. The older unit is located in the northeastern part of the map area and composed of amphibolite and granitic gneiss.

The high grade rocks of Trousers Lake Complex are covered by lower grade Cambro-Ordovician metasedimentary rocks. The Cambro-Ordovician rocks comprise quartz sandstone intercalated with phyllite (Fyffe and Pronk, 1985). The sandstone contains 60 to 85 percent quartz, 15 to 40 percent chlorite and mica. The mica is mostly sericite with minor biotite and muscovite. The phyllite is comprised of sericite and chlorite (Crouse, 1977).

The deformed granite (Ordovician) crops out in the northeastern corner of the map area (Fig. 1), is concordant with the Cambro-Ordovician rocks and has a fabric (foliation) parallel to trends in the Cambro-Ordovician rocks (i.e., NW-NNW). The deformed granite is mainly pink, equigranular, and medium-grained. Recrystallized phases of the granite contain crystals of perthite and plagioclase up to 4 mm in diameter embedded in a finer matrix of quartz and biotite (Fyffe and Pronk, 1985). The deformed granite contains abundant roof pendants of Cambro-Ordovician rocks.

In the northwestern corner of the map area (Fig. 1), a mafic mass belonging to the Devonian Redstone Mountain Pluton is exposed. This mass is composed mostly of olivine gabbro (Fyffe and Pronk, 1985). The gabbro consists of phenocrysts of olivine, clinopyroxene and plagioclase about 5 mm in diameter, set in a diabasic matrix of plagioclase and minor actinolite and biotite (Fyffe and Pronk, 1985).

3.2.0 Geology of North Pole Pluton

Special attention will be given to the North Pole Pluton during the course of this report, because uranium and associated metals in the Long Lake area are spatially, temporally and possibly genetically associated with it.

The North Pole Pluton (Fig. 1) is a post-tectonic, peraluminous granite that intrudes the Cambro-Ordovician rocks discordantly (Fyffe and Pronk, 1985). Chemically and texturally, the North Pole Pluton is similar to the Pokiok Batholith of New Brunswick and the South Mountain Batholith of Nova Scotia (Fyffe and Pronk, 1985). The Pokiok Batholith lies adjacent to uraniferous stibnite-bearing quartz veins in the Silurian metasedimentary rocks (Lake George antimony mine). The South Mountain Batholith hosts Sn-U deposits.

Recent mapping by Fyffe and Pronk (1985) indicates that the North Pole Pluton is divided into three phases: quartz feldspar porphyry (younger), biotite-muscovite granite, and biotite granite (older).

3.2.1 Biotite Granite

The biotite granite (Fig. 1) constitutes most of the pluton. It is generally pink in colour and contains coarse-grained, equigranular crystals of quartz, alkali feldspar and plagioclase in equal proportion. Biotite forms 1 to 2 percent of the rock. The alkali feldspar is an orthoclase perthite containing domains of microcline (Fyffe and Pronk, 1985). The plagioclase is altered to sericite and epidote. Biotite is partly altered to chlorite.

Two sets of orthogonal steep joints trending near 30 and 120 are displayed by the biotite granite (Fyffe and Pronk, 1985). Metal deposits in the area are associated with the southeast-trending joints.

3.2.2 Biotite-Muscovite Granite

The biotite-muscovite granite (Fig. 1) is second in areal extent and intrudes the biotite granite. The biotite and muscovite together account for 3 to 5 percent of the rock (Fyffe and Pronk, 1985). The equigranular two-mica granite occurs predominantly in the western side of Long Lake and is identified by its medium-grain size and light grey to light pink colour. In addition to mica, the granite contains 25 to 35 percent quartz, 30 percent plagioclase, 15 to 20 percent potassium feldspar and 5 percent chlorite (altered from biotite). Sphene, apatite, epidote and opaque minerals are present as accessories. (Fyffe and Pronk, 1985).

Two-mica granites are recognized by a number of geologists for their metallogenic specialization in U, Sn, Mo, Be, Li and F mineralization. The U-producing Hercynian granite of Massif Central, France is the best example of two-mica granites (Moreau, 1976).

3.2.3 Quartz Feldspar Porphyry

The quartz feldspar porphyry (Fig. 1) occurs as dykes intruding the biotite granite. The dykes, located mainly in the eastern side of Long Lake, are trending northwesterly, parallel to the 120 trending joints in the biotite granite. The phenocrysts consist of plagioclase, quartz, orthoclase and minor biotite (Fyffe and Pronk, 1985). The phenocrysts are about 2 mm in diameter, they constitute about 50 percent of the rock and are embedded in a matrix of quartzo-feldspathic material. The plagioclase phenocrysts are almost entirely altered to sericite. Orthoclase is partially replaced by calcite. Biotite is completely altered to chlorite. Miarolitic cavities were observed in these dykes (Fyffe and Pronk, 1985).

The quartz feldspar porphyry is extensively altered by hydrothermal solutions. Fresh varieties are pink in colour whereas, the altered varieties are greenish grey (Fyffe and Pronk, 1985).

3.3.0 Age of North Pole Pluton

Samples taken for age determination from various phases of the pluton suggest that the granitic phases have been intruded over a relatively short period of time.

Rb-Sr isochron ages of 378±7 Ma are assigned by Fyffe *et al*. (1981) to the various phases of the pluton. A K-Ar age determination on biotite from the granite taken from a drill hole gave an age of 391±14 Ma (Hauseux, 1980b). This age agrees, within the limits of error, with the Rb-Sr age.

A K-Ar whole-rock determination on the biotite-muscovite granite gave an age of 355±18 Ma (Fyffe and Pronk, 1985). Fyffe and Pronk referred this age to the cooling stage of the granite. A Rb-Sr determination on muscovite granite from a drill hole yielded an age of 408 Ma (Hauseux, 1982) which Fyffe and Pronk (1985) believed to represent the age of crystallization of the granite.

A K-Ar whole-rock determination on samples from the quartz feldspar porphyry gave an age of 337±17 Ma (Fyffe and Pronk, 1985). This age contradicts the Rb-Sr age determination (278 Ma, Hauseux, 1982) on mineral separates from an altered sample of the quartz feldspar porphyry. Fyffe and Pronk (1985) related this contradiction to hydrothermal activity assumed to have operated on the granite after crystallization.

3.4.0 Depth of Emplacement of North Pole Pluton

A rough estimate of the depth of emplacement for the North Pole Pluton was determined predominantly from the stability fields of the mineral assemblages in the pluton and the country rocks. The first estimate was made on the basis of the presence of andalusite in the aureole of the granite in the country rocks and indicates a depth of about 13 km below the surface (Holdaway, 1971). Recently, Fyffe and Pronk (1985) used primary muscovite for depth of emplacement estimation. Their estimation is based on an empirical diagram given by Carmichael *et al*. (1974) in which a depth greater than 12 km is assumed for primary muscovite-bearing granites.

On the basis of the average normative quartz, orthoclase, and albite (Q-Or-Ab) ternary diagram of Tuttle and Bowen (1958), Fyffe and Pronk (1985) have concluded that the biotite granite crystallized at 1 kb P_{H_2O} (Fig. 3), which suggests an emplacement at a depth of at least 3.5 km. The quartz feldspar sample crystallized at 0.5 Kb,

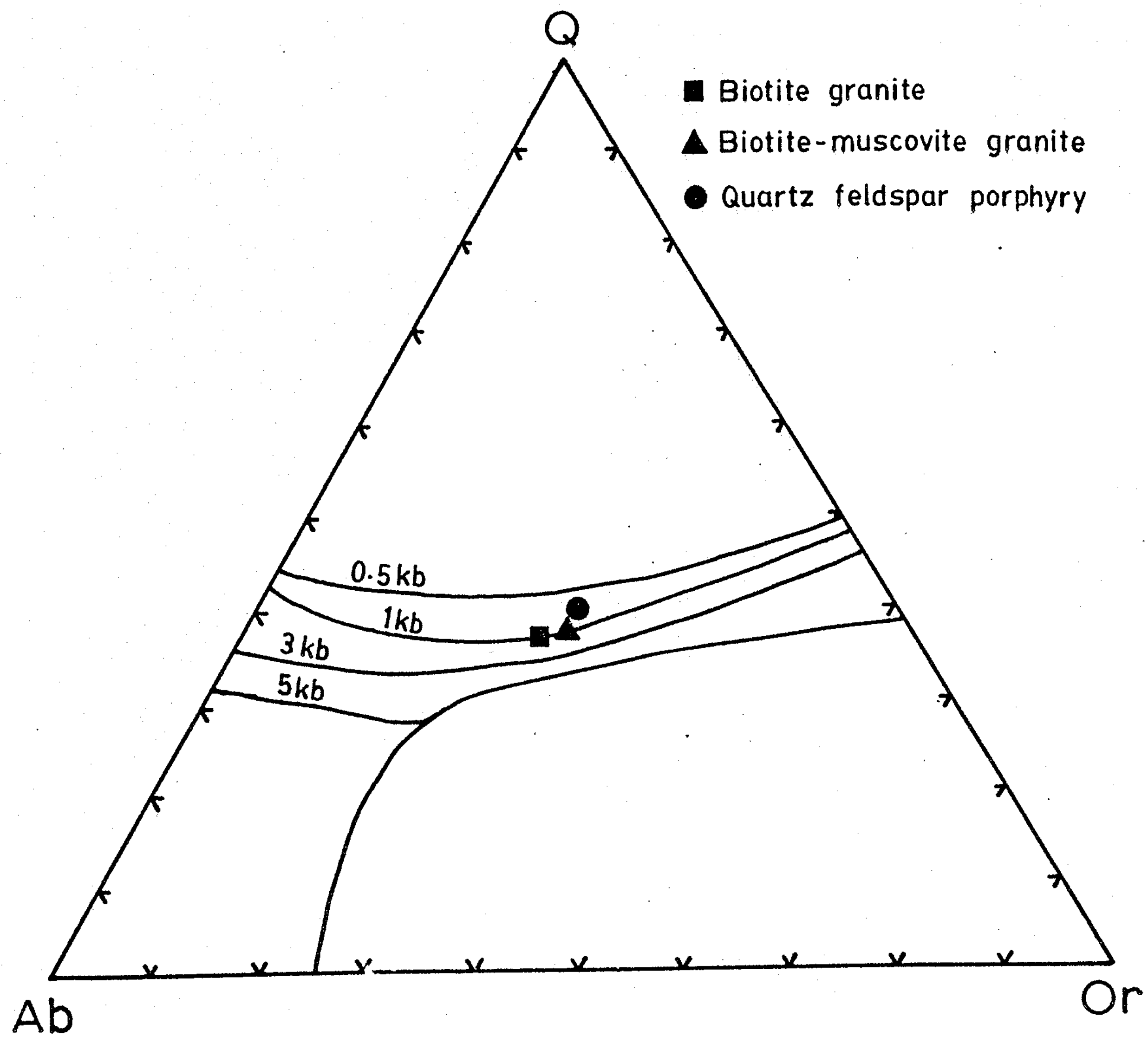


Figure 3. Q - Or - Ab ternary diagram for normative quartz, orthoclase and albite (after Fyffe and Pronk,1985)

which is equivalent to a depth of 2 km of the surface Fig. 3). This variation in depth of emplacement between the biotite granite and the quartz feldspar porphyry led Fyffe and Pronk (1985) to suggest that over a kilometre of overburden rocks were removed by erosion between the time of the biolite granite emplacement and the quartz feldspar porphyry intrusion.

Geophysical modelling of the North Pole Pluton by using gravity data yield a value of 8 km as the probable thickness of the overall pluton body (Burke and Chandra, 1983). The model also reveals that the Cambro-Ordovician metasedimentary rocks covering the granite varies in thickness from 0 to 1 km.

3.5.0 Brecciation of North Pole Pluton

Brecciation was observed in several localities over the North Pole Pluton, particularly on the eastern side of Long Lake (Fig. 1, Hauseux, 1980a, 1982). As indicated from the map (Fig. 1) the breccia zones are distinctly elongated in the northwest-southeast direction. They are located near or along the northwesterly-trending shear zones. The majority of the polymetallic vein-type uranium mineralization zones in the North Pole Pluton are associated with these breccias. The breccia zones are characterized by their extensive hydrothermal alteration and by their content of chalcedony (usually jasperoid) veins, features typical of hydrothermal processes.

The breccia zones of the Long Lake area contain angular granitic fragments of variable sizes (up to 1.5 cm). Quartz, alkali feldspar and plagioclase are the essential constitutents of the fragments embedded in a fine-grained matrix of the same material. The matrix also contains grains of sericite, biotite and chlorite. Epidote grains are sometimes associated with the chlorite.

The alkali feldspar and plagioclase fragments are usually strongly strained and are crosscut by quartz (chalcedony) filled fractures.

Breccia pipes have long been considered excellent targets for mineral exploration, in general, and for uranium in particular. (Kents, 1964, Sawkins, 1969; Fletcher, 1977 and Simmons and Sawkins, 1983). In the Long Lake area both breccia faults and the host rock lithology of North Pole Pluton are possibly the major ore controls.

The mechanism responsible for breccia generation in the Long Lake area is not fully known at present. However, Fyffe and Pronk (1985) stated that brecciation may have occurred during release of silica-rich hydrothermal fluids into the fractures at the eastern side of Long Lake.

Brecciation is a characteristic feature of hydrothermal systems, generated around felsic to intermediate igneous rocks emplaced at shallow depths in the crust (Sotnikov et al., 1974 and Allman-Ward et al., 1982). Scherkenbach (1982) suggested that breccia occurs as a result of a sharp drop in P_{H_2O}. This sharp drop in pressure can take place when hot magmatic hydrothermal solutions at depth rise through fractures or faults to the surface. The breccias may also form by hydraulic ramming of residual fluids and magma during cooling of the granite (Lindsey and Fisher, 1985).

Another mechanism was proposed by Fisher (1976) during his study of vein-type U deposits in Front Range, Colorado. There U ore is found in fault breccia systems. According to Fisher, breccia is generated whenever Laramide faulting is at a high angle to metamorphic foliation, and maximized at places where the intersection angle approaches ninety degrees.

In the Long Lake area the trend of the breccia faults are parallel to the trends of the metamorphic foliation of the Cambro-Ordovician metasedimentary rocks (NW-NNW), suggesting some support for the probability of the brecciation being produced more by the action of hydrothermal fluids than by the purely mechanical method described by Fisher (1976).

3.6.0 Wall-Rock Alterations

Hauseux (1980a) has identified three episodes of hydrothermal and supergene alteration in the Long Lake area. The hydrothermal alterations are in general associated with highly fractured and brecciated zones.

The three episodes of alteration are the following:

1. Sericite-chlorite-silica-pyrite

   The sericite-chlorite-silica-pyrite hydrothermal alteration is associated with northwesterly trending quartz-pyrite veining of the North Pole Pluton. This veining is believed to be the earlier of two stages of veining related to post-magmatic northwest-southeast faulting.

2. Kaolin-sericite-calcite (fluorite)

The kaolin-sericite-calcite hydrothermal alteration is associated with the later stage of northwesterly trending calcite-veining.

3. Fe-Mn-Oxide Staining

The Fe-Mn staining occurred within the top 30 m of the weathered zone of the granite by supergene processes. It is the last episode of alteration that affected the North Pole Pluton.

3.7.0 Mineralization

Uranium- and sulphide-bearing quartz (mostly jasperoid chalcedony) veins occur in at least four northwesterly trending faults that intersect the North Pole Pluton (Fig. 1). The mineralization and associated alteration are most commonly concentrated in the fault breccia. Pyrite, chalcopyrite, sphalerite, galena, covellite and molybdenite are the main sulphide minerals found in these polymetallic veins (Hauseux, 1980a). Small amounts of arsenopyrite, matildite and native bismuth are also found. Cassiterite and autunite-torbernite have been identified in float only. Uranium was also found in veins intersected in trenches and drill holes but no mineral identifications were made.

Uranium distribution in float samples was investigated by Gasparrini (1981). Three styles of mineralization were identified: (a) uranium in discrete grains; (b) uranium in fracture-fillings and (c) uranium diffused within the rocks.

Four phases of secondary uranium minerals were recognized by a microscope-electron microprobe study of two thin sections from medium-grained muscovite granite float (Gasparrini, 1981). These phases are:

1. Uranium-phosphorous-copper

   The mineral of this compound is most abundant and identified as torbernite $Cu(PO_4)_2(UO_2)_2 \cdot 8\text{-}12H_2O$. The mineral is distributed among the rock-forming minerals of the granite.

2. Uranium-phosphorous-iron-copper compound

   The mineral of this compound was identified as iron torbernite (mixture of iron oxide and torbernite). The mineral forms platy crystals.

3. Iron-phosphorous compound with minor uranium

   The mineral of this compound was not identified. The mineral is very fine and it is deep red in colour under transmitted light. It is distributed in fractures and dispersed through the rock.

4. Iron-uranium-phosphorous compound

   This mineral (not identified) is less common than the above. It is opaque under transmitted light.

3.8.0 Chronological Development of the North Pole Pluton Metallogeny

Metallogenic developments of the North Pole Pluton and associated geological events are illustrated in Figure 4. Sequential summary of these events is as follows:

1. Deposition of the Cambro-Ordovician sedimentary rocks in a paraplatformal environment.
2. During the Taconian Orogeny (Ordovician) the Cambro-Ordovician rocks were tightly folded, regionally metamorphosed (subgreenschist-amphibolite grade), intruded by granite, uplifted and deeply eroded. Sedimentary rocks at contact with the granitic rocks were thermally metamorphosed to chlorite-cordierite grade.
3. During the Acadian Orogeny (late Lower to Middle Devonian), the rocks underwent open-fold deformation along northeast-southwest axes.
4. North Pole Pluton was emplaced at this stage and metamorphosed the contact rocks to alkali feldspar-cordierite-andalusite- muscovite hornfels.
5. Northwest-southeast trending wrench faulting and associated shear zones were generated at the later stages of the Acadian Orogeny.
6. The rocks along these faults were hydrothermally metamorphosed. Chloritization, sericitization, silicification and pyritization are the major alterations identified for this stage.

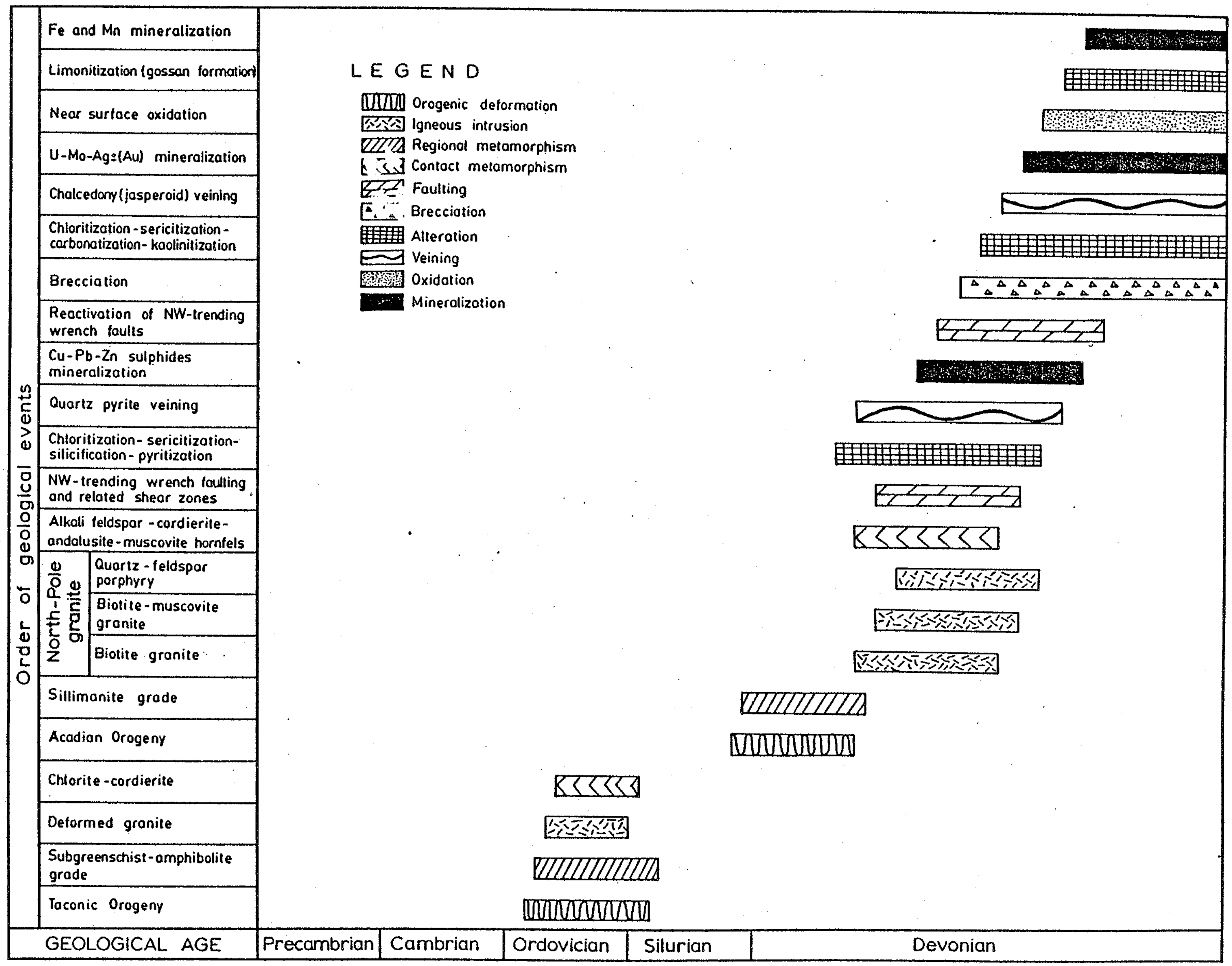


Figure 4. Geochronological sequence of metallogenic development in the Long Lake area.

7. This process led to quartz-pyrite vein generation some of which were accompanied by Cu-Pb-Zn sulphides mineralization.

8. The northwest-trending wrench faults were reactivated and this event was accompanied by brecciation of the granitic rocks of North Pole Pluton along these faults. That brecciation was promoted by pulses of hydrothermal fluids is evidenced by the generation of a second episode of hydrothermal alteration (chloritization, sericitization, carbonatization and kaolinitization) of the wall rocks. These events also produced chalcedony (jasperoid) veining.

9. At this stage there was further deposition of Cu-Zn-Pb sulphides. U-Mo-Ag $\pm$ (Au) minerals were added.

10. Supergene processes aided by the action of meteoric waters near the surface led to depletion of Fe and Mn from the already deposited sulphides. The limonite produced gave staining.

SECTION FOUR

REVIEW OF GEOCHEMICAL AND GEOPHYSICAL SURVEYS FOR URANIUM AND ASSOCIATED METALS IN LONG LAKE AREA

4.1.0 Introduction

Extensive reconnaissance along with detailed geochemical and geophysical exploration was carried out in the Long Lake area. These surveys were conducted by several private and governmental exploration organizations. Most of the surveys were carried out by Canadian Occidental Petroleum (1980-1982) to trace the source(s) of anomalous levels of uranium and base metal sulphides previously detected in the area during routine stream sediment sampling. These surveys led to the discovery of uranium- bearing sulphide veins and autunite-torbernite-bearing float.

In the following sections a brief summary of the result of these surveys is given.

4.2.0 Geochemical Surveys

4.2.1 Lake Sediments Geochemistry

Lake sediment sampling was carried out in Long Lake by Canadian Occidental Petroleum to delineate possible areas of uranium and associated metals concentration. The survey was a follow-up to the discovery of mineralized float on the lake shores in order to identify targets for the drilling program suggested to be carried out on the lake. A total of 439 lake sediment samples were collected and geochemically analysed for their U, Cu, Pb, Zn, Ag, Mo and Mn contents (Leonard, 1982). Seventeen multi-element anomalies were identified. Uranium along with Zn and Mn are widespread throughout the lake, probably due to their high mobility in the hydromorphic environment.

The multi-element anomalies (Leonard, 1982) are in general elongated, suggesting that they may be related to metal concentrations along shear zones. The anomalies have different trends, but the majority of them are trending either northeasterly or northwesterly (see geochemical anomalies over Long Lake in Fig. 13). The northwesterly trending anomalies are located in the centre of the lake and appear to be related to a major northwesterly trending fault. This, combined with the occurrence of mineralized vein-type float along the lake shore suggests that vein-type mineralization may indeed be present in the centre of Long Lake. The northeasterly trending anomalies, on the other hand, are located mostly near the shores and in the opinion of the authors of this report, they may be attributed to a train of mineralized float from the centre of the lake.

Statistical abundance of the metals for which the Long Lake sediments were analysed, are given in Table 4. The global abundances of these metals in lake sediments are also listed for comparison. With the exception of Cu and Ag, all other elements are exceeding

Table 4. Means and ranges of U and other elements analysed in the Long Lake sediments and their global averages.

Elements	Range	Mean	Global * Average
U (ppm)	0.2- 215.0	20.0	3.2
Mo (ppm)	0.5- 126.0	5.0	2.0
Ag (ppm)	0.5- 2.1	0.4	0.9
Mn (ppm)	73.0-12000.0	734.0	670
Cu (ppm)	1.0- 65.0	12.0	57
Pb (ppm)	6.0- 180.0	29.0	20
Zn (ppm)	19.0- 1960.0	302.0	80

* Barwise and Whitehead (1983)

their corresponding global abundances, particularly uranium, which exceeds its global average by an order of six. The low levels of Ag and Cu in the lake sediments relative to their global abundances may be due to their low mobility in the hydromorphic environment rather than to their low contents in the granitic rocks underlying the lake.

Statistical correlation coefficients computed for the 439 samples are given in Table 5. Uranium has a strong positive correlation with Cu and Zn and low to moderate correlations with Ag, Pb, Mo and Mn. It is of interest to note that only positive correlations were observed among the analysed elements. This may suggest that they are derived from the same geological source, such as from a fracture-filled vein.

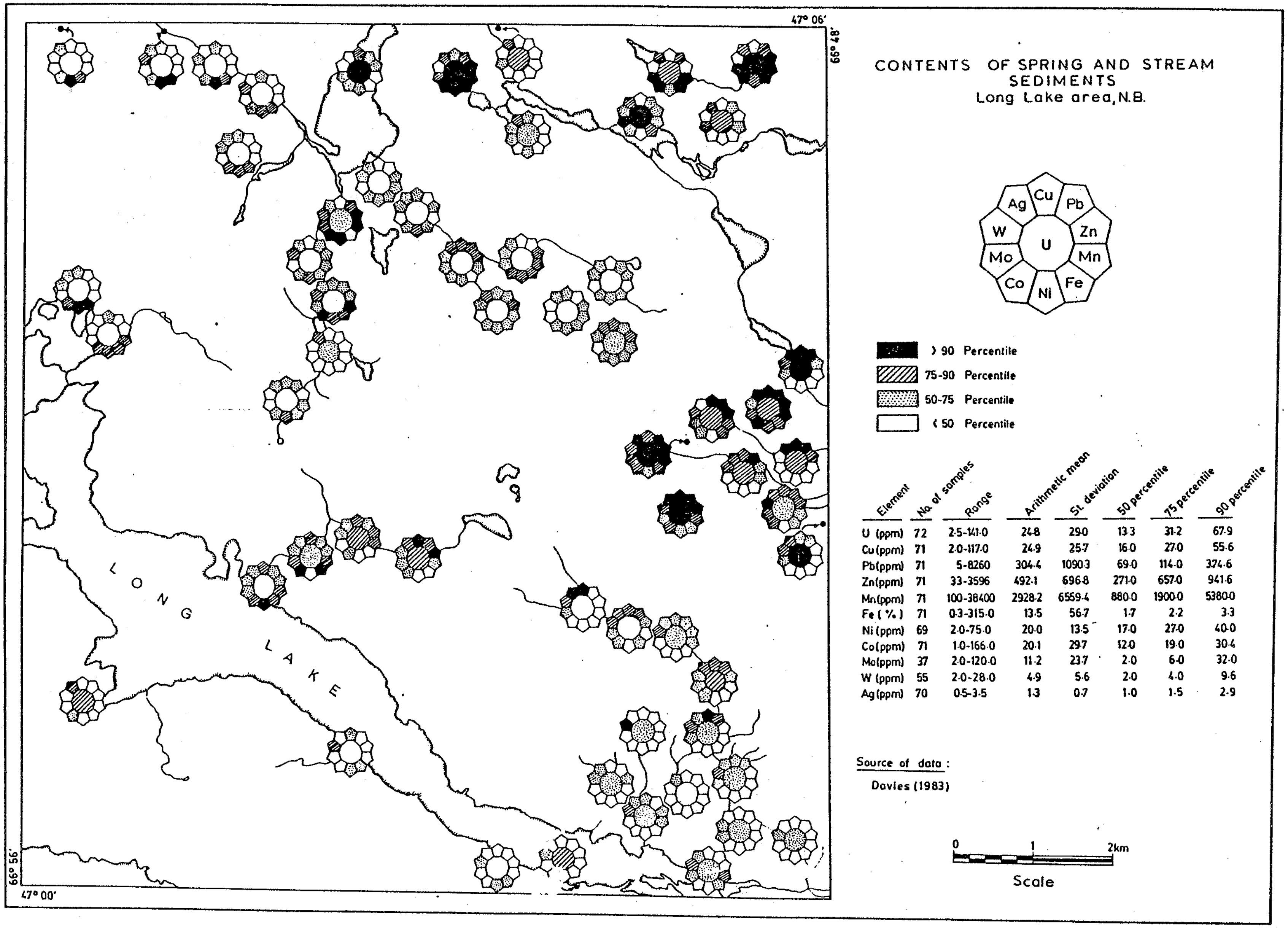
4.2.2 Spring and Stream Sediments Geochemistry

Stream sediments sampling was the first, and probably the most successful survey to locate the mineralization in the study area. Anomalous U (up to 149 ppm) was identified (1978) in stream sediment samples previously (1971) collected for analysis of Cu, Mo, Zn and Ag by Canadian Occidental Petroleum (Hauseux, 1980a).

Spring and stream sediments sampling was conducted for the Long Lake area by New Brunswick Department of Natural Resources and Energy (Davies, 1983). The collected samples were analysed for U, Cu, Pb, Zn, Co, Ni, Mn, Fe, Mo, W and Ag contents (Appendix I). A compilation map was prepared for the analysed elements (Fig. 5). The data were treated statistically. The background level is chosen as the 50 percentile of the population (median). Different symbols were

Table 5. Correlation coefficients among elements analysed from lake sediment samples from Long Lake.

	U	Cu	Pb	Zn	Mn	Mo	Ag
Ag	0.27	0.26	0.18	0.18	0.05	0.15	1.00
Mo	0.17	0.14	0.21	0.21	0.39	1.00	
Mn	0.04	0.25	0.27	0.32	1.00		
Zn	0.54	0.61	0.30	1.00			
Pb	0.18	0.36	1.00				
Cu	0.49	1.00					
U	1.00						



Element	No. of samples	Range	Arithmetic mean	St. deviation	50 percentile	75 percentile	90 percentile
U (ppm)	72	2.5-141.0	24.8	29.0	13.3	31.2	67.9
Cu (ppm)	71	2.0-117.0	24.9	25.7	16.0	27.0	55.6
Pb (ppm)	71	5-8260	304.4	1090.3	69.0	114.0	374.6
Zn (ppm)	71	33-3596	492.1	696.8	271.0	657.0	941.6
Mn (ppm)	71	100-38400	2928.2	6559.4	880.0	1900.0	5380.0
Fe (%)	71	0.3-315.0	13.5	56.7	1.7	2.2	3.3
Ni (ppm)	69	2.0-75.0	20.0	13.5	17.0	27.0	40.0
Co (ppm)	71	1.0-166.0	20.1	29.7	12.0	19.0	30.4
Mo (ppm)	37	2.0-120.0	11.2	23.7	2.0	6.0	32.0
W (ppm)	55	2.0-28.0	4.9	5.6	2.0	4.0	9.6
Ag (ppm)	70	0.5-3.5	1.3	0.7	1.0	1.5	2.9

Figure 5

used to express various levels of anomalies, computed on the bases of 50 percentile, 75 percentile and 90 percentile (Fig. 5). Some of the samples were also analysed for As, Sb, Ba and Au contents, but with the exception of As in few locations, the metal contents were not anomalous. Unexpectedly, uranium content in the area underlain by the North Pole Pluton is in general moderate, whereas it is high in the area underlain by the Precambrian amphibolite and the Ordovician granite (see Fig. 1). It is possible that U migrated either in solution or as particles from the area underlain by the North Pole Pluton (high topography) to areas underlain by Precambrian amphibolites and Ordovician granites (relatively lower area). Another possible explanation is that the metal-bearing late phase quartz feldspar porphyry of North Pole Pluton was intruded into these rocks (Fig. 1) and provided the uranium and associated metals. No evidence exists to believe that the amphibolites and the deformed granite are the sources of the uranium and the associated metals. Statistical abundances of U and other metals in the analysed samples are shown in Table 6.

In order to interpret the results of spring and stream sediment samples in terms of geological controls, a statistical factor analysis was performed on the data by the present authors. Varimax rotated principal component option (SAS, 1982) was used for this purpose. Three factors were retained for the analysis. The retained factors show the following metal associations:

Factor I: Zn-Mn-Co-Pb-Ni

Factor II: Ag-U-Cu

Table 6. Statistical abundances of elements in spring and stream sediment samples for the Long Lake area.

Element	n	Range	Mean	St.Dev.	Mode	Median 50 percentile	75 percentile	90 percentile	95 percentile	Global averages
U	72	2.5- 141.0	24.8	29.0	4.1	13.25	31.2	67.9	100.2	
Cu	71	1- 117	24.9	25.7	11	16	27	55.6	96.6	55
Pb	71	5- 8260	304.4	1090.3	19	69	114	374.6	1424.0	13
Zn	71	33- 3596	492.1	696.8	33	271	657	941.6	2028.4	70
Mn	71	100-38400	2928.2	6559.4	1700	880	1900	5380.0	18860	950
Fe	71	0.3- 315	13.5	56.7	0.65	1.7	2.2	3.3	99.6	5.0
Ni	69	2- 75	20	13.5	27	17	27	40	42	75
Co	71	1- 166	20.1	29.7	5	12	19	30.4	95.8	25
Mo	37	2- 120	11.2	23.7	2	2	6	32	84.0	1.5
W	55	2- 28	4.9	5.6	2	2	4	9.6	20.8	1.5
Ag	70	0.5- 3.5	1.3	0.7	1	1	1.5	2.9	3	0.07
As	19	3- 85	12	19.4	3	6	10	39.0	85.0	1.8
Sb	19	0.1- 0.6	02	0.1	0.1	0.1	0.1	0.4	0.6	0.2
Ba	19	110- 360	299.5	50.6	340	320	340	360	360	425

* All elements in ppm except Fe in percent.

Factor III: Fe-Mo

Factor I, is composed of Zn, Mn, Co, Pb and Ni but uranium has no contribution. This factor is probably related to bedrock which is enhanced in these metals. Chemical analyses of samples from the bedrock by Hauseux (1980a) and Fyffe and Pronk (1985) indicate that uranium content is near normal.

Factor II, is composed of U, Ag and Cu. This factor is probably related to secondary geological processes such as hydrothermal alteration and deposition, possibly related to vein type mineralization.

Factor III shows that only Fe and Mo are significant. This factor is also related to secondary geological processes which led to Fe and Mo mineralization.

Statistical correlation coefficients among the analysed metals in spring and stream sediments samples is shown in Table 7. Uranium has a strong positive correlation with Ag and Cu, a pattern also observed in Factor II of factor analysis. Both Ag and Cu can be used as a pathfinder for uranium in spring and stream sediments in the area.

4.2.3 <u>Soil Geochemistry</u>

The Canadian Occidental Petroleum also has carried out (1980) soil sampling search for areas of potential uranium and other metal concentrations. Most of the samples were collected from the area underlain by the North Pole Pluton.

Table 7. **Correlation coefficients for elements in spring and stream sediment samples of Long Lake area**

	U	Cu	Pb	Zn	Mn	Fe	Ni	Co	Mo	W	Ag
Ag	0.85	0.70	0.52	0.32	0.15	−0.17	0.20	−0.01	−0.05	0.03	1.00
W	−0.03	−0.17	0.06	−0.06	0.02	−0.09	0.04	0.09	−0.17	1.00	
Mo	0.06	−0.32	−0.03	0.07	0.16	0.25	−0.01	0.18	1.00		
Co	−0.08	−0.02	0.32	0.68	0.60	0.37	0.43	1.00			
Ni	0.04	0.12	0.19	0.46	0.38	−0.22	1.00				
Fe	−0.16	−0.01	−0.06	0.00	0.00	1.00					
Mn	−0.12	0.06	0.72	0.92	1.00						
Zn	0.05	0.29	0.67	1.00							
Pb	0.38	0.25	1.00								
Cu	0.58	1.00									
U	1.00										

Prior to sampling, several test pits were dug in different locations of the study area to determine the relative distribution of metals in various soil horizons. The test indicated that metal concentrations tend to be high in the 'B' horizon. Therefore, whenever it was possible the 'B' horizon was sampled. Three-thousand soil samples were collected in the summer of 1980 over the eastern side of Long Lake (Gleeson, 1980) and another 732 samples from the western side of the lake (Lipowicz, 1980). These samples were analysed for U, Cu, Pb, Zn, Mn, Mo and Ag contents.

Statistical abundances of the analysed metals are given in Table 8, along with their global averages.

About 54 multi-element soil anomalies were located in this survey, the majority of them on the eastern side of Long Lake in an area underlain by the North Pole Pluton. These anomalies have, in general, a linear pattern with west-northwest, east-west and northeast trends. This pattern could be a reflection of mineralization along linear features, such as shear zones.

Other than Mo and U (slightly above global averages) the rest of the metals are, in general, depleted on the western side of Long Lake.

Two common metal associations were observed in the soil samples. The first is between Cu, Pb, Zn, Mn and Ag in areas underlain by biotite granite. The second metal association includes U and Mo in northwesterly trending anomalies along both shores of Long Lake.

Table 8. **Mean, standard deviations and ranges of analysed metals in soils of the Long Lake area.**

Metals	n*	Eastern Long Lake		n	Western Long Lake		Global Averages
		Ranges	Mean ± St.Dev.		Ranges	Mean ± St.Dev.	
U(ppm)	2990	0.1- 680	4.5± 20.4	732	0.2-178.0	2.8± 10.1	2.7 @
Cu(ppm)	2358	0.5- 3500	25.5± 90.5	732	0.5- 70.0	7.5± 5.1	25 @
Pb(ppm)	2986	0.5- 7200	73.9± 185.4	732	4.0-540.0	24.4± 22.7	19 @
Zn(ppm)	2986	2-21700	190.9± 525.3	732	3.0-132.0	41.1± 21.2	60 @
Mn(ppm)	2360	6-99999	927.4±[illegible]3.0	732	8.0-30200	319.9±1231.3	550 @
Mo(ppm)	2358	0.5- 470	4.1± 14.9	732	0.5- 38.0	1.9± 2.4	1.0 @
Ag(ppm)	2360	0.2- 32	2.1± 1.5	732	0.4- 2.6	1.0± 0.3	0.1

* n = number of samples
@ Barwise and Whitehead (1983)
x Hansford et al. (1984)

4.2.4 Till Geochemistry

The first direct sign of mineralization in the Long Lake area was in mineralized boulders in glacial tills scattered in the area particularly around Long Lake shores.

Since long ago tracing of mineralized boulders has been used successfully as a prospecting method for mineral deposits in glaciated terrains (Dreimanis, 1958). The method is used most successfully for uranium exploration mainly because a scintillometer can easily identify even buried (less than50 cm deep) uranium-bearing boulders (Paterson et al., 1979). The Pleutajokk uranium deposit of northern Sweden was discovered in this manner (Gustaffson and Minell, 1977). In Canada, several uranium deposits have been discovered since 1970 by tracing trains of radioactive ore boulders (Seguin et al., 1984).

Uranium is commonly associated with base metal sulphides as well as W, Sn, Mo and Ag in the Miramichi Anticlinorium, and it may be possible by tracing radioactive boulders to locate these nonradioactive ore deposits.

In the Long Lake area a geochemical study of tills was carried out in the summer of 1983 (Fyffe and Pronk, 1985) to test their geochemical response. Till samples collected were analysed for U, Cu, Pb, Zn, Mn, Fe, Co, Ni, W, Mo and Au. Results of the analyses are summarized in Table 9.

Anomalous contents of U, Pb, Zn, Cu and Mn were detected in till samples from the area east of Long Lake which is underlain by granitic rocks of the North Pole Pluton.

Table 9. **Statistical abundances of metals in till samples from Long Lake area (after Fyffe and Pronk, 1985).**

Element	**Range**	**Mean ± St. Dev.**
U (ppm)	1.2 - 9.9	3.6 ± 1.7
Cu (ppm)	1.0 - 76.0	14.2 ± 9.0
Pb (ppm)	9.0 -183.0	28.7 ± 19.3
Zn (ppm)	12.0 -515.0	66.1 ± 58.4
Mn (ppm)	40.0 -710.0	234.7 ± 117.5
Fe (%)	0.71- 5.30	2.67± 0.87
Co (ppm)	3.0 - 22.0	10.6 ± 3.5
Ni (ppm)	3.0 - 59.0	21.0 ± 11.5
Ag (ppm)	0.5 - 3.0	1.2 ± 0.7
Mo (ppm)	2.0 - 8.0	2.1 ± 0.7
W (ppm)	2.0 - 24.0	3.2 ± 2.5
Au (ppm)	-	0.05

NOTE: Number of samples = 173

Fyffe and Pronk (1985) noted that anomalous Pb, Zn, Cu and Mn are related to northwest-trending fracture zones in the biotite granite. Uranium anomalies are spatially associated with highly silicified and brecciated granite and with quartz feldspar porphyry dykes of the North Pole Pluton. No anomalous values were found in the area underlain by biotite-muscovite granite of North Pole Pluton. Fyffe and Pronk (1985) have estimated that the Long Lake anomalies are displaced east- southeastward from their bedrock origin over a distance of 1 to 2 km.

4.2.5 Seep Water Geochemistry

Limited water sampling was conducted by Canadian Occidental Petroleum (Hauseux, 1980a). Six water samples were collected from four seeps in an area underlain by biotite granite at the eastern side of Long Lake, near Cronin Brook. The aim of the survey was to test the level of various elements, particularly, U in these water samples in an attempt to define uranium and other metal deposits in the area. Levels of anion complexes, alkalinity and conductivity of the water samples were also determined. Results of this survey are summarized in Table 10.

It was expected that uranium level in the water samples would be low because of the alkaline nature (av. pH = 8.54) of the water but it appears that the level of uranium is normal to above normal (Table 10) for natural waters which is of the order of 0.01 to 0.8 ppb (Boyle, 1982).

Table 10. Geochemical abundances of six seep water samples from Long Lake area (after Hauseux, 1980).

Elements	Range	Average
U (ppb)	0.07- 1.26	0.45
Cu (ppb)	2.00- 6.00	1.80
Zn (ppb)	4.00- 6.00	19.20
Mo (ppb)	ND* - 5.00	4.00
Mn (ppb)	ND	ND
Ag (ppb)	ND	ND
Fe (ppb)	ND	ND
Na (ppb)	2560.00-5360.00	3918.00
K (ppb)	280.00-1860.00	778.00
Ca (ppb)	1800.00-7000.00	4040.00
Mg (ppm)	350.00-1150.00	728.00
Cl (ppb)	ND -3770.00	1648.00
F (ppb)	480.00-3680.00	1660.00
HCO_3 (ppm)	29.00- 72.00	41.00
SO_4 (ppm)	10.00- 22.00	15.40
PO_4 (ppm)	ND - 0.07	0.01
SiO_2 (ppm)	9.30- 19.70	12.80
pH	6.63- 9.99	8.54
Conductivity (mho/cm)	55.0 - 174.0	131.0

* ND = Not detected

4.3.0 Geophysical Surveys

4.3.1 Introduction

Several geophysical surveys were carried out in the Long Lake area in order to delineate suitable geological features for uranium and associated metals mineralization. Some of the surveys such as radiometric techniques were used directly for uranium detection. Others were used indirectly to map structural elements and lithological units with which uranium deposits are expected to occur. These techniques included electromagnetic, magnetic and grav ty surveys.

4.3.2 Very-low Frequency Electromagnetic Technique (VLF)

The VLF survey was mainly performed over Long Lake. It was conducted during the winter of 1981, on the ice (Jagodits, 1981). The objectives of the survey were to map the sub-bottom geology particularly the shear zones with which polymetallic uranium veins are believed to be associated and to check the source of the geochemical anomalies delineated by lake sediment survey.

The survey was able to define several conductors. On the basis of disruptions in the continuity of these conductors three sets of shear zones trending north-south, north-northeast and north-northwest were identified.

4.3.3 Induced Polarization (IP)

To verify the results of the VLF survey, an induced polarization survey (apparent resistivity and apparent chargeability) was run over the same lines as the VLF. It was also hoped that faults or breccia zones, particularly mineralized ones, could be defined by areas of low resistivity (high conductivity).

Remarkable low resistivity zones extending through the centre of Long Lake were detected in this survey. The apparent chargeabilities computed over the same profiles produced anomalies coinciding with the low apparent resistivities. These anomalous zones may be related to the presence of polymetallic uranium veins deposited along faults believed to run through the centre of the lake.

4.3.4 Magnetic

A ground magnetic survey was conducted over Long Lake (Jagodits, 1981) to map the sub-bottom geology. The survey was unable to detect structural or lithological anomalies. However, a smooth magnetic gradient increasing from south to north of the lake was identified. This gradient may be attributed to a decrease in rock magnetism in the south as a result of transformation of magnetite to hematite by hydrothermal alteration.

An airborne fluxgate magnetic survey was conducted in 1950, by the Geological Survey of Canada (Fig. 6). By combining the aeromagnetic data (Fig. 6) with the geological data (Fig. 1), it is noted that the North Pole Pluton is associated with a low magnetic

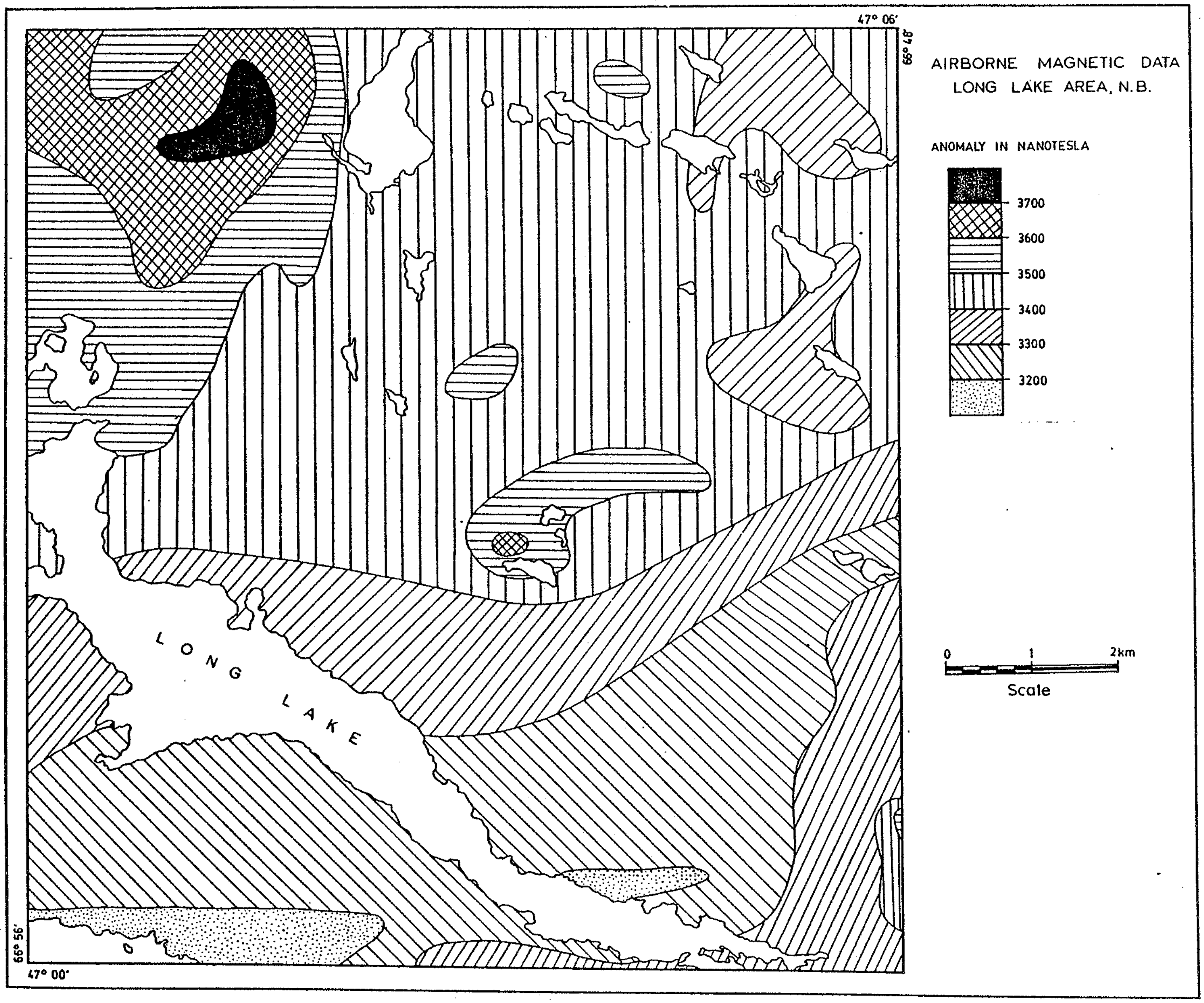

AIRBORNE MAGNETIC DATA
LONG LAKE AREA, N.B.
ANOMALY IN NANOTESLA
3700
3600
3500
3400
3300
3200
0
1
2km
Scale
LONG LAKE
47° 06'
66° 48'
66° 56'
47° 00'

Figure 6

response, relative to the country rocks. The magnetic contours (Fig. 6) over the pluton are in general smooth with gentle gradients suggesting that the granitic rocks of the North Pole Pluton are homogenous and have not been disturbed by structural deformation. The northeasterly trending nature of the magnetic anomaly over North Pole Pluton (Fig. 6) is probably related to a regional structural trend within the country rocks.

4.3.5 Gravity

Although it is not expected that gravity data will be of any direct help for mineralization detection in the Long Lake area, it is very useful in defining the granitic masses which may be favourable for the type of mineralization sought. Uraniferous granites of Europe (Plant *et al*., 1980, and Simpson and Plant, 1984) and of Nova Scotia (Chatterjee and Muecke, 1982) are associated with negative gravity anomalies (greater than-40 mgals). The gravity data over Long Lake area (Fig. 7) indicates a strong negative anomaly (greater than-48 mgals) over the North Pole Pluton. The centre of this gravity low coincides with the area where brecciation, hydrothermal alteration and mineralization are intensive (Fig. 1).

4.3.6 Alphametry

During the winter of 1981, the Canadian Occidental Petroleum Co. conducted an alphameter survey in the eastern Long Lake area (Leonard, 1982). The survey was carried out in order to detect anomalous radon (Rn) in the area as a possible guide for uranium

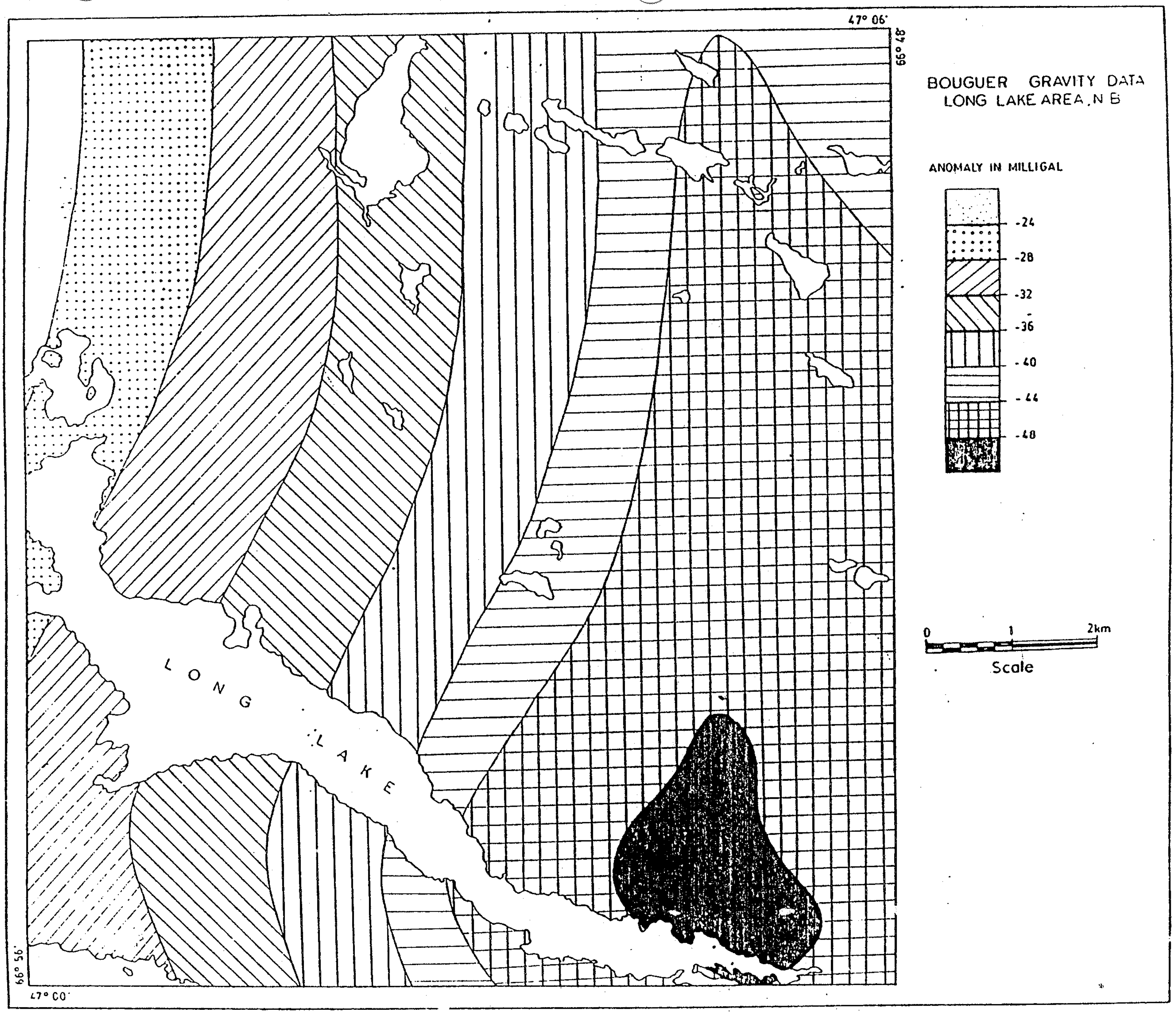

BOUGUER GRAVITY DATA
LONG LAKE AREA, N B
ANOMALY IN MILLIGAL
-24
-28
-32
-36
-40
-44
-48
0
1
2km
Scale
47° 06'
66° 48'
66° 56'
47° 00'
LONG LAKE

Figure 7

mineralization concealed by the overburden. The result of the alphameter survey indicated that the dominant trend for Rn in surface waters is northwest-southeast, northeast- southwest and east-west (Leonard, 1982). Most of the anomalies were confined to the eastern shore of Long Lake.

SECTION FIVE

AIRBORNE GAMMA RAY SPECTROMETRY DATA OF LONG LAKE AREA

5.1.0 Introduction

Two airborne gamma ray spectrometry surveys were carried out in the Long Lake area. The first survey was carried out as part of the Canada-New Brunswick Uranium Reconnaissance Program. The results of the survey were released by the Geological Survey of Canada in the spring of 1977 (D.N.R., 1977). The survey was conducted by flight lines 5 km apart.

The second airborne gamma ray spectrometry survey was carried out in 1984, as part of Canada-New Brunswick Mineral Development Agreement and the data was released by the Geological Survey of Canada in the spring of 1985 (D.N.R.E., 1986). The data of this survey are used in the present report, because they are of better quality and resolution than the 1977 data. A 256 channel spectrometer, with twelve 102 x 102 x 406 mm NaI(Tl) detectors was used in the 1984 survey. The lines were flown at a mean terrain clearance of 125 m with flight lines at 1 km line spacing.

The airborne gamma ray spectrometry data of eU (ppm), eTh (ppm) and K(%) were digitized at 1 km square grids. The grid points that fall on areas covered with waters were excluded from the analysis. The digitized values of eU, eTh and K of individual rock units were treated separately. The aim of the analysis was to define favourable lithological units which might have served as sources for the uranium mineralization.

5.2.0 Interpretation of Airborne Gamma Ray Spectrometry Data of Long Lake Area

The digitized data of eU, eTh and K were processed statistically in order to define radioelement anomalies. The arithmetic means, and standard deviations of eU, eTh and K for the Long Lake area are 1.80±0.41 ppm, 6.30±1.20 ppm and 1.30±0.30 ppm, respectively. The arithmetic means plus two standard deviations were considered as the threshold levels for eU, eTh and K in the area. Areas with radioelement contents above the arithmetic means are shown on Figure 8. Areas that exceed the mean plus two standard deviations (anomalous values) are also indicated on Figure 8, which shows two prominent anomalous areas. One anomaly is located on the eastern side of Long Lake over the North Pole Pluton and the other in the northeastern corner over the Ordovician (deformed) granites (Fig. 8). The radiometric anomaly over the North Pole Pluton coincides with anomalous uranium concentrations along highly altered and brecciated quartz-bearing faults (Fig. 1), and with a large negative Bouguer gravity anomaly (Fig. 7).

The radiometric anomaly over the Ordovician granites (Fig. 8) is oriented parallel to a fracture system (northwesterly trending) known to intersect the granite, and may be related to a late phase uranium-bearing quartz feldspar porphyry dyke of the North Pole Pluton (Fig. 1). It appears that the eU and eTh anomalies are separated from each other (Fig. 8). This suggests that uranium may have migrated northwesterly from its original place of deposition.

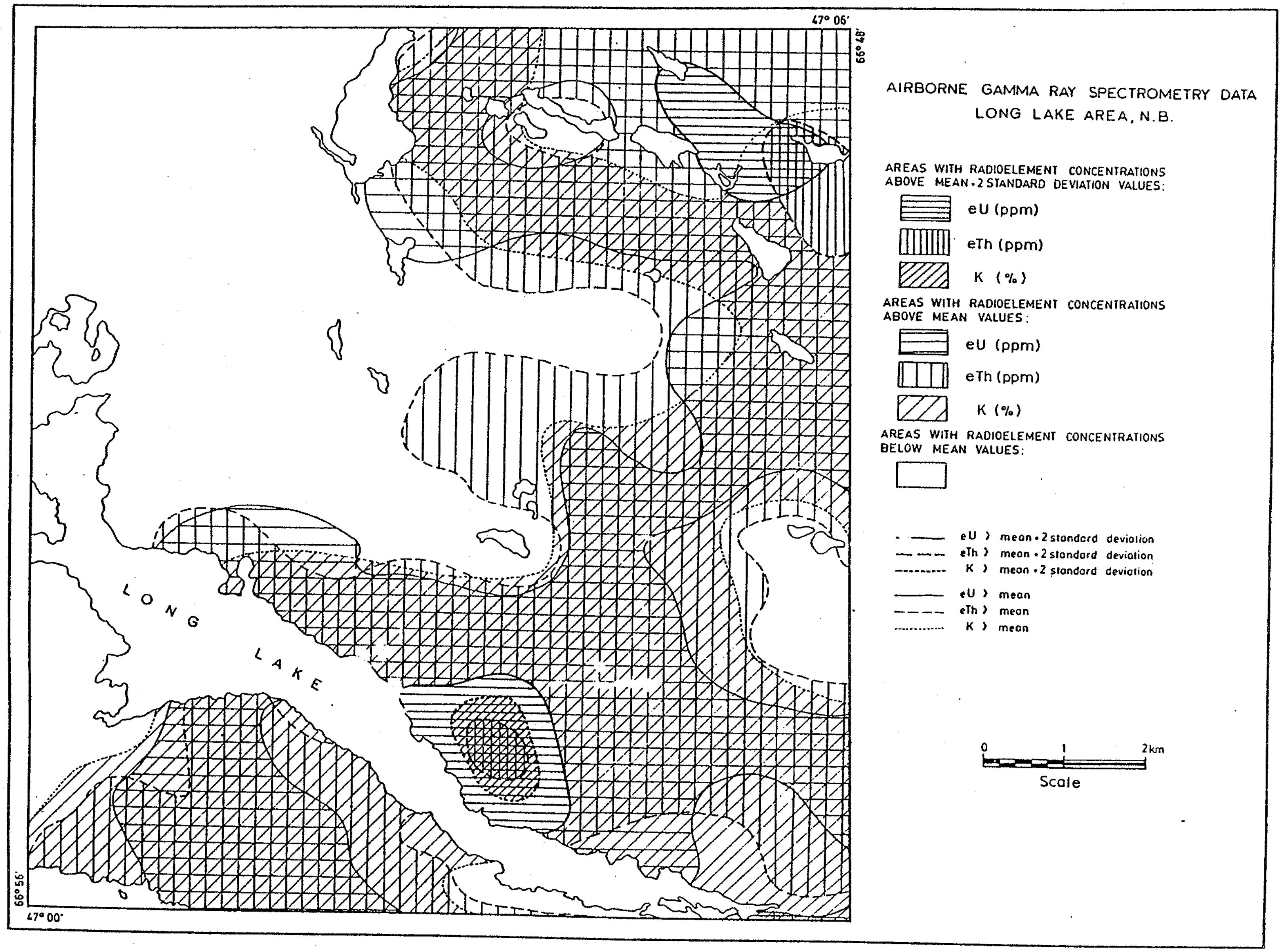

AIRBORNE GAMMA RAY SPECTROMETRY DATA
LONG LAKE AREA, N.B.
AREAS WITH RADIOELEMENT CONCENTRATIONS ABOVE MEAN+2 STANDARD DEVIATION VALUES:
eU (ppm)
eTh (ppm)
K (%)
AREAS WITH RADIOELEMENT CONCENTRATIONS ABOVE MEAN VALUES:
eU (ppm)
eTh (ppm)
K (%)
AREAS WITH RADIOELEMENT CONCENTRATIONS BELOW MEAN VALUES:
eU > mean+2 standard deviation
eTh > mean+2 standard deviation
K > mean+2 standard deviation
eU > mean
eTh > mean
K > mean
0
1
2km
Scale
LONG LAKE
47° 06'
66° 48'
66° 56'
47° 00'

Figure 8

5.3.0 Uranium Favourability Indicies of Long Lake Area

Quantitative uranium 'favourability indices' as developed by Saunders (1978, 1979) and Pirkle et al. (1980, 1982) are used for the Long Lake aeroradiometric data in order to test the applicability of these indices in the Long Lake area and to identify the best indices for delineating favourable areas for uranium mineralization. These indices are based on the assumption that the radioelement concentration in the overburden material is proportional to the amount of radioelement in the underlying bedrocks. These indices are thought to be useful in areas covered by overburden material such as, in the Miramichi Anticlinorium where bedrocks outcrops are scarce.

5.3.1 Saunders' Method

Saunders (1978, 1979) has proposed three statistical indices (U1, U2 and U3) to identify uraniferous provinces. These indices are based on statistical analysis of eU, eTh and K data from aeroradiometric maps.

The three uranium favourability indicies are:

$$U1 = \frac{(MeU+MeTh+MK).RSD(eU).RSD(eU/eTh).RSD(eU/K)}{M(eU/eTh)\ .\ M(eU/K)} \quad \text{------ (5-1)}$$

$$U2 = \frac{MeTh\ .\ MK}{MeU} \quad \text{------ (5-2)}$$

$$U3 = \frac{MeTh\ .\ MK}{(MeU)^2} \quad \text{------ (5-3)}$$

where:

M = Arithmetic mean

RSD = Relative standard deviation (coefficient of variation)

According to Saunders (1978, 1979) uraniferous provinces can be identified by their high U1, U2 and U3 indicies. Saunders has applied the technique on selected quadrangles regardless of the lithology and age of the rocks involved. In the present study the indicies were calculated for different lithological units in the area.

The results of the three favourability indices obtained for the Long Lake data are given in Table 11. It appears that the results of U2 and U3 are erratic. Favourability index U1 is the best of the three, and is high for the two-mica granite of the North Pole Pluton.

Since Saunders' formulae are largely based on the mean values of eU, eTh and K, particularly for U2 and U3 indices, then it was expected in advance that the results of the application of technique on the Long Lake data would not be valid, because the mean eU, eTh and K contents in the different lithological units are comparable (Table 11).

5.3.2 Principal Component Analysis Method

Pirkle et al. (1980, 1982) have proposed uranium favourability indices based on principal component analysis. Principal component analysis is a multivariate statistical technique that models the distribution of data variance, unlike Saunders' method, which is based upon the mean. The variability of eU, eTh and K are attributed to geological processes operating on the rocks.

In geological rock units the amount of U, Th and K present is proportional to the radioactive daughter isotopes ^{214}Bi, ^{208}Tl and ^{40}K respectively emitted from these rocks (assume that the system is under secular equilibrium).

Table 11. Statistical abundances of eU, eTh and K contents in various rock units of Long Lake area and calculated favourability indices of the rock units.

Age	Rock Units	No. Samples	Mean ± St. Dev. eU (ppm)	Mean ± St. Dev. eTh (ppm)	Mean ± St. Dev. K (%)	eU/eTh	eU/K	RSD (eU)	RSD (eU/eTh)	RSD (eU/K)	U_1	U_2	U_3	Eigen-values	% of total variance explained	Principal Components	Variables (eigenvectors) U	Variables (eigenvectors) Th	Variables (eigenvectors) K	|UPC1|/|UPC3|	|UPC2|/|UPC3|
Lower Devonian	Bt.-musc. granite	19	1.96±0.36	6.56±1.08	1.58±0.17	0.30±0.06	1.24±[illegible]	0.18	0.19	0.12	0.37	5.29	2.70	2.60 0.32 0.08	0.87 0.11 0.02	1 2 3	0.55 0.81 0.20	0.58 -0.54 0.61	0.60 -0.22 -0.77	2.75	4.05
Lower Devonian	Bt. granite	19	1.83±0.42	6.52±0.89	1.46±0.28	0.28±0.04	1.25±0.[illegible]	0.23	0.15	0.14	0.14	5.20	2.86	2.51 0.27 0.23	0.84 0.09 0.07	1 2 3	0.58 -0.13 -0.80	0.58 -0.63 0.52	0.57 0.76 0.29	0.73	0.16
Lower Devonian	Gabbro	5	1.24±0.29	4.82±0.40	0.86±0.05	0.26±0.05	1.42±0.27	0.23	0.18	0.19	0.15	3.34	2.70	2.47 0.42 0.10	0.82 0.14 0.04	1 2 3	0.61 -0.05 -0.79	0.55 0.74 0.38	0.56 -0.67 0.48	0.77	0.06
Ord.	Foliated granite	25	2.05±0.35	7.06±1.05	1.31±0.20	0.29±0.02	1.60±0.33	0.17	0.08	0.21	0.06	4.51	2.22	2.19 0.71 0.10	0.74 0.23 0.03	1 2 3	0.59 -0.53 0.61	0.65 -0.13 -0.75	0.48 0.84 0.27	0.97	0.87
Cambro-Ord.	Metased. rocks	31	1.57±0.29	5.47±0.83	1.05±0.21	0.29±0.05	1.52±0.23	0.19	0.18	0.15	0.09	3.66	2.33	2.31 0.57 0.12	0.77 0.19 0.04	1 2 3	0.51 0.85 0.17	0.59 -0.49 0.64	0.63 -0.22 -0.75	0.92	0.77
Precam.	Amphibolite	3	1.81±0.15	6.83±0.86	1.45±0.82	0.27±0.01	1.25±0.06	0.09	0.05	0.05	0.01	5.47	3.03	2.78 0.22 0.00	0.93 0.07 0.00	1 2 3	0.60 -0.05 -0.80	0.56 0.74 0.38	0.57 -0.67 0.47	0.75	0.06

In airborne gamma ray spectrometry data, the three principal component (PC) analyses for the three variable eU, eTh and K can be represented as follows:

$PC1 = a_1K + b_1Bi + C_1Tl$ ------------ (5-4)

$PC2 = a_2K + b_2Bi + C_2Tl$ ------------ (5-5)

$PC3 = a_3K + b_3Bi + C_3Tl$ ------------ (5-6)

a, b and c = factor loadings

Since we are interested in uranium; therefore we examine the ^{214}Bi (emitted by uranium) loadings on PC1, PC2 and PC3 which are designated as UPC1, UPC2 and UPC3, respectively. These loadings can be described as follows:

UPC1 = fraction of U originally deposited within a geologic unit.

UPC2 = fraction of U that has been mobilized by concentrating or leaching mechanisms.

UPC3 = portion of U that has not been affected by concentrating or leaching mechanisms and, thus, of the amount of non-mobilized U present.

The two uranium favourability indices and their meanings as explained by Pirkle et al. (1982) are:

(a) UPC1/UPC3 ratio:

The ratio provides an indicator of the absolute U mobilization. Large values of this ratio indicate that most of the originally deposited U is available for transportation while small values indicate little U available for transportation.

(b) UPC2/UPC3 ratio:

This ratio indicates the proportion of mobilized to nonmobilized U.

Large values indicate that most of the U available for transportation has been mobilized and small values of the ratio indicate little U mobilization.

The following conditions can be produced by applying the principal component analysis technique:

(1) Large UPC1/UPC3 ratio accompanied by large UPC2/UPC3 ratio means that the geological unit is favourable for uranium mineralization.

(2) Large UPC1/UPC3 ratio accompanied by small UPC2/UPC3 ratio means that only little U was originally deposited and hence the geological unit is unfavourable for U mineralization.

The principal component analysis technique has been tested successfully in uranium-producing areas in U.S.A. such as Shirley Basin, Wind River Basin and South Texas Coastal Plain (Pirkle et al., 1982). It has shown that all of the more favourable areas have UPC1/UPC3 values greater than 2.

The technique is used for the Long Lake aeroradiometric data. The results obtained for the two favourability indices are given in Table 11 for various lithological units. The results of the analysis is encouraging and has successfully delineated the 2-mica granite of North Pole Pluton as the most favourable unit for U mineralization in the Long Lake area. Both ratios, UPC1/UPC2 and UPC2/UPC3 are large and exceed 2. Plot of UPC1/UPC3 ratio vs UPC2/UPC3 ratio for the different lithological units in the Long Lake area is shown in Figure 9. If we assume that the value 2 is the ratio separating the favourable units from the unfavourable units, then it appears that the 2-mica granite of North Pole Pluton is the only favourable unit for U mineralization in the area (Fig. 9).

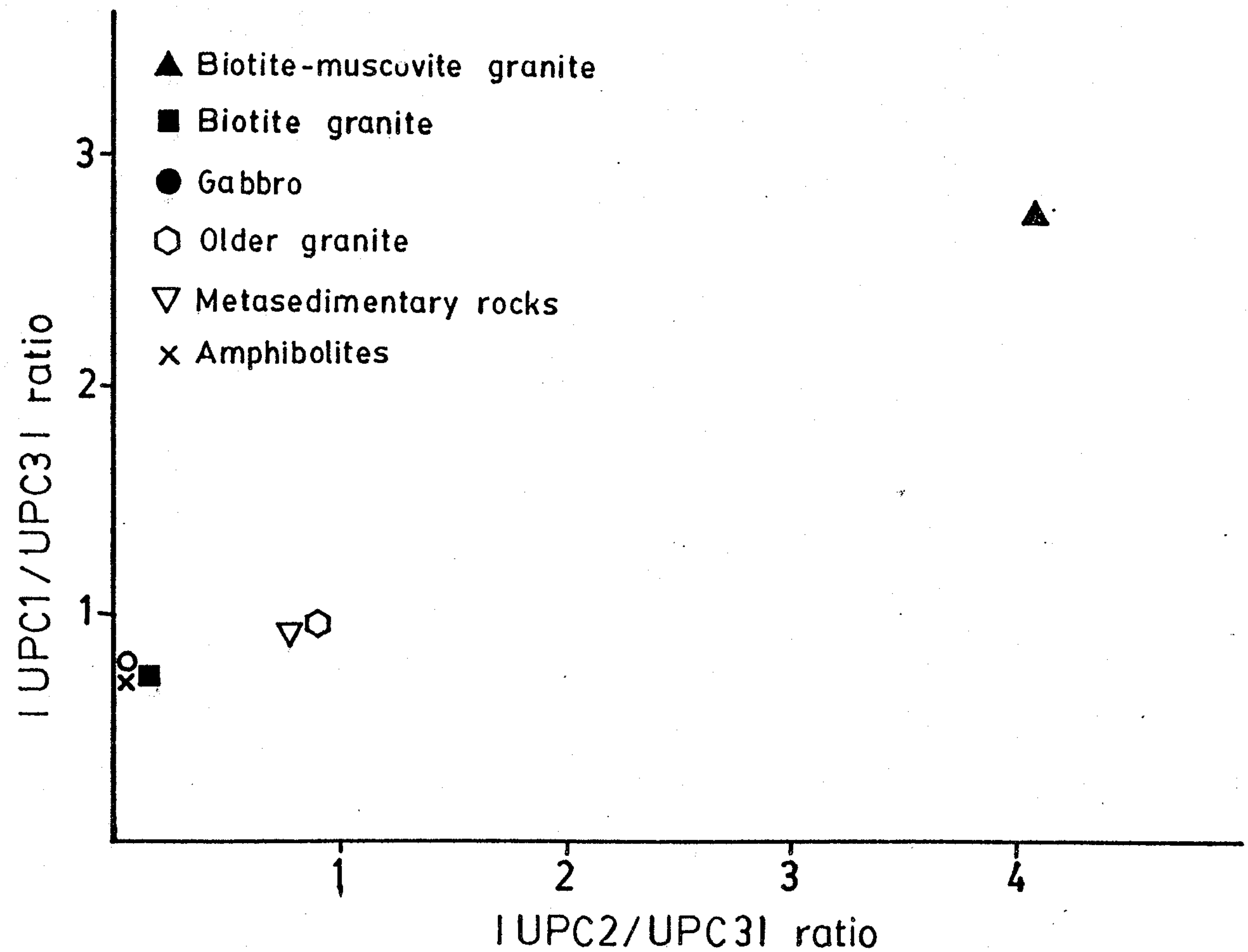


Figure 9. Plot of |UPC1/UPC3| ratio vs. |UPC2/UPC3| ratio for various lithological units in the Long Lake area.

SECTION SIX

TRENCHING, DRILLING AND URANIUM METALLOGENESIS OF LONG LAKE AREA

6.1.0 Introduction

Following encouraging results obtained from geochemical and geophysical surveys in the Long Lake area, Canadian Occidental Petroleum conducted a trenching and drilling program to determine the cause of the geochemical and geophysical anomalies. In this report only a brief review of the trenches and drilling data is presented. For further details refer to Hauseux (1980a, 1980b, 1981 and 1982).

6.2.0 Trenching

Twenty-seven back-hoe trenches have been dug in the Long Lake area, most of them over or near geochemical and geophysical anomalies in areas underlain by granite of the North Pole Pluton. Base-metal sulphide veins were located in most of the trenches along with anomalous levels of U, Ag, Mo, Sn and Au.

The trenches were systematically sampled and the samples were chemically analysed for their U, Th, Cu, Pb, Zn, Mo, Sn, Ag and Au contents (Appendix II).

A geological cross-section of Trench 27 is shown in Figure 10. Geochemical profiles of U, Th, Sn, Mo, Ag, Zn, Pb, and Cu were also plotted in Figure 10 in order to examine relationships between these elements and the

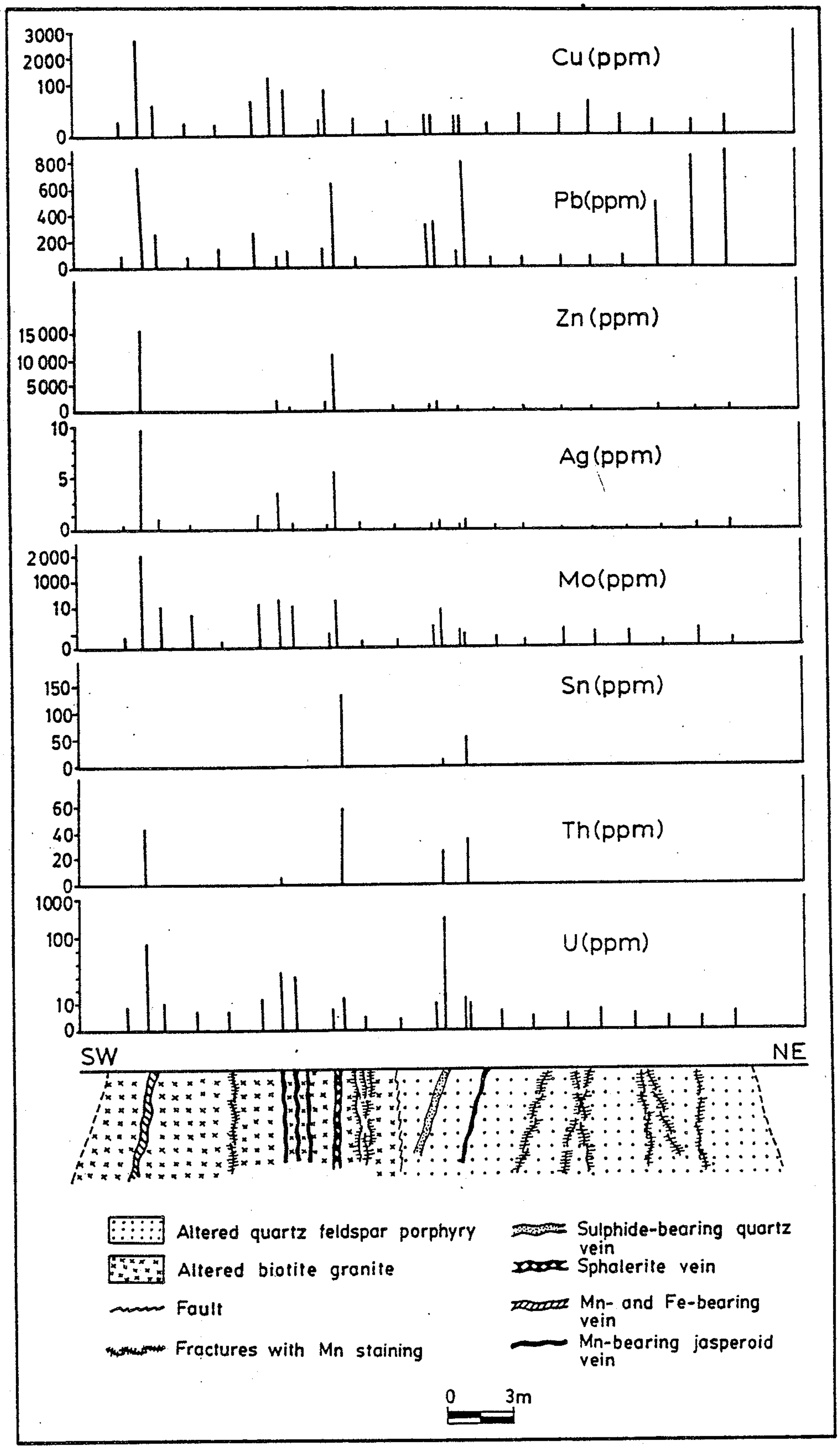


Figure 10. Geological cross-section and geochemical profiles of U,Th,Sn,Mo,Ag,Zn,Pb and Cu for trench No. 27 in the Long Lake area.

geological features (fracturing, veining and alteration) exhibited by the bedrocks.

As shown in Figure 10, uranium abundances increased remarkably in fracture-filling veins, particularly in quartz veins crosscutting the quartz feldspar porphyry. Smaller amounts of uranium are also concentrated (in lesser amounts than in quartz veins) in Fe- and Mn-bearing veins along with Th, Mo, Ag, Zn, Pb and Cu. Mo and Pb also favour the quartz veins.

The portions of the host granite that have not been affected by fracturing, alteration or veining appear to contain normal levels of U and other elements. Hence, it seems that U and associated mineral deposits in the Long Lake area are formed chiefly as a result of hydrothermal action within the fracture systems. Bedrock lithology may also play a role in the mineralization, because mineralization is more intensive in fractures and veins intersecting the quartz feldspar porphyry dykes and the biotite-muscovite granite, than in the biotite granite of the North Pole Pluton.

6.3.0 Diamond Drilling

Several holes were diamond drilled in the area to investigate various geochemical and geophysical anomalies and to locate the source(s) of uranium and associated metals.

Fifty-nine drill holes have been completed in the Long Lake area since 1956 by several exploration companies. Most of the drilling performed after 1979 was carried out by the Canadian Occidental Petroleum. The drill cores were systematically analysed for Cu, Pb, Zn, Ag and Mo contents. In addition, some cores were analysed for U, Th, Co, Mn, W, Sn, Sb, Bi and Au contents. Best results obtained from the drill holes are shown in Table 12.

Table 12. Best analytical results from the drill core conducted by Canadian Occidental Petroleum in the Long Lake area (after Hauseux, 1982).

Elements	Concentration/Thickness	Hole No.
1980 Drilling Program:		
U	49.0 ppm/0.46 m	80-3
Cu	18,800 ppm/0.30 m	80-1
Pb	2,160 ppm/1.52 m	80-4
Zn	153,000 ppm/0.30 m	80-3
Ag	52.0 ppm/1.52 m	80-1
Mo	260.0 ppm/0.61 m	80-1
1981 Drilling Program:		
U	860.0 ppm/0.30 m	81-10
Cu	40,000 ppm/0.30 m	81-9
Pb	19,200 ppm/0.15 m	81-6
Zn	96,000 ppm/0.30 m	81-1
Ag	86.0 ppm/0.30 m	81-9
Mo	540.0 ppm/0.30 m	81-7
1982 Drilling Program:		
U	3,440 ppm/0.15 m	82-16
Cu	29,200 ppm/0.46 m	82-15
Pb	25,600 ppm/0.10 m	82-19
Zn	31,400 ppm/0.11 m	82-15
Mo	2,040 ppm/0.03 m	82-17

High concentrations of uranium were observed in holes that were drilled at or near the centre of Long Lake where a mineralized fault is presumably present. Two of these holes (82-16 and 82-18) are plotted in Figure 11. Lithological variation of host rocks, fracturing, alteration, veining and mineralization as well as analytical results for U, Pb, Cu, Zn and Mo are also presented on Figure 11. Only a few samples from the cores were analyzed for uranium, as indicated by bars on Fig. 11. From the few samples analysed, it appears that U is concentrated along shear zones crosscutting granitic rocks of North Pole Pluton, particularly those which are brecciated and accompanied by chalcedony veins. It seems also that uranium mineralization favours moderately fractured and altered host rocks. High uranium concentration in the veins accompanies high concentrations of Mo and Pb (Fig. 11).

A block diagram was constructed for part of the Long Lake area on the basis of some of the drill hole data (Fig. 12), and various vein-type deposits encountered in the drill holes were also plotted. It appears that the mineralization in the area is more intensive near the centre and eastern shore of Long Lake.

6.4.0 Uranium Metallogenesis of Long Lake Area

The staff of Canadian Occidental Petroleum collected a considerable amount of samples (float, outcrop and trenches) during their survey exploration program. These samples were chemically analysed for U, Th, Cu, Pb, Zn, Mo, Sn, Ag and Au contents. Results of the analyses are listed in Appendix II. Most of the samples were taken from the granitic rocks of the North Pole Pluton. The uranium and other element contents of the samples were processed statistically to determine their abundances. Because almost all the

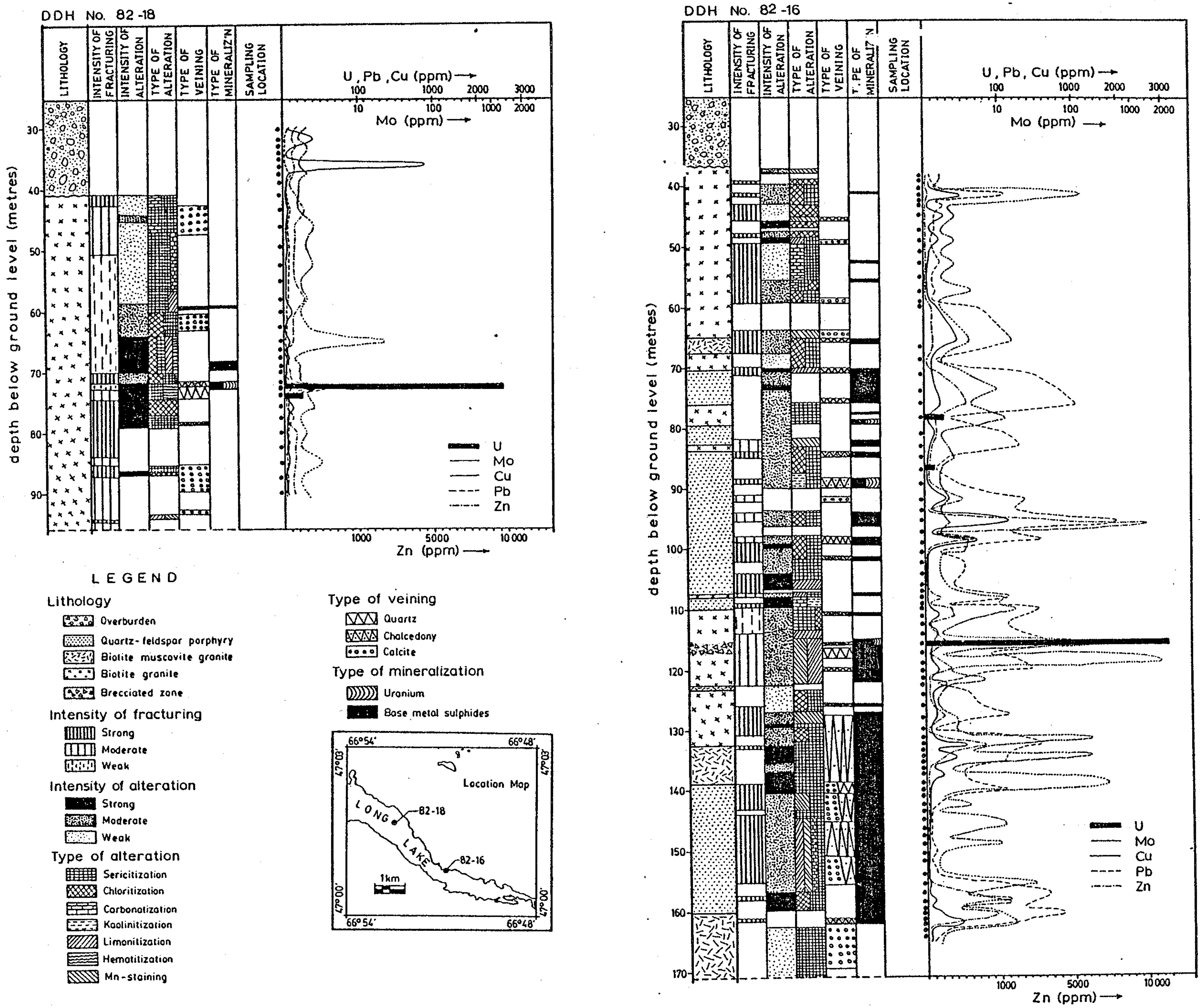
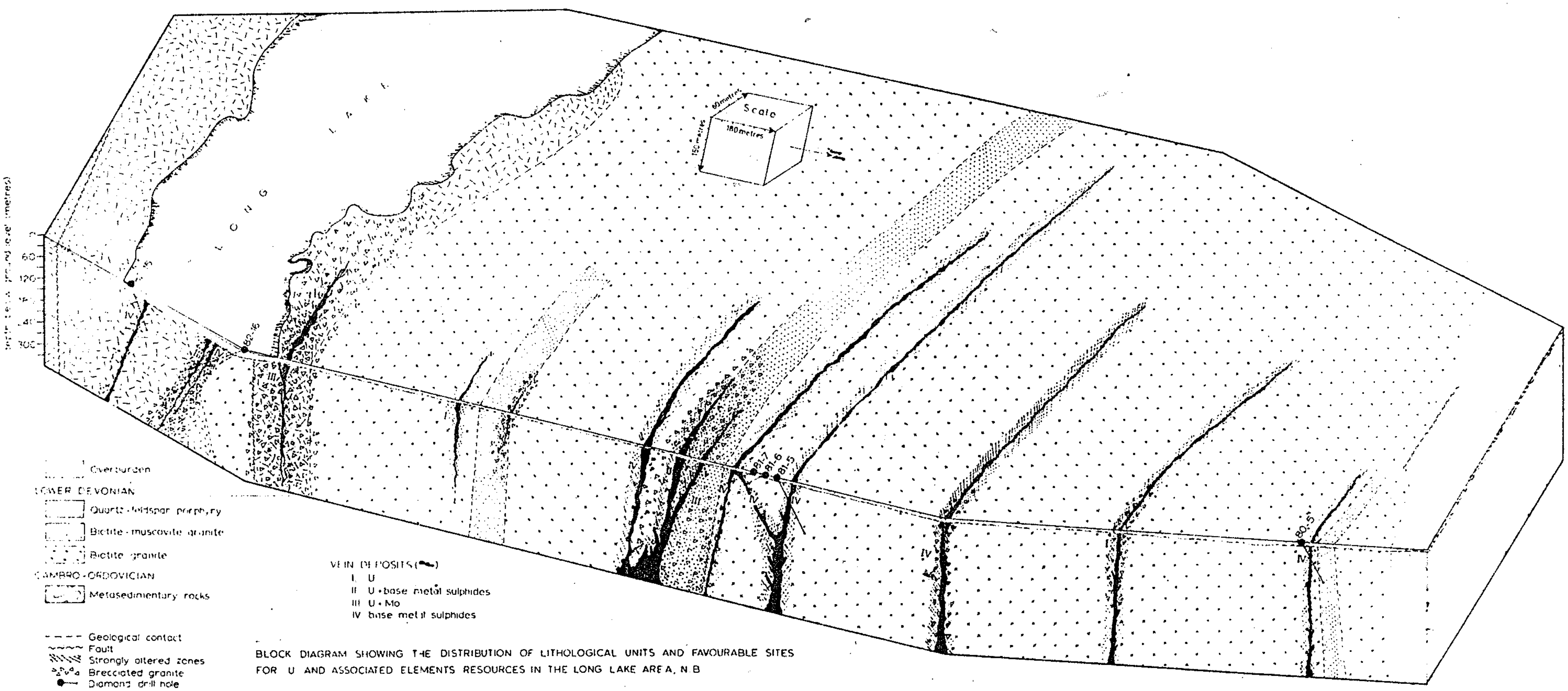


Figure 11. Down-hole plot from drill holes 82-16 and 82-18 of U,Mo,Cu,Pb and Zn in the Long Lake area.



BLOCK DIAGRAM SHOWING THE DISTRIBUTION OF LITHOLOGICAL UNITS AND FAVOURABLE SITES FOR U AND ASSOCIATED ELEMENTS RESOURCES IN THE LONG LAKE AREA, N B

Figure 12

float samples are mineralized and their sources were not fully identified, they were dealt with separately. On the other hand the trench samples of the bedrock were combined with the outcrop samples in the statistical analyses.

Statistical abundances of elements in the bedrock and float samples in the Long Lake area are given in Table 13.

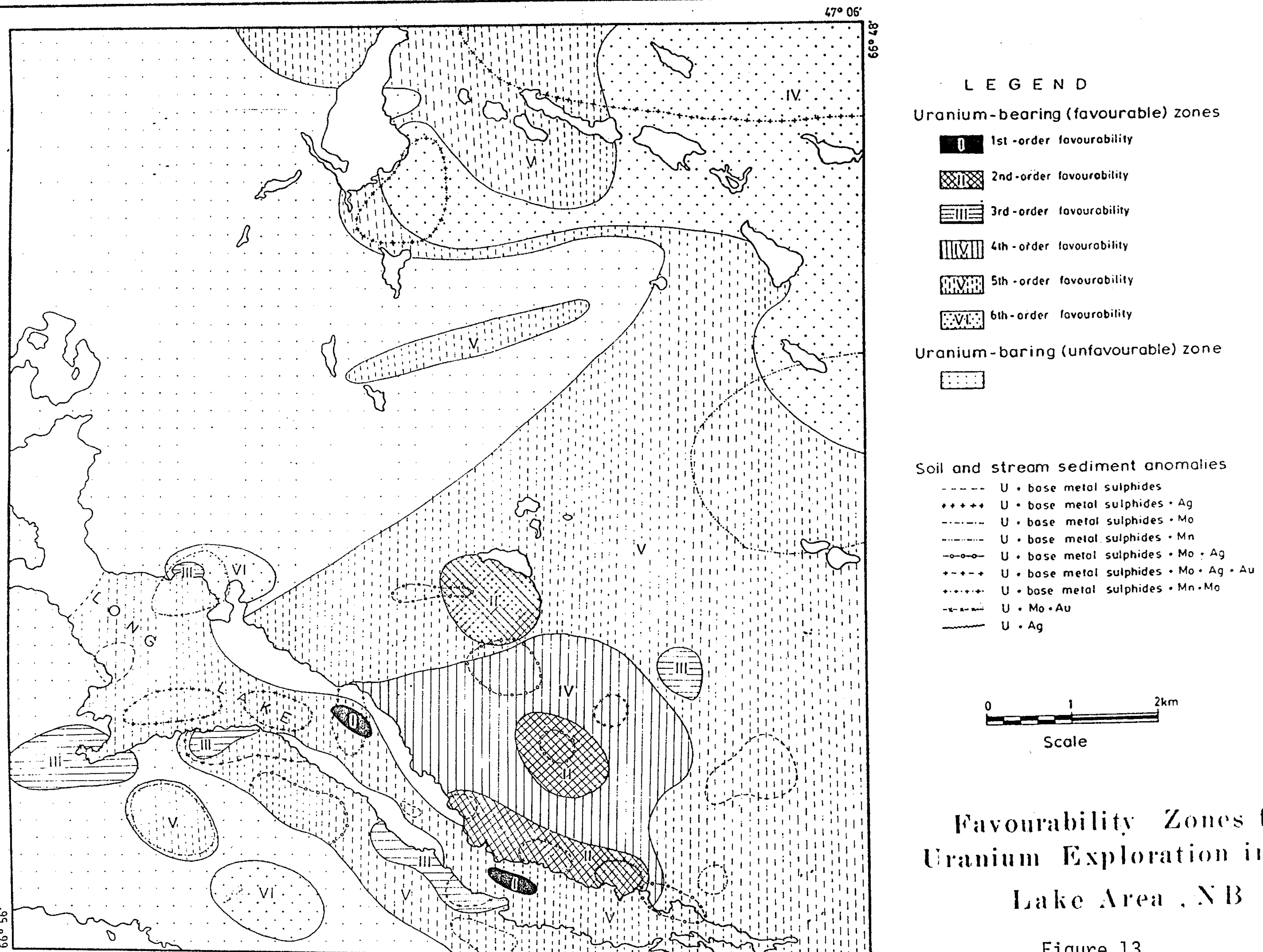
The median (50 percentile) of the data was chosen to represent the threshold level of elements in the samples. Anomalous levels (greater than50 percentile) of U and Th in the bedrock and float samples were plotted on the geological map of Long Lake area (Fig. 1). Furthermore, the U and Th anomalies were classified according to their statistical element abundances (75 percentile, 90 percentile and 95 percentile; Table 13) into three different classes; low, medium and high (Fig. 1). Anomalous levels of Cu, Pb, Zn, Mo, Sn, Ag and Au in the samples are also given beside U and Th on the map (Fig. 1). As shown in Figure 1, most of the highly anomalous occurrences are located on the eastern side of Long Lake. These occurrences are in close association with the quartz feldspar porphyry dykes and with highly altered and brecciated zones within these rocks. The centre of mineralization on the eastern side of Long Lake coincides with the large negative gravity anomaly as well as with an airborne radiometric anomaly.

Table 13. Statistical abundances of elements in bedrock and float samples in the Long Lake area.

	BEDROCK SAMPLES						FLOAT SAMPLES					
Element	n	Mean±St.Dev.	50 Percentile (Median)	75 Percentile	90 Percentile	95 Percentile	n	Mean±St.Dev.	50 Percentile (Median)	75 Percentile	90 Percentile	95 Percentile
U (ppm)	54	93.6± 427.8	6.4	14.8	70.0	503.7	31	274.2±672.6	26.4	130.0	1202.0	2256.0
Th(ppm)	52	68.3± 119.9	24.0	41:8	208.7	394.8	25	11.9±8.4	11.0	16.5	22.8	31.0
Cu(ppm)	55	2172.7±6745.0	92.0	196.0	5828.0	21840.0	31	83.5±203.8		83.0	160.0	660.0
Pb(ppm)	54	929.2±2482.0	168.0	800.0	2760.0	3130.0	31	241.0±409.6	100.0	240.0	816.0	1460.0
Zn(ppm)	55	2990.3±7020.6	480.0	2270.0	9420.0	19560.0	31	800.9±3284.1	48.0	219.0	1044.0	8115.9
Mo(ppm)	51	76.6± 288.3	11.0	24.0	117.6	408.0	26	4693.0±23519.0	15.5	101.5	451.0	78370.3
Sn(ppm)	15	150.1± 253.2	58.0	134.0	653.8	976.0	-	-	-	-	-	-
Ag(ppm)	47	17.9± 48.1	2.0	8.0	57.2	106.8	15	2.72±4.3	1.0	3.0	11.0	17.0
Au(ppm)	5	1168.2±1498.2	200.0	2800.0	3000.0	3000.0	6	18.3±12.0	17.5	31.0	31.0	31.0

6.5.0 Favourability Zones for Uranium Exploration in Long Lake Area

On the basis of geochemical anomalies (soils, lake sediments, spring and stream sediments, bedrocks and drill cores) and radiometric anomalies, the Long Lake area is divided into favourable and unfavourable areas for U and associated elements exploration (Fig. 13). The favourable areas are further subdivided into six zones with different orders of favourablity. These zones of favourability were delineated according to the quantity and quality of the data used in their identifications. For example, in the first-order favourability zones, positive signs of mineralization were obtained from drill cores, overburden materials, bedrock and radiometric data. In the sixth-order favourability, anomalous U was found only in spring and stream sediment samples. Hence, future exploration for U in the Long Lake area should take into consideration the same order. The best target, as the available data indicates, for U exploration in the area would be the centre of Long Lake and its eastern side.



Favourability Zones for Uranium Exploration in Long Lake Area, NB

Figure 13

SECTION SEVEN

URANIUM RELATIONSHIP WITH THE PETROCHEMISTRY OF NORTH POLE PLUTON

7.1.0 Introduction

Many uranium deposits around the world are directly linked to granitic rocks. This link can be observed also in the Long Lake area where polymetallic vein-type uranium deposits are in time and space associated with the Lower Devonian granitic rocks of the North Pole Pluton. In order to understand such a relationship it will be necessary to investigate the petrochemical characteristics of the granitic rocks.

Analyses of eighteen samples, including both fresh and altered rocks, were selected from the report by Fyffe and Pronk (1985) and used in the present report. Sample locations and the analytical results are given in Appendix III.

Averages for the major and selected trace elements of various phases of the North Pole Pluton are presented in Table 14.

Mineralogical variation between the three phases of the North Pole Pluton is also shown in the significance variation in major and trace element geochemistry (Table 14).

The data in Table 14 indicate that the North Pole Pluton has a narrow range of SiO_2 content, a feature typical of S-type granites of Chappel and White (1974). Geochemically the North Pole Pluton is a very evolved granite (SiO_2 greater than 70 wt.%).

Table 14. Averages of major and trace elements in fresh and altered rocks of various phases of the North Pole Pluton and their comparison with normal and uraniferous granites.

Chemical Composition	Biotite granite				Biotite-muscovite granite				Quartz-feldspar porphyry						(a) Average normal granites	Uraniferous Granites	
	unaltered		altered with sulphide mineralization		unaltered		Silicified and brecciated		unaltered		mildly altered		Intensely altered			(b) British Caledonides (n = 69)	South (c) Mountain Batholith (n = 136)
	n	average	n	average	n	average	n	average	n	average	n	average	n	average			
SiO_2(%)	4	71.2	5	72.7	2	73.9	2	83.6	1	76.5	1	76.5	3	76.8	71.3	-	74.48
TiO_2(%)	4	0.44	5	0.39	2	0.15	2	0.14	1	0.15	2	0.12	3	0.14	0.31	0.13	0.08
Al_2O_3(%)	4	14.8	5	14.0	2	14.2	2	8.7	1	13.3	2	13.4	3	12.8	14.32		13.90
Fe_2O_3(%)	4	0.53	5	1.83	2	0.55	2	0.67	1	0.70	2	0.87	3	1.85	1.21	0.88	
FeO(%)	4	2.0	5	3.1	2	1.1	2	0.34	1	0.64	2	0.49	3	1.90	1.64		0.93
MnO(%)	4	0.07	5	0.13	2	0.04	2	0.02	1	0.05	2	0.03	3	0.24	0.05		0.02
MgO(%)	4	0.75	5	0.69	2	0.44	2	0.18	1	0.30	2	0.25	3	0.24	0.71	0.13	0.05
CaO(%)	4	1.29	5	0.12	2	0.74	2	0.11	1	0.28	2	0.09	3	0.10	1.84	0.26	0.75
K_2O(%)	4	4.1	5	4.0	2	4.9	2	3.6	1	4.9	2	5.2	3	3.8	4.07	5.0	4.39
Na_2O(%)	4	3.5	5	0.2	2	3.3	2	0.19	1	3.4	2	0.86	3	0.16	1.68	3.13	3.48
P_2O_5(%)	4	0.10	5	0.09	2	0.09	2	0.06	1	0.0	2	0.03	3	0.06	0.12		0.44
CO_2(%)	4	0.06	5	0.04	2	0.01	2	0.04	1	0.18	2	0.06	3	0.04	0.05		
Be(ppm)	4	6.0	5	4.8	2	6.0	2	7.15	1	6.8	2	8.25	3	5.7	5.0		
Ba(ppm)	4	507.5	5	271.0	2	435.0	2	220.0	1	300.0	2	175.0	3	168.3	600	258	39
Cu(ppm)	4	12.5	5	73.4	2	10.5	2	6.0	1	3.0	2	37.5	3	93.7	10.0	0.0	31
F (ppm)	4	362.5	5	796.0	2	305.0	2	385.0	1	600.0	2	450.0	3	673.3	810.0		4500
Mo(ppm)	4	1.75	5	9.4	2	0.75	2	7.0	1	1.0	2	3.0	3	6.67	1.8		1.4
Pb(ppm)	4	24.0	5	99.6	2	25.0	2	75.0	1	18.0	2	129.5			20.0	26.0	
Rb(ppm)	4	163.8	5	337.0	2	219.0	2	228.5	1	201.0	2	280.0	3	370.7	150.0	455.0	769
B (ppm)	4	4.5	5	27.0	2	3.0	2	52.5		-	2	10.0	3	11.3	12		
Sn(ppm)	4	6.73	5	99.8	2	41.0	2	7.05	1	4.6	2	8.0	3	75.3	3.0		39
Sr(ppm)	4	117.0	5	5.67	2	68.5	2	14.5	1	99.0	2	13.5	3	7.0	285.00	67.0	38
Zn(ppm)	4	180.5	5	419.0	2	52.5	2	60.0	1	96.0	2	202.5	3	1313.0	40.0	28.0	86
W (ppm)	4	4.0	5	14.4		-		-		-	2	4.0	3	6.0	1.5		2
Li(ppm)	4	12.75	5	23.80	2	24.0	2	96.0	1	6.0	2	9.5	3	1[illegible].0	30.0	75.0	517
Bi(ppm)	4	0.06	5	3.36	2	0.6	2	0.06		-	2.	0.08	3	2.2	.15-2		
Zr(ppm)	4	138.8	5	273.0	2	87.5	2	72.5	1	75.0	2	60.0	3	78.3	180.0	65	
S (ppm)	4	62.5	5	1224.0	2	20.0	[illegible]	370.0	1	120.0	2	40.0	3	5906.7	330		
U (ppm)	4	5.1	5	5.3	2	4.2	[illegible]	7.75	1	4.9	2	17.65	3	11.53	4.0	12.60	8.3

(a) Average major elements composition from LeMaitre (1976); Sr, Rb, Zr, Ni, Zn, Cu, Cr, U, Th, Pb, Co, Li and Be from Taylor (1964); F from Allman and Koriting (1969)

(b) Data from Simpson et al. (1979) and Plant et al. (1980)

(c) Data from Clarke and Muecke (1985); U from Chatterjee and Muecke (1982)

Fresh samples from different phases of North Pole Pluton fall well within the area of 'peraluminous' granites (Fig. 14) as indicated by their high Al/(Na + K + Ca) ratios. This also suggests that the granitic rocks of the North Pole Pluton may be derived by partial melting of pre-existing sedimentary rocks.

Uranium content in the granitic rocks of the North Pole Pluton appears to be increased considerably in response to hydrothermal alteration (Fig. 15). The effect of alteration on U content in the biotite granites seems to be minimum. The hydrothermal effect on U content is most apparent in the biotite- muscovite granites where a two fold increase is noted (Fig. 15) but is most pronounced in the quartz feldspar porphyry.

It also appears that U content is higher in zones of mild rather than intense alteration (Fig. 15). This relationship is also observed in the drill cores.

Uranium content in the various granitic phases of North Pole Pluton is contrasted with average U content in normal granites and with uraniferous granites of the British Isle and Nova Scotia (Fig. 16). Figure 16 indicates that U is low relative to uraniferous granites, but is slightly higher than in normal granites. This may suggest that U content in the North Pole Pluton is derived from rocks originally containing low U. Alternatively, U may have been depleted from the surface rocks of North Pole Pluton, possibly by meteoric water operating at the surface of the granites.

The major element compositions (Fig. 17) as well as trace element compositions (Fig. 18 and 19) of various phases of North Pole Pluton were also contrasted with normal granites and uraniferous granites. As in uraniferous granites, the North Pole Pluton is characterized by higher SiO_2, K_2O and Na_2O

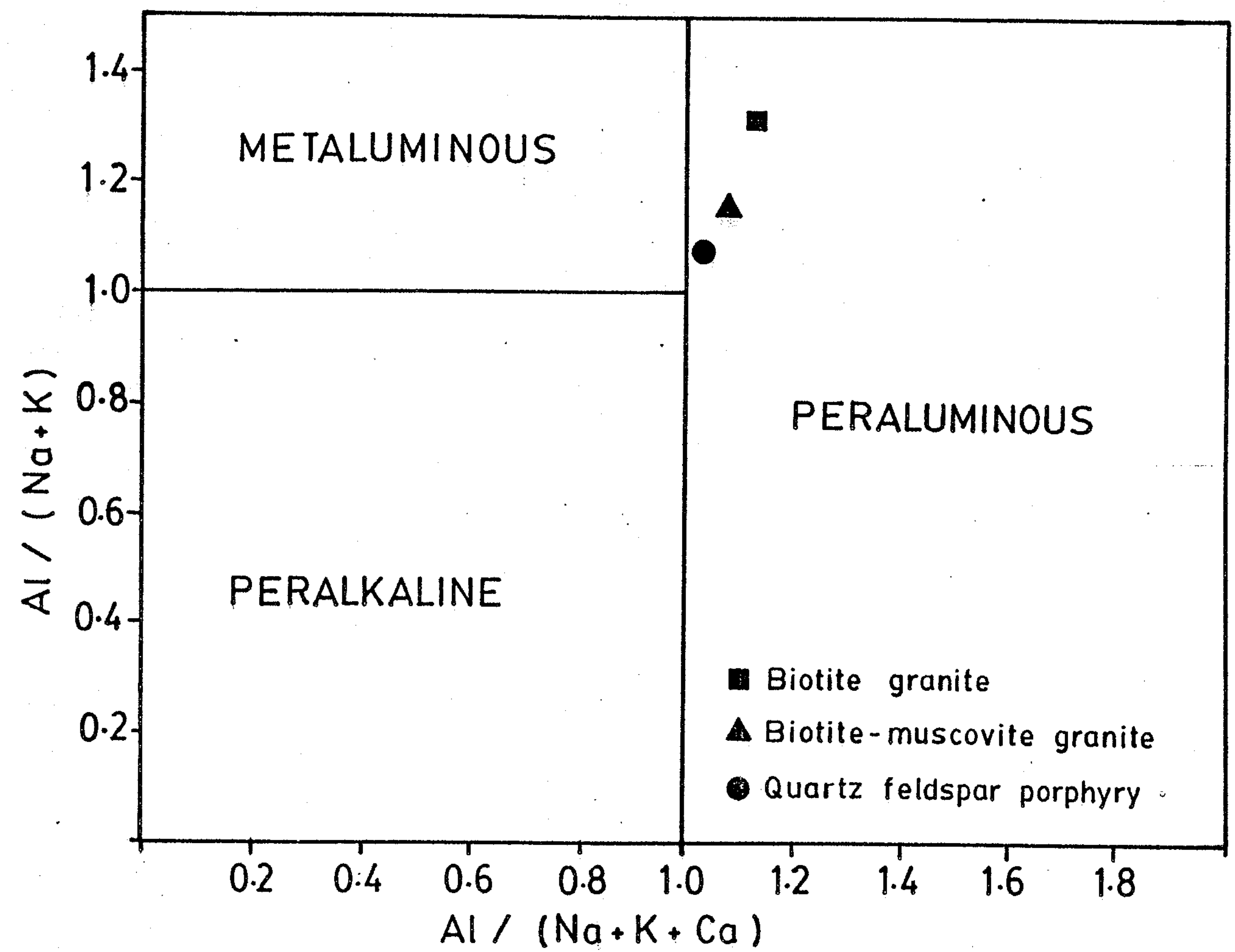


Figure 14. Plot of Al/(Na+K) vs. Al/(Na+K+Ca) for the unaltered rocks of the North Pole Pluton.

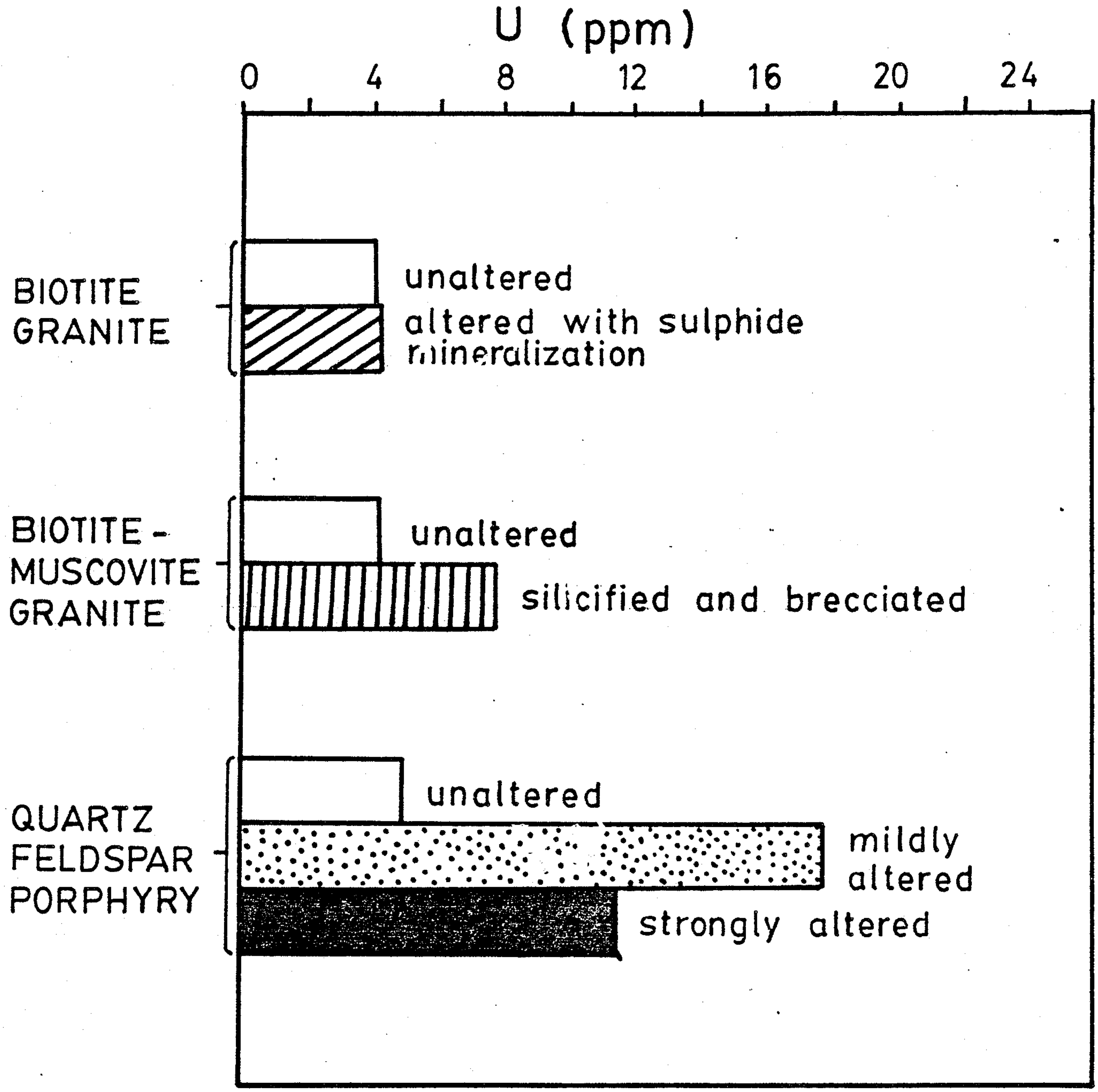


Figure 15. The effect of alteration on U content in the North Pole Pluton.

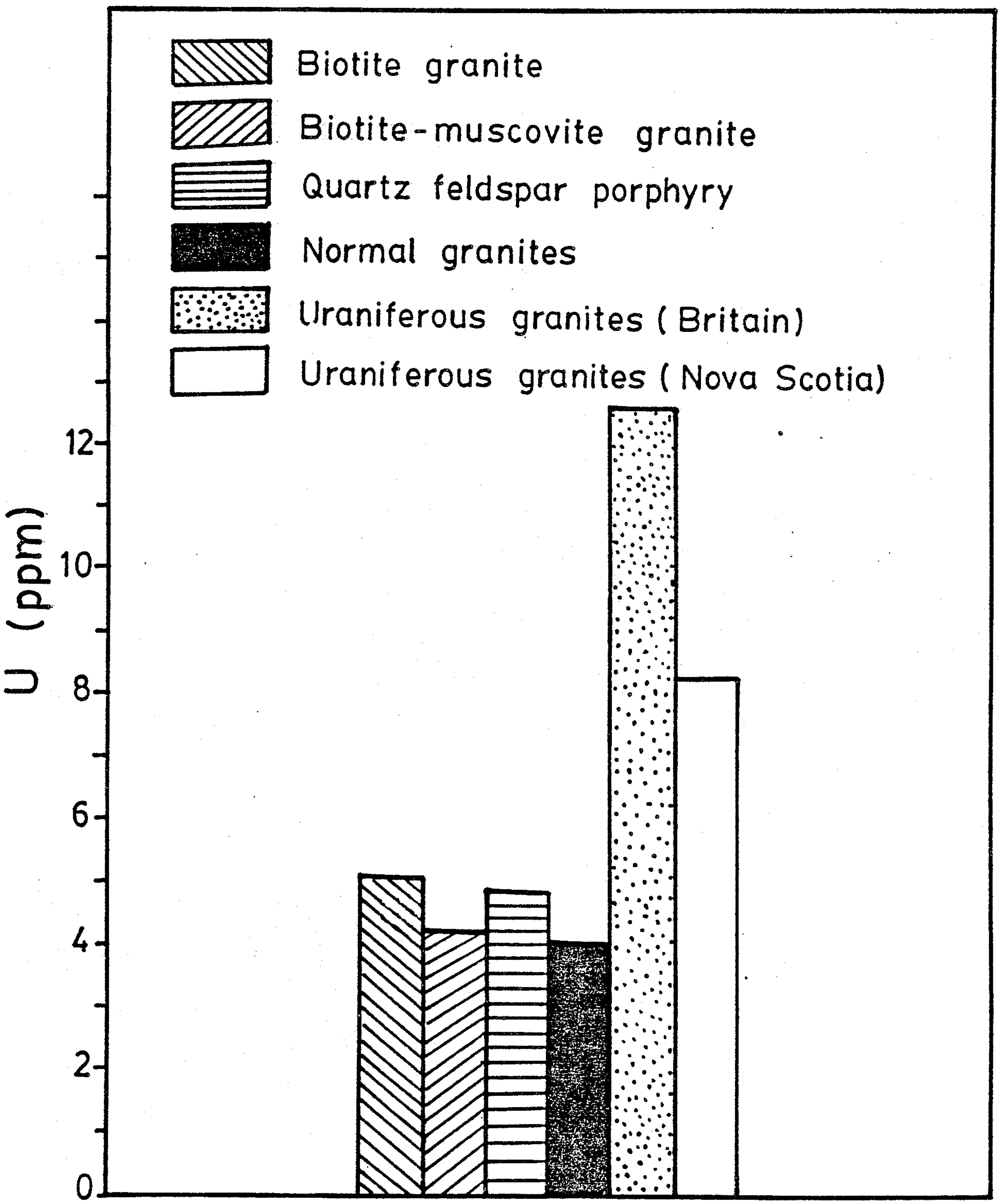


Figure 16. Uranium contents in various phases of the North Pole Pluton and comparison with the contents of normal and uraniferous granites.

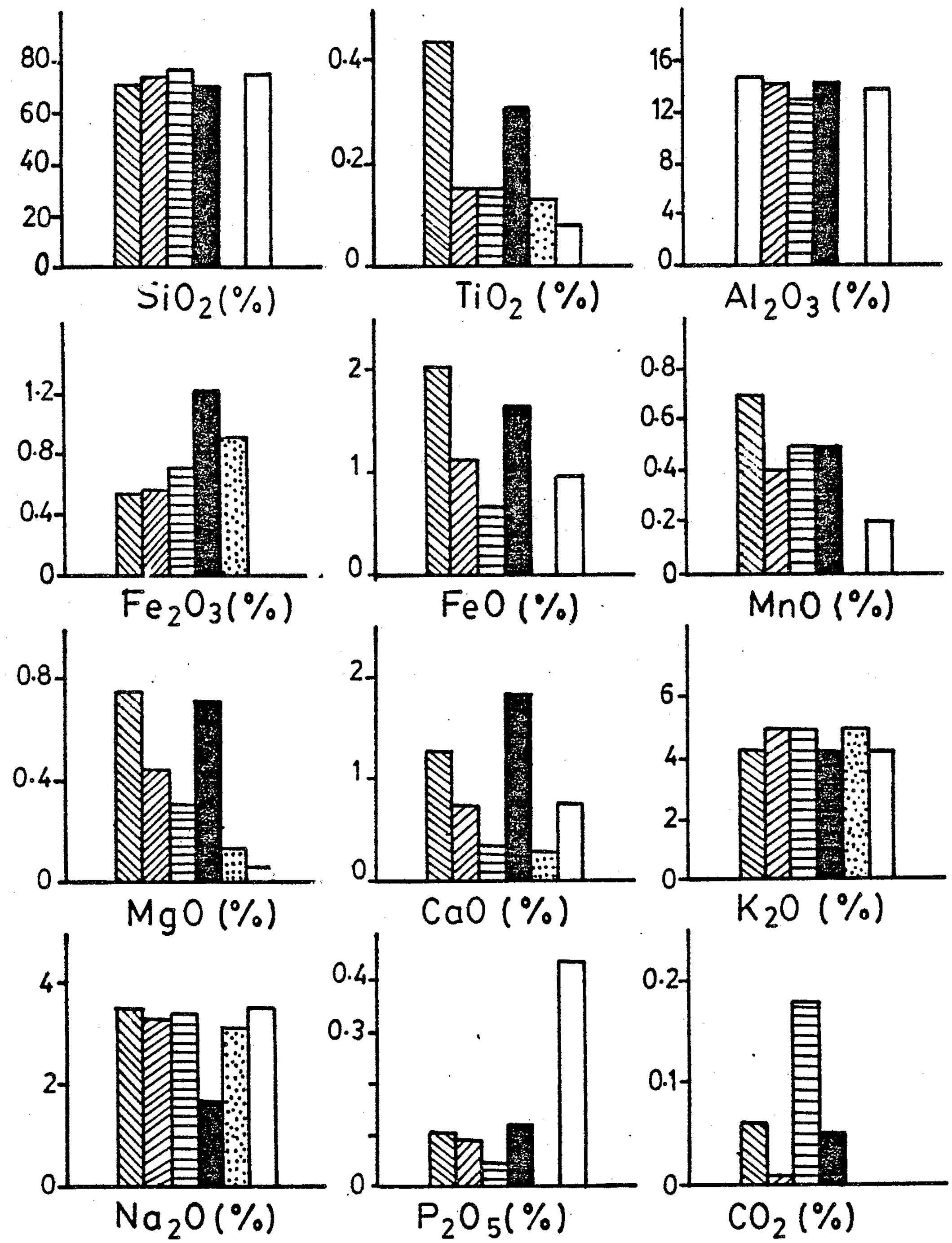


Figure 17. SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, K_2O, Na_2O, P_2O_5 and CO_2 contents in various phases of the North Pole Pluton and comparison with the contents of normal and uraniferous granites (legend as in Figure 16).

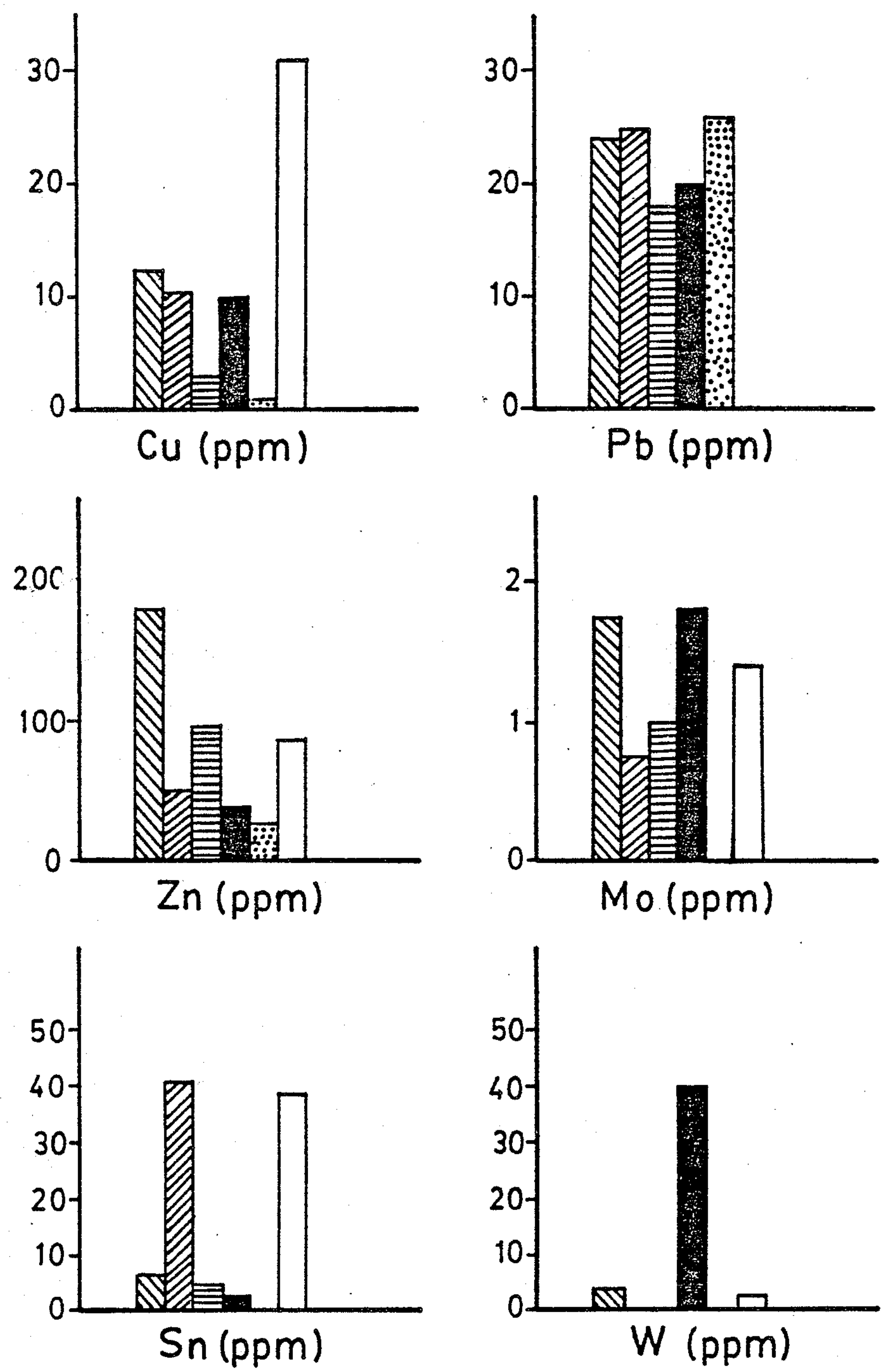


Figure 18. Cu,Pb,Zn,Mo,Sn and W contents in various phases of the North Pole Pluton and comparison with the contents of normal and uraniferous granites (legend as in Figure 16).

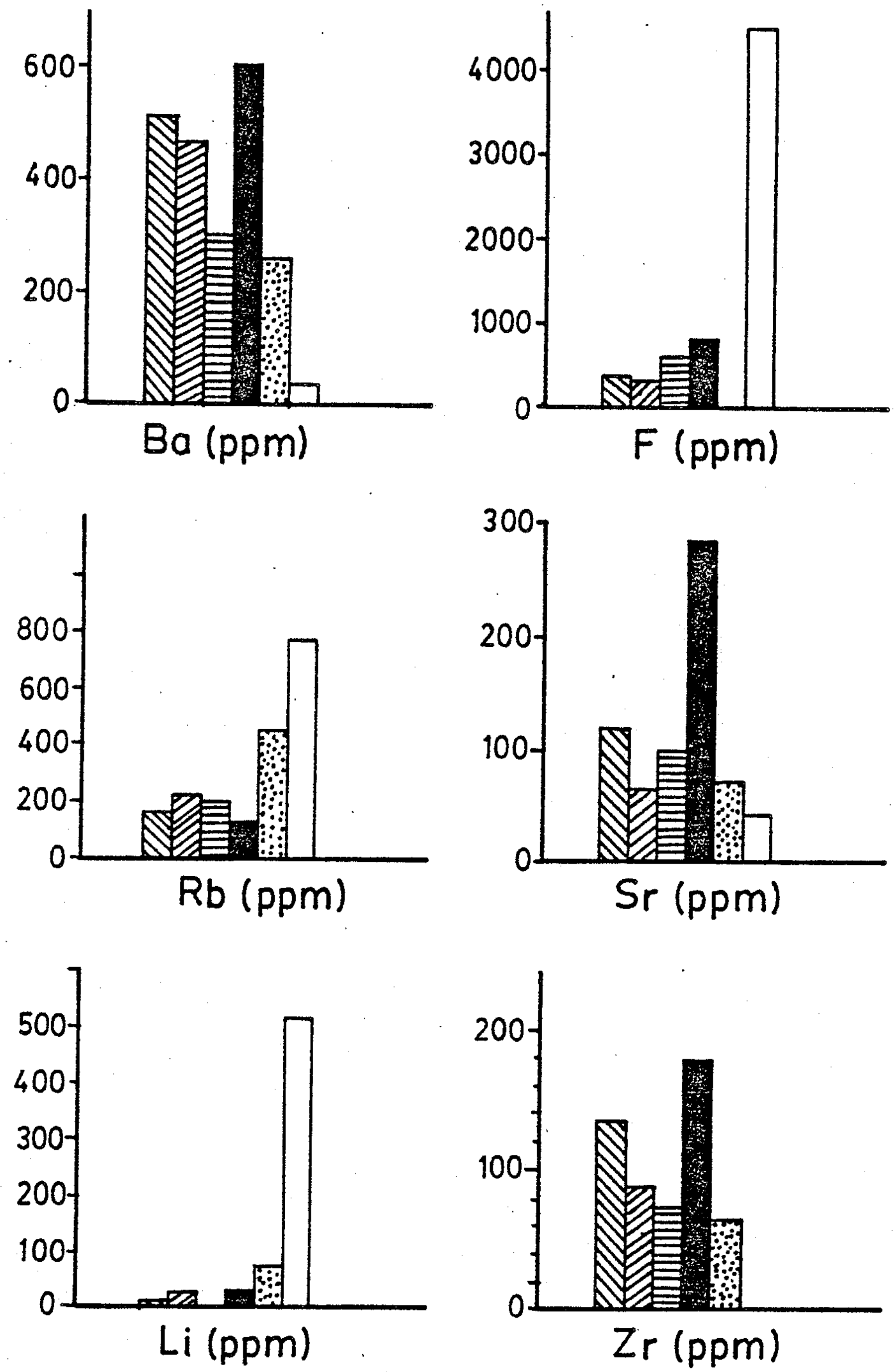


Figure 19. Ba,F,Rb,Sr,Li and Zr contents in various phases of the North Pole Pluton and comparison with the contents of normal and uraniferous granites (legend as in Figure 16).

contents relative to normal granites particularly for the two-mica granite and the quartz feldspar porphyry phases. The TiO_2, Fe_2O_3, FeO, MgO and CaO contents are low in both North Pole Pluton and uraniferous granites relative to normal granites.

The trace element composition varies dramatically within the various phases of the North Pole Pluton (Fig. 18 and 19). The biotite granites and the biotite-muscovite granites contain base metal sulphide values higher than in normal granites. Tin abundance is high in the two-mica granites in comparison to normal granites and uraniferous granites (Fig. 18). The Ba, F and Li contents are low in North Pole Pluton relative to normal and uraniferous granites (Fig. 19). Rb values are high relative to normal granites (a feature of uraniferous granite as well). Sr and Zr contents in North Pole Pluton are lower than in normal granites and in uraniferous granites. Enrichment factors in the chemical composition of the various phases of the North Pole Pluton and uraniferous granites were computed and are presented in Table 15.

7.2.0 Uranium Variation with Petrologic Indices of North Pole Pluton

The mean U values vs the mean SiO_2 values plot (Fig. 20) for various phases of the North Pole Pluton show that the higher mean values of U in general are in the more siliceous biotite granites and in the two-mica granites (Fig. 20). There is no apparent relationship between U and silicification as represented by SiO_2 content in the quartz feldspar porphyry.

The Rb, Sr and Ba contents of the North Pole Pluton have been plotted in the Rb-Sr-Ba variation diagram (Fig. 21) of El Bouseily and El Sokkary

Table 15. Enrichment factors* in major and trace elements for various phases of North Pole Pluton and for uraniferous granites.

Elements	North Pole Pluton			Uraniferous granites	
	Biotite granite	Two-mica granite	Quartz feldspar porphyry	Cairngorm Pluton, Britain	South Mountain Batholith, N. S.
SiO_2 (%)	1.0	1.0	1.1	-	1.0
TiO_2 (%)	1.4	0.5	1.2	0.4	0.3
Al_2O_3(%)	1.0	1.0	0.9	-	1.0
Fe_2O_3(%)	0.4	0.5	0.6	0.7	-
FeO (%)	1.2	0.7	0.4	-	0.6
MnO (%)	1.4	0.8	1.0	-	0.4
MgO (%)	1.1	0.6	0.4	0.2	0.1
CaO (%)	0.7	0.4	0.2	0.1	0.4
K_2O (%)	1.0	1.2	1.2	1.2	1.1
Na_2O (%)	2.1	2.0	2.0	1.9	2.1
P_2O_5 (%)	0.8	0.8	0.3	-	3.7
CO_2 (%)	1.2	0.2	3.6	-	-
U (ppm)	1.3	1.1	1.2	3.2	2.1
Cu(ppm)	1.3	1.1	0.3	0.0	3.1
Pb(ppm)	1.2	1.3	0.9	1.3	-
Zn(ppm)	4.5	1.3	2.4	0.7	2.2
Mo(ppm)	1.0	0.4	0.6	-	0.8
Sn(ppm)	2.2	13.7	1.5	-	13.0
W (ppm)	2.7	-	-	-	1.3
Ba(ppm)	0.8	0.7	0.5	0.4	0.1
F (ppm)	0.4	0.4	0.7	-	5.6
Rb(ppm)	1.1	1.5	1.4	3.0	5.1
Sr(ppm)	0.4	0.2	0.3	0.2	0.1
Zr(ppm)	0.8	0.5	0.4	0.4	-

* Enrichment factor = $\frac{\text{element concentration}}{\text{global average}}$

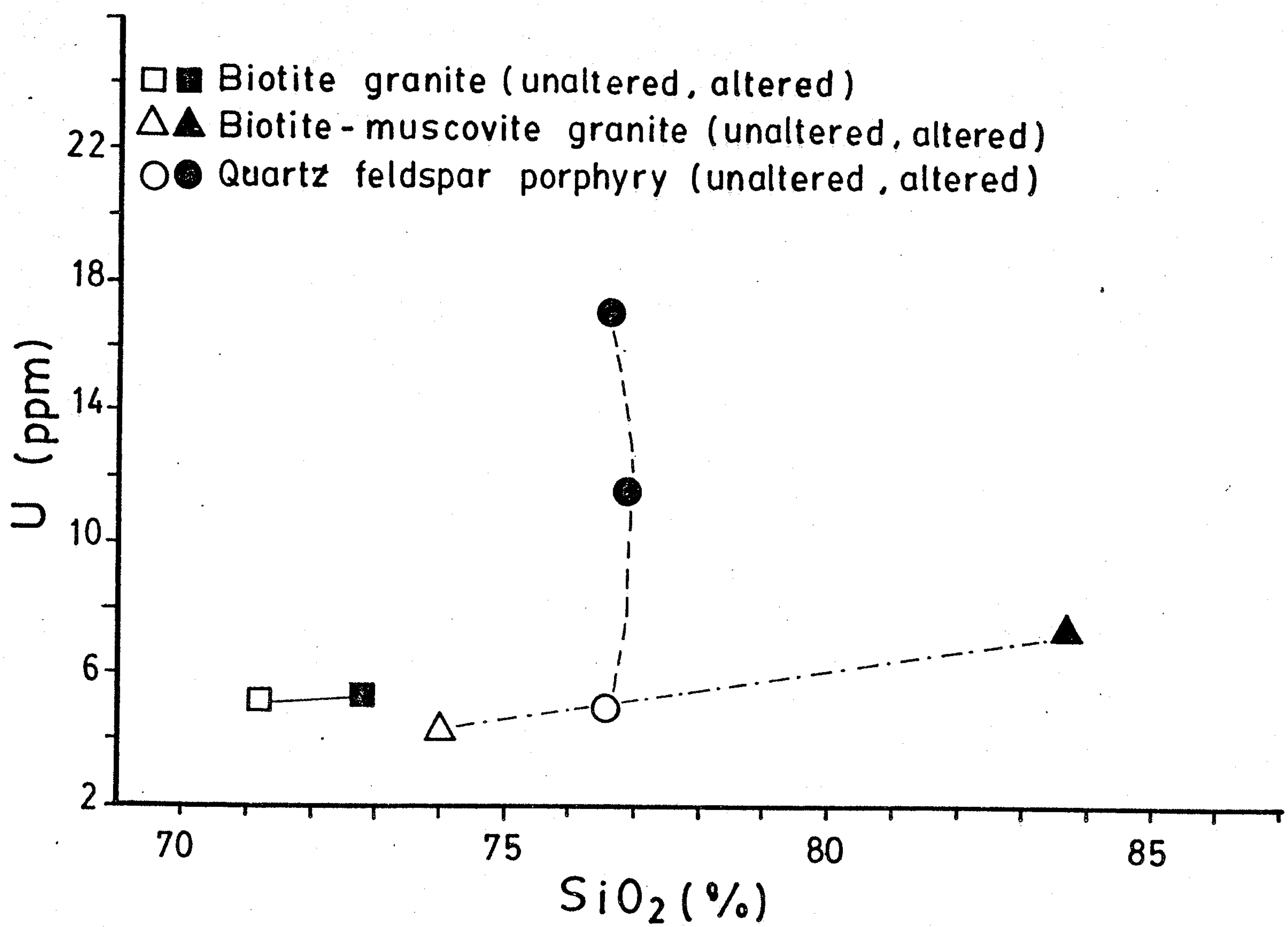


Figure 20. Plot of U vs. SiO_2 for the rocks of the North Pole Pluton.

(1975). These authors used this variation diagram to classify granites, evaluate differentiation trends and detect specialization in Sn-bearing granites. As shown in Figure 21, the unaltered rocks of the pluton fall within the area of normal granites, whereas the U-bearing altered rocks of North Pole Pluton fall within the area of differentiated (specialized) granites enriched in Sn.

Uranium vs felsic index plot (Fig. 22) in granitic rocks of North Pole Pluton reveals that (despite a significant degree of magmatic differentiation as represented by felsic index) uranium content remained almost constant within the fresh rocks of different phases of the Pluton. The increase of U content with felsic index is more pronounced in the altered rocks of the late-phase quartz feldspar porphyry (Fig. 22).

To examine the effect of fo_2 on behaviour of U in the pluton, the degree of oxidation (Fe_2O_3/FeO) was plotted against U contents (Fig. 23). Degree of oxidation (fo_2) insignificantly affected U in the fresh rocks. In the altered rocks U increased substantially with a degree of oxidation particularly in the quartz feldspar porphyry (Fig. 23).

Mean U content of the three phases of the North Pole Pluton plotted against weathering index of Parker plot (Parker, 1970) (Fig. 24) suggests that the degree of weathering is high for the two-mica granites and low for the biotite granites. Figure 24 also shows that U generally decreases systematically with increasing degree of weathering of the host rocks. Therefore, the low U content in the granitic rocks of North Pole Pluton relative to uraniferous granites (Fig. 16) may be attributed to weathering processes acting on the surface rocks.

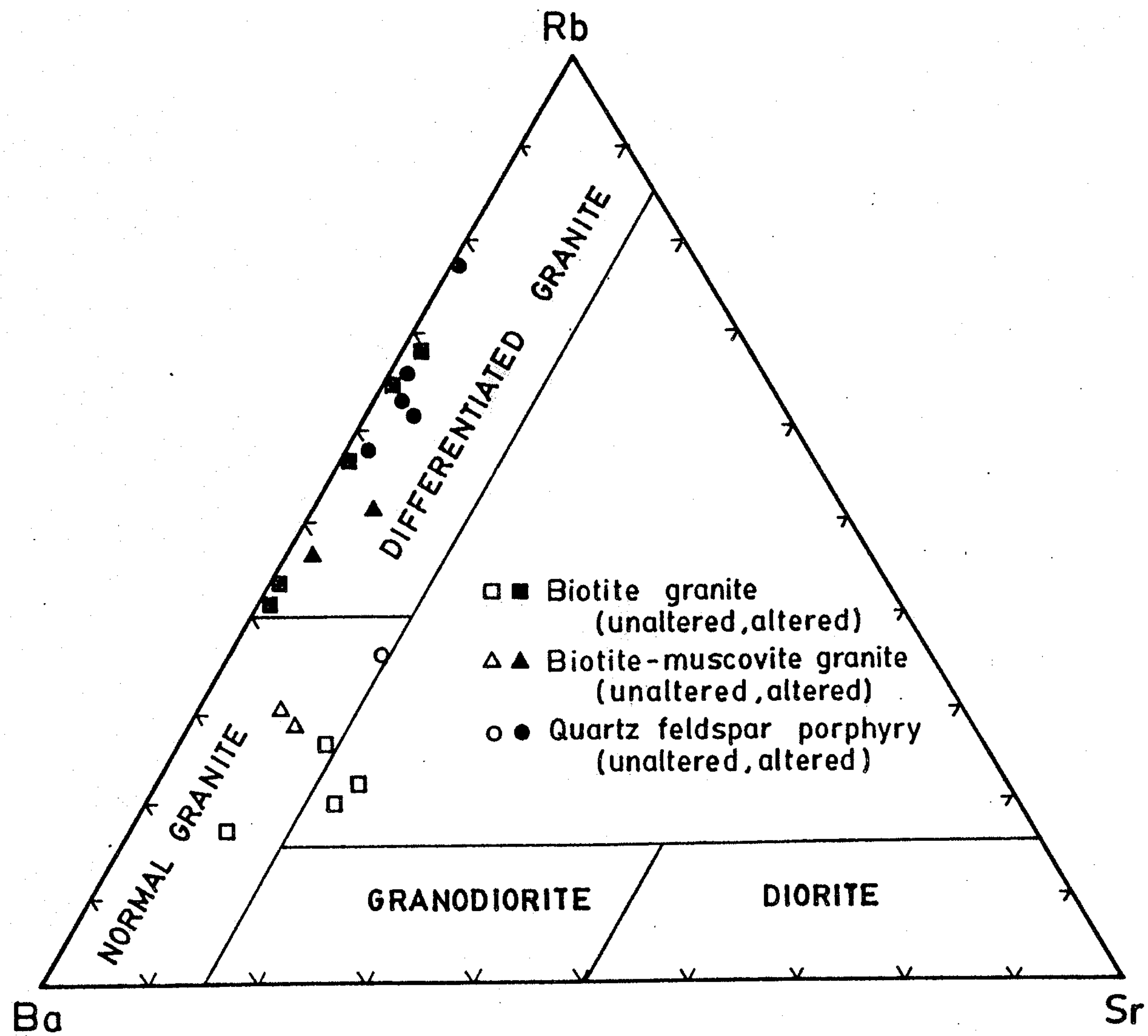


Figure 21. Rb - Sr - Ba ternary variation diagram for the rocks of the North Pole Pluton.

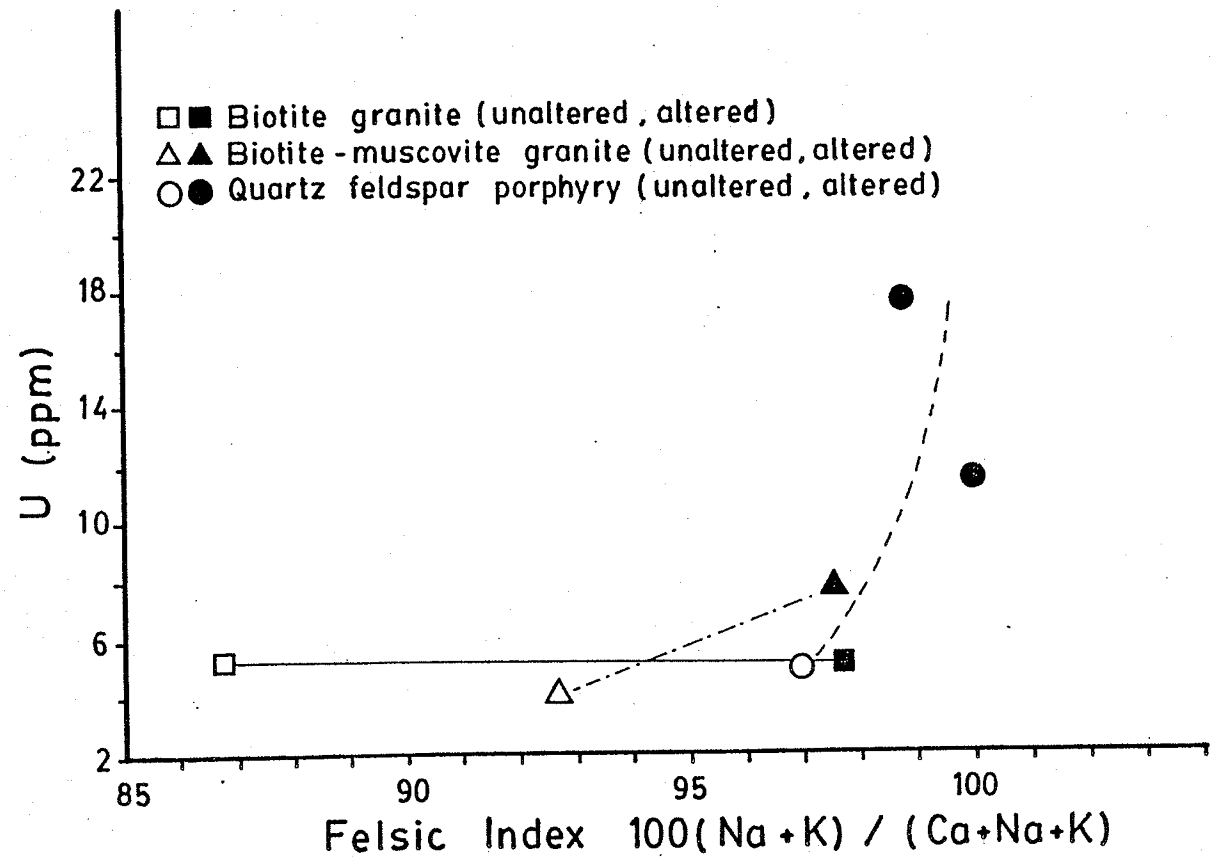


Figure 22. Plot of U vs. felsic index for the rocks of the North Pole Pluton.

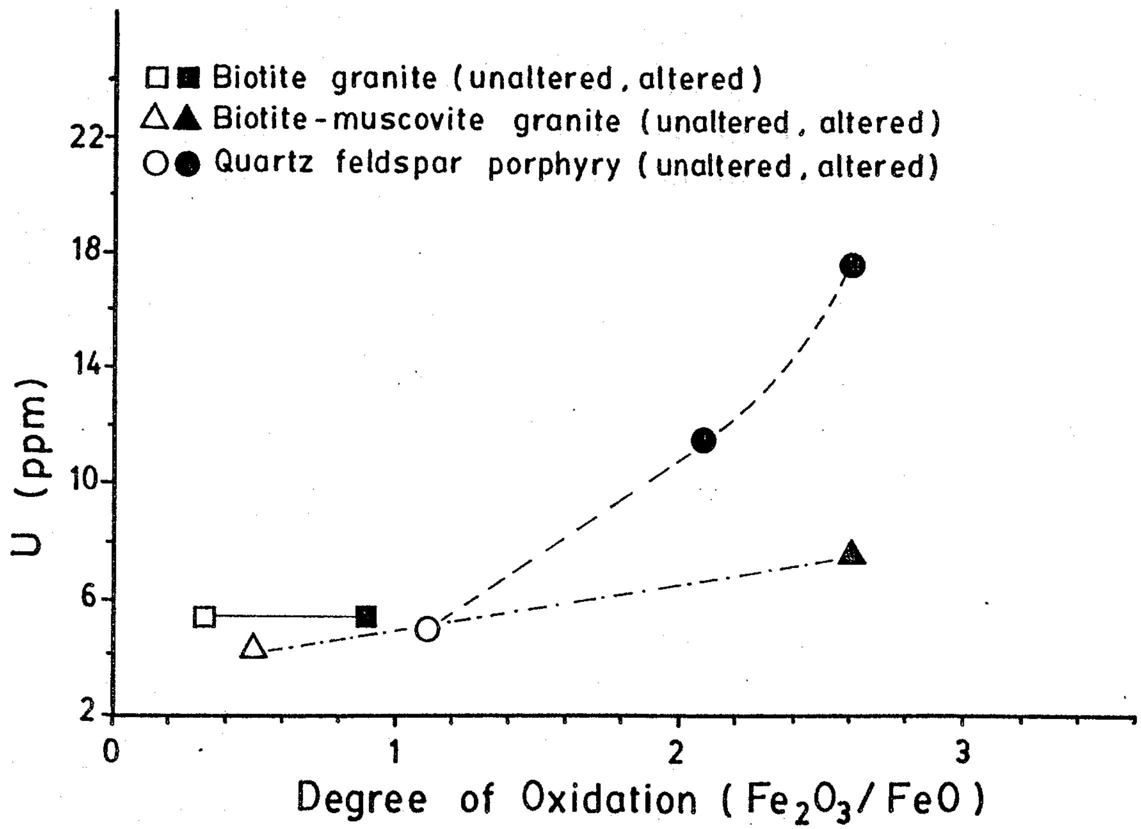


Figure 23. Plot of U vs. degree of oxidation for the rocks of the North Pole Pluton.

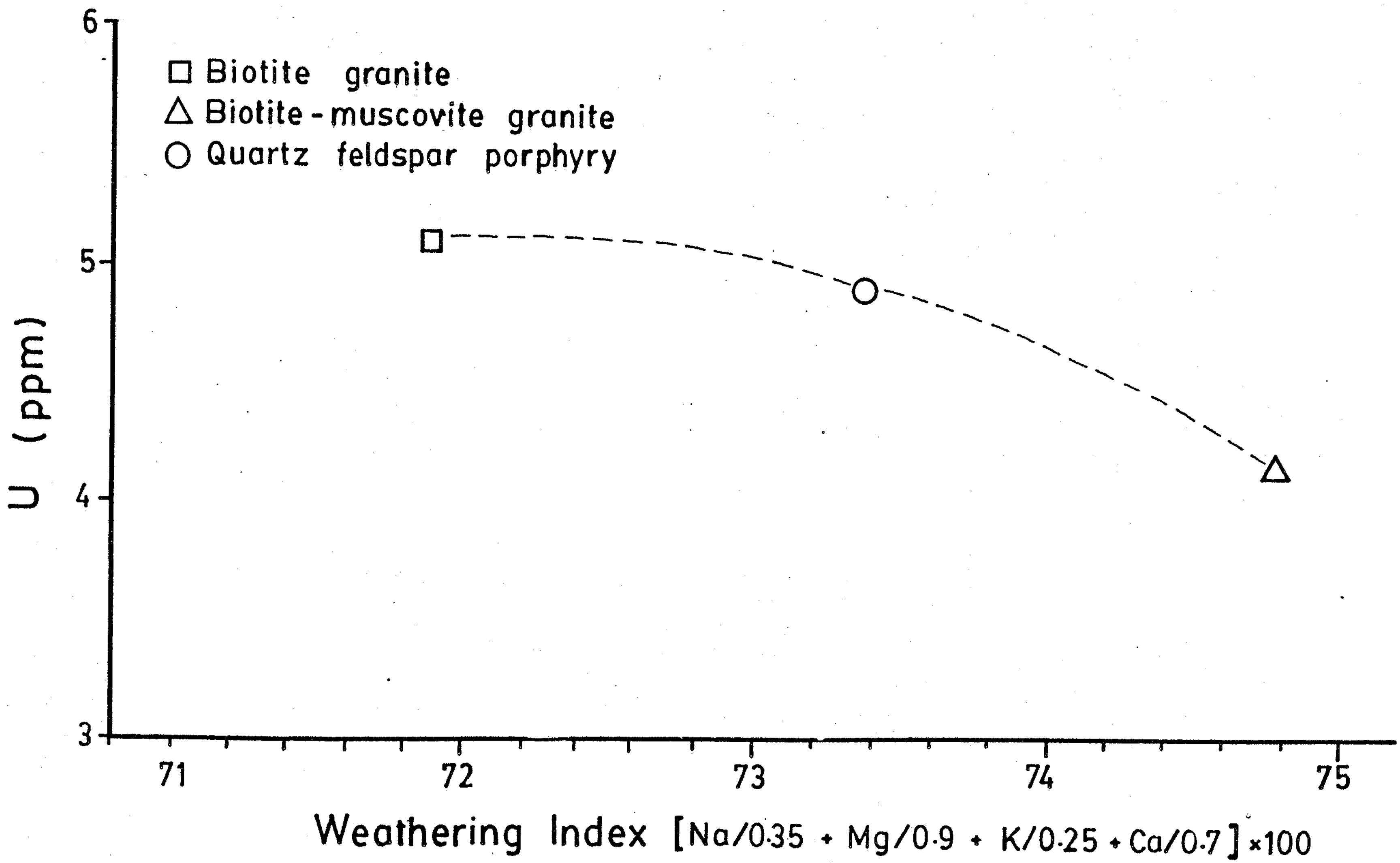


Figure 24. Plot of U vs. weathering index for the rocks of the North Pole Pluton.

7.3.0 Statistical Relationship Between Uranium and Major and Trace Elements.

7.3.1 Major Elements

To determine the relationship between mean values of U in the North Pole Pluton and the mean values of the major elements, nonparametric Spearman Rank correlation coefficients were calculated (Table 16). Uranium is significantly and positively correlated with SiO_2 and negatively with TiO_2, MgO, CaO, and Na_2O. Uranium has insignificant and negative correlation with K_2O possibly as a result of its redistribution and concentration within the rocks by postmagmatic hydrothermal and weathering processes.

To delineate, with respect to U, patterns of elemental association within the granitic rocks of North Pole Pluton, varimax rotated factor analysis was performed (SAS, 1982). Loadings on three retained factors for the major oxides of the pluton are given in Table 17.

Factor I, separates SiO_2 from TiO_2, Al_2O_3, FeO, MgO, CaO and P_2O_5. This factor, as indicated from its constituents, is related to magmatic processes. Although U has a low contribution in this factor, it follows SiO_2 during magmatic processes. Uranium has a larger contribution in Factor II, where it accompanied MnO, FeO and Fe_2O_3. This factor is related to hydrothermal processes which lead to U concentration in the rocks. Uranium has no contribution in Factor III.

7.3.2 Trace Elements

Spearman Rank correlation coefficients were also computed among the trace element contents of North Pole Pluton (Table 18). Uranium shows significant positive correlation with Zn, Cu and Sr and significant negative

Table 17. The Varimax-rotated factor loadings for the first three factors retained for the major elements of the North Pole Pluton.

Elements	Factor I	Factor II	Factor III
SiO_2 %	-0.91	-0.08	-0.31
TiO_2 %	0.82	-0.14	-0.18
Al_2O_3%	0.75	0.16	-0.60
Fe_2O_3%	0.06	0.54	-0.30
FeO %	0.73	0.51	-0.25
MnO %	0.18	0.84	-0.12
MgO %	0.95	-0.13	-0.15
CaO %	0.57	-0.60	0.24
K_2O %	-0.06	-0.11	0.88
Na_2O %	0.28	-0.62	0.66
P_2O_5 %	0.76	-0.10	-0.06
CO_2 %	-0.15	-0.31	0.56
U (ppm)	-0.34	0.69	0.08

Table 16. Matrix of Spearman Rank correlation coefficients for major elements in the North Pole Pluton

	U	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	K_2O	Na_2O	P_2O_5	CO_2
CO_2	0.06	0.21	-0.21	0.18	-0.18	-0.39	-0.42	-0.23	0.15	0.39	0.26	0.02	1.00
P_2O_5	-0.21	-0.66	0.46	0.71	-0.17	0.37	0.13	0.56	0.53	-0.01	0.25	1.00	
Na_2O	-0.38	-0.29	0.13	0.38	-0.65	-0.33	-0.37	0.24	0.77	0.59	1.00		
K_2O	-0.07	0.06	-0.20	0.19	-0.41	-0.46	-0.56	-0.17	0.17	1.00			
CaO	-0.59	-0.53	0.38	0.51	-0.56	-0.07	-0.15	1.00					
MgO	-0.49	-0.92	0.87	0.73	-0.11	0.70	0.44	1.00					
MnO	-0.03	-0.46	0.34	0.20	0.29	0.88	1.00						
FeO	-0.10	-0.70	0.54	0.46	0.23	1.00							
Fe_2O_3	0.18	0.19	0.06	-0.26	1.00								
Al_2O_3	-0.20	-0.82	0.58	1.00									
TiO_2	-0.30	-0.71	1.00										
SiO_2	0.45	1.00											
U	1.00												

Table 18. Matrix of Spearman Rank correlation coefficients for trace elements in the North Pole Pluton.

	U	Be	Ba	Cu	F	Mo	Pb	Rb	B	Sn	Sr	Zn	W	Li	Bi	Zr	S
S	-0.09	-1.00	0.09	0.43	0.64	0.88	0.37	0.43	0.23	0.60	-0.56	0.49	0.74	0.60	0.43	-0.12	1.00
Zr	-0.55	0.12	0.18	0.20	0.44	0.18	0.03	0.64	0.87	0.58	0.60	-0.55	0.45	0.52	0.75	1.00	
Bi	-0.31	-0.43	0.06	0.37	0.84	0.62	-0.09	0.83	0.93	0.83	-0.97	-0.26	0.74	0.89	1.00		
Li	-0.20	-0.60	0.35	0.20	0.99	0.62	-0.14	0.71	0.70	0.66	-0.91	-0.31	0.65	1.00			
W	-0.62	-0.74	0.13	0.35	0.58	0.95	0.56	0.53	0.63	0.97	-0.79	0.18	1.00				
Zn	0.31	-0.49	-0.64	0.60	-0.23	0.35	0.37	0.03	-0.20	0.09	0.18	1.00					
Sr	0.29	0.56	-0.09	-0.29	-0.87	-0.73	0.06	-0.74	-0.82	-0.85	1.00						
Sn	-0.60	-0.60	0.03	0.37	0.58	0.88	0.43	0.60	0.75	1.00							
B	-0.29	-0.23	-0.13	0.55	0.66	0.45	-0.06	0.90	1.00								
Rb	0.03	-0.43	-0.23	0.77	0.75	0.44	-0.14	1.00									
Pb	-0.71	-0.37	0.23	0.09	-0.20	0.53	1.00										
Mo	-0.44	-0.88	0.09	0.35	0.58	1.00											
F	-0.06	-0.64	0.28	0.29	1.00												
Cu	0.26	-0.43	-0.64	1.00													
Ba	-0.55	-0.09	1.00														
Be	0.09	1.00															
U	1.00																

correlations with Zr, W, Sn, Pb and Ba contents. Unexpectedly, U shows insignificant correlation with Li, Rb and Be contents, possibly because of its redistribution within the rocks by hydrothermal and weathering processes.

Factor analysis performed on the trace elements (Table 19) suggests that U contribution is high in Factor III where it is most likely attributed to secondary mineralization. Uranium mineralization accompanied Cu and Zn mineralization. The low contribution of U in Factor I and Factor II may suggest that U mineralization in the granitic rocks of North Pole Pluton took place during the late stage hydrothermal processes (i.e., at lower temperature).

Factor II reveals that secondary mineralization of Mo, Pb, Sn and W had occurred possibly earlier than U mineralization during the hydrothermal processes.

Factor I indicates that Cu, F, Rb, B, Sn, Li, Bi and Zr have high contribution in the rocks and this factor may be related to magmatic processes.

7.4.0 Uranium Contents with Respect to the Genesis of North Pole Pluton

At least three groups of granites exist with distinctive mineral associations; I-type, S-type and A-type granites. Exploration for minerals in granites is usually based on these three types of granitic genesis. For instance many Cu-Mo porphyry deposits are associated with I-type granites (Takahashi et al., 1980) whereas U, Sn, W and Li are usually associated with S-type and A-type granites (Oshin and Rahman, 1986 and Sawka and Chappell, 1986).

Table 19. The Varimax-rotated factor loadings for the first three factors retained for the trace elements of the North Pole Pluton.

Elements	Factor I	Factor II	Factor III
U (ppm)	-0.19	-0.31	0.87
Be (ppm)	-0.26	-0.73	-0.08
Ba (ppm)	-0.44	0.41	-0.70
Cu (ppm)	0.70	0.14	0.58
F (ppm)	0.83	0.31	0.02
Mo (ppm)	0.09	0.90	-0.14
Pb (ppm)	0.09	0.72	-0.18
Rb (ppm)	0.96	0.0	0.26
B (ppm)	0.97	-0.04	-0.07
Sn (ppm)	0.72	0.69	0.05
Sr (ppm)	-0.72	-0.26	-0.45
Zn (ppm)	-0.06	0.20	0.93
W (ppm)	0.35	0.87	-0.13
Li (ppm)	0.74	0.49	-0.02
Bi (ppm)	0.87	0.34	-0.21
Zr (ppm)	0.89	0.15	-0.41
S (ppm)	0.0	0.87	0.48

Chappell and White (1974) have divided the granites of eastern Australia into I- and S-type which correspond to some extent to the calc-alkaline and alkali granites (Moreau, 1976 and Pitcher, 1979), respectively. The I-type granites are considered to have been generated from igneous source rocks, whereas the S-type granites are considered to have been generated from sedimentary rocks (Chappell and White, 1974, and White and Chappell, 1983). The S- and I-type classification is genetic. Ishihara (1977) has added a new classification which is descriptive, in which he classified the granitic rocks of Japan into an ilmenite-series and a magnetite-series. Magnetite-series granites are equivalent to I-type granites, whereas the ilmenite-series granites include I- and S-type granites. Ilmenite-series granites of Japan are enriched with Sn in greisen, whereas magnetite-series have associated Mo and base metal deposits.

An additional type has been added to the classification, A-type (anorogenic) granites, by Loiselle and Wones (1979). Collins et al. (1982) and Loiselle and Wones (1979) believe that the A-type granites formed by crystallization of magma derived from a granulite terrane from which an earlier magma had been produced, i.e., formed late in the magmatic cycle. Anderson (1983) suggested an alternative source for anorogenic granitic magmas, fusion of the lower crust containing I-type granite.

To determine the classification of the North Pole Pluton with respect to I-, S- and A-type granites, distinguishing geological features for these granites were compiled and listed in Table (20). These features were compared with geological features observed in North Pole Pluton. As shown in Table 20, it appears that the North Pole Pluton is comparable to S-type granites and to a lesser extent to A-type granites.

Table 20. Geological features of the North Pole Pluton and its comparison to I-, S-, and A-type granitoids.

Criteria	I-type Granitoids	S-type Granitoids	A-type Granitoids	North Pole Pluton
Examples	.Sierra Nevada Batholith .Cairngorm Pluton, British caledonides.	.Hercynian granites of Masif central .Hercynian granites of SW England .South Mountain Batholith, N.S.	.Nigerian Younger granites, Africa .Cornwall Granite, England .PikesPeak Batholith, U.S.A. .Bolivia granites.	
Associated mineral deposits	.Cu-Mo porphyry	.U, Sn, W, F	U, Sn, W, Mo	U, Sn, W, Mo, Cu, Pb, Zn, Ag and Au
Origin	.Generated at deeper level in the earth's crust over subduction zones.	.Generated by anatexis in areas of thickened silicic crust (partial melting of sedimentary protolith).	.Generated along rift zones and within stable continental blocks (anorogenic)	.Partial melting of sedimentary protolith.
Mineralogy	.Hornblende is common. .Presence of magnetite. .Normative diopside or corundum (<1%). .Presence of sphene.	.Absence of hornblende and magnetite. .Presence of aluminosilicate minerals: biotite, muscovite, cordierite, sillimanite and andalusite. .Presence of garnet rather than sphene. .Large amount of normative corundum (>1).	.Hastingsite and biotite common.	.Biotite and muscovite common. .Absence of hornblende .Large amount of normative corundum (>1%).
Chemistry	.Broad SiO_2 composition .$[Al_2O_3/(Na_2O+K_2O+CaO)]$ 1.0 .High content of Na_2O (Na_2O >3.2% in felsic members and >2.2% in mafic members) .High CaO content .Relatively high fo_2 $[Fe_2O_3/(Fe_2O_3+FeO)]>1.0$ .Variation diagrams are linear or near linear .Low initial $^{87}Sr/^{86}Sr$ ratio (0.704-0.706)	.Restricted SiO_2 composition (>70 wt.%) .Highly peraluminous $[Al_2O_3/(Na_2O+K_2O+CaO)]>1.0$ .Low content of Na_2O (Na_2O 3.2% in felsic members and <2.2% in mafic members) .Low CaO content .Significantly low fo_2 (Fe_2O_3 / $Fe_2O_3+Fe_2O$)<1.0 .Variation diagrams are irregular .Low Rb/Sr ratio .High initial $^{87}Sr/^{86}Sr$ ratio (>0.706)	.Restricted SiO_2 composition (>70 wt.%) .Metaluminous-peraluminous and peralkaline (Na_2O+K_2O)<Al_2O_3<(Na_2O+ CaO+K_2O) .High content of Na_2O(>3%) .Low CaO content .Low Al_2O_3 content .Low to moderate fo_2 .High Rb/Sr and K/Ba ratios .Enriched in the incompatible trace elements: (REE except Eu), Zr, Nb, Ta .Initial $^{87}Sr/^{86}Sr$ ratios range from 0.703-0.713.	.Restricted SiO_2 composition (>70 wt.%) .Peraluminous [Al_2O_3/ (Na_2O+K_2O+CaO)] 1.1% .High content of Na_2O [3.3%] .Low CaO .Low fo_2 .Variation diagrams are irregular .High initial $^{87}Sr/^{86}Sr$ ratio (>0.706)

The North Pole Pluton intruded after the closure of the Iapetus Ocean, as did other Paleozoic granitoid rocks of the Appalachian Orogen (Chatterjee and Strong, 1985), and therefore is later than the subduction process and is not a characteristic I-type granitoid of a circum-Pacific type.

The North Pole Pluton is therefore favourable for U, Sn, W and Li mineralization as are other S-type and A-type granites around the world.

SECTION EIGHT

CONCEPTIONAL GEOLOGICAL MODEL ON URANIUM MINERALIZATION IN NORTH POLE PLUTON

8.1.0 Introduction

From the geological data and geological concepts established throughout this study an interpretative model is proposed to describe the geological processes that led to polymetallic vein-type uranium mineralization in the North Pole Pluton. The model presented is a modified version of a previous model on U mineralization in Long Lake area, proposed by Hassan et al. (in press).

The source of the U and associated metals, mechanism of their mobilization, and precipitation along fractures crosscutting granitic rocks are the main factors considered in the model.

Polymetallic vein-type U deposits, similar to those at Long Lake are found in many places in the world. Most are associated with S-type (peraluminous) two-mica granites, and many are also connected with hydrothermally altered and brecciated zones. The best examples are those associated with granitic rocks of Massif Central of France (Moreau, 1976), the Hercynian granites of Britain (Simpson and Plant, 1984), the granitic rocks of South Mountain Batholith of Nova Scotia (Chatterjee and Strong, 1985) and the two mica granites in Schwarzach area of Germany (Dill, 1985). Both supergene (meteoric waters) and hypogene (hydrothermal fluids) processes have been proposed as being active in the formation of these vein deposits.

8.2.0 The Proposed Model

The magmatic-hydrothermal model described by Simpson *et al*. (1982) and Chatterjee *et al*. (1982) and the 'per descensum' model of Barbier (1974) are applicable to some extent in the development of U deposits in the North Pole Pluton.

In the magmatic hydrothermal model, a melt (usually granitic in composition) produces U and other metal enriched hydrothermal fluids that move upward from deeper zones in the earth's crust to deposit these metals along shear zones.

In the 'per descensum' model, continental weathering by highly oxidized meteoric waters deplete U from surface rocks and deposit it wherever a suitable reduction zone is intersected.

The brecciation of the host granites along fractures, alteration of wall rocks, and the formation of quartz veins in North Pole Pluton are some of the features that support the hydrothermal model. The supergene model is supported by secondary U mineralization (autunite- torbernite) found in float. These two minerals are usually formed in supergene deposits (Dill, 1983). It may be that they were deposited in bedrock near the surface prior to their separation and transportation by weathering and/or glacial processes. Thus, as far as these specimens are concerned they could be supergene.

Metals, including U, could have been introduced into the Long Lake area during the generation of the highly evolved granite of North Pole Pluton (Fig. 25) as the chemical data suggests. The pluton was probably derived from metal enriched sedimentary rocks as indicated by its peraluminous nature.

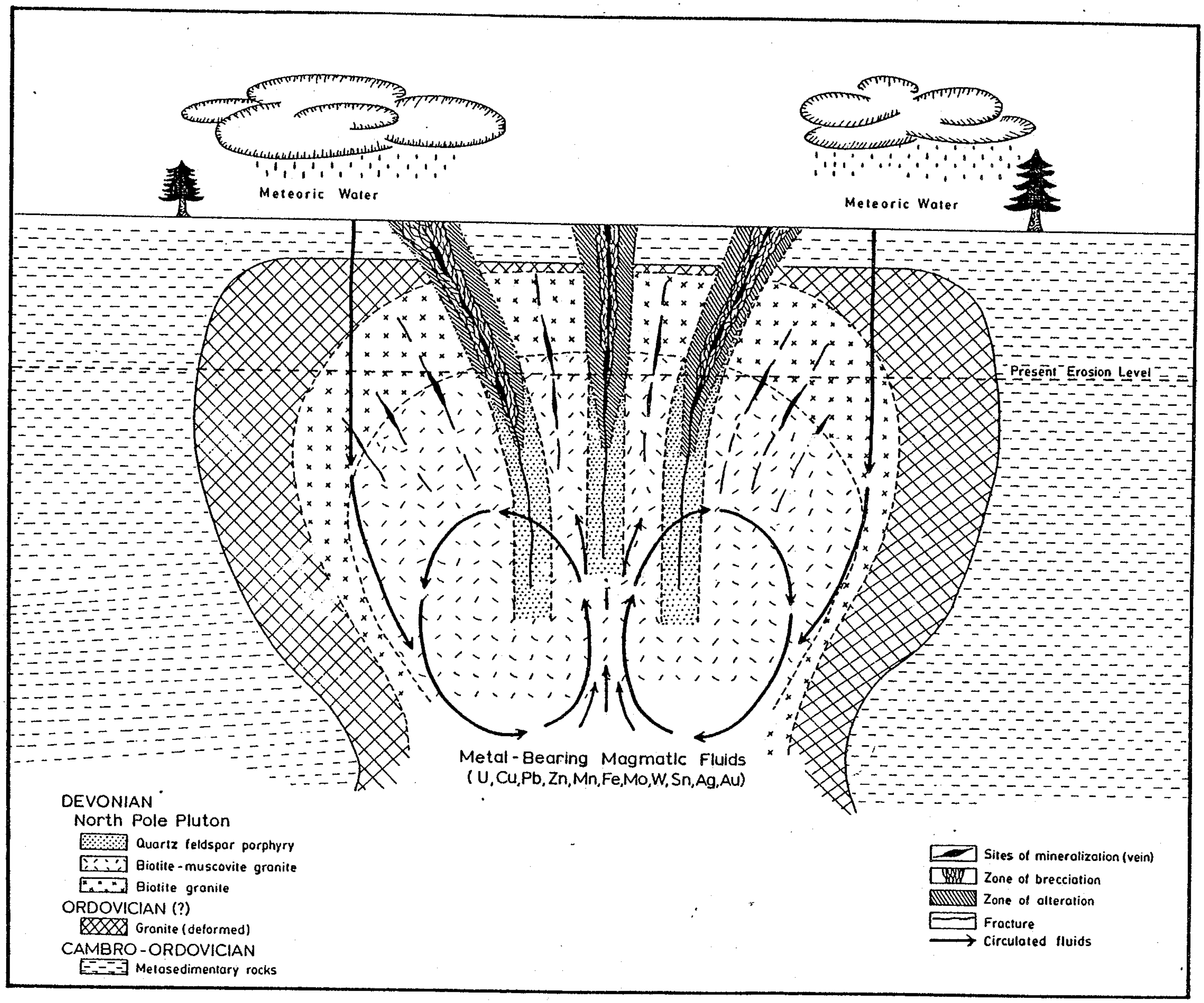


Figure 25. Proposed coceptual model for U and associated metals concentration in the North Pole Pluton.

Furthermore, the magma was apparently enriched with water (Fyffe and Pronk, 1985), and therefore capable of producing a hydro- thermal system as a separate magmatic aqueous phase (hydrothermal fluid) upon cooling and crystallization (Burnham and Ohomoto, 1980). Moreover, excess water will enhance solubilities of U and sulphides into the melt.

The granitic rocks of North Pole Pluton have seemingly provided the heat energy required to activate the hydrothermal cell. Radiogenic heat released by granites could keep hydrothermal convective cells operating for long periods of time (Fehn et al., 1978).

As the magma moved upward in the earth's crust to crystallize in the epizone, its content of U and other metals might have been enhanced as a result of its contamination with country rocks (Cambro-Ordovician metapelites).

The structural features produced (faults, joints, fractures and brecciation) within the granitic rocks of North Pole Pluton, as a result of the Acadian Orogeny, played an important role in U mineralization. These structural features increased the permeability of the wall rocks and acted as conduits for hydrothermal fluids flow in the rocks and thus, enhanced the capacity of hydrothermal solutions for mineralization.

The continuity of the hydrothermal fluids to flow and circulate in the convective cell was maintained probably by periodic opening of fractures, as a result of consecutive seismic activities (Mawer and Williams, 1985), similar to the recent series of earthquake (M_b = 5.7) in the study area with epicentre located within the North Pole Pluton (Berry et al., 1982). Studies by several investigators elsewhere also indicated that vein-type hydrothermal deposits are frequently formed in seismically active areas (Golovin, 1979; Sibson et al., 1975; Plant et al., 1985 and Durrance, 1985). Chemical reactions between the metal-bearing hydrothermal fluids and the wall rocks along the fractures, may have resulted in the precipitation of quartz (chalcedony) along with U and associated metals (Fig. 4). The wall rocks in turn were altered to chlorite, sericite, calcite and kaolinite. A chemical environment favourable for reduction and precipitation of U is most probably provided by sulphide minerals, precipitated along the fractures prior to U mineralization (Fig. 4). The loss of CO_2 from the hydrothermal fluids to the wall rocks during carbonization might also have led to U mineralization (Rich et al., 1977).

The loss of alkalies (K and Na) as a result of more rock sericitization may lead to precipitation of silica (quartz or chalcedony) along veins. The data showed that U deposition accompanies chalcedony precipitation more than quartz precipitation. Quartz is a stable form of silica at P-T condition, found in hydrothermal systems and its presence usually indicates a slow change in chemical conditions, accompanied by precipitation (Fournier, 1986). In contrast, chalcedony precipitates under rapid changes in the physical or chemical conditions of the fluids at temperatures below 180 degrees C. These conditions are; (1) rapid cooling, (2) mixing of different waters (3) pH changes and (4) by reaction of the fluids with the silica in the host rocks (Fournier, 1986). It is possible that precipitation of U in the North Pole Pluton was favoured by some combination of these physico-chemical changes.

Meteoric water may have played a major roll in U mineralization in the North Pole Pluton (Fig. 25). Meteoric water containing dissolved oxygen could have dissolved phosphates from the Cambro-Ordovician metasedimentary rocks and become slightly acidic during its percolation in the rocks. When such water passed through the fractures of North Pole Pluton it could have dissolved U along with Cu. The sulphide minerals that were precipitated along fractures during hydrothermal processes, may have provided the reduction zone favourable for secondary deposition of autunite and torbernite.

SECTION NINE

URANIUM FAVOURABILITY OF MIRAMICHI ANTICLINORIUM GRANITIC PLUTONS

9.1.0 Introduction

A study on metallogeny of U and elements associated with it in New Brunswick by Hassan et al. (in press) indicated that almost all of the uranium occurrences in the Miramichi Anticlinorium are located on, or adjacent to the granitic plutons (Fig. 2). Hassan et al. (in press) have claimed that the granitic plutons served as sources for these U occurrences. Therefore, the present section is largely confined to an investigation of these plutons in order to select the most favourable for future follow-up U exploration.

The study of U and associated metals in Long Lake area has revealed a close relationship between U mineralization and certain geological characteristics of the host granitic rocks. Hence, an attempt is made here to use these favourable characteristics (signatures) on the Miramichi Anticlinorium plutons to estimate their potential for U mineralization.

Because only limited data are available on most of the plutons and because of the limited time assigned for the present study, only a rough estimate of U potential in the granitic plutons is possible at this stage.

The data used to estimate the U favourability are airborne radiometric data, gravity data and limited geochemical data.

9.2.0 Airborne Radiometric Data for Miramichi Anticlinorium Granitic Plutons

A map showing the airborne radiometric contours of eU was compiled for the Miramichi Anticlinorium (Fig. 26). On this map, areas with eU values above 2ppm (average background) were outlined. In addition, U anomalies with various amplitudes are marked with different symbols.

The anomalous eU regions (Fig. 26) are at least spatially linked to the granitic plutons (Fig. 2). It also appears that the highest eU radiometric anomalies are closely associated with the W-Sn-Mo-bearing granitic rocks of the Burnt Hill, Trout Brook and Dungarvon plutons. These granites are also associated with the strongest negative gravity anomalies (Table 21) in comparison to other plutons in the area.

The airborne radiometric data of eU, eTh and K over the granitic plutons were digitized at a one square kilometer grid. Average concentrations of eU eTh and K calculated from the digitized grids over the plutons are given in Table 21. Table 21 illustrates that the Burnt Hill, Trout Brook, Dungarvon and the Mount Elizabeth plutons contain higher eU, eTh and K relative to other granitic plutons in the Anticlinorium; the Burnt Hill Pluton appears to be the most favourable for U mineralization as shown in Table 21. The Burnt Hill, Trout Brook and Dungarvon Plutons are all associated with known U occurrences (Fig. 2). Thus, the Mount Elizabeth Pluton may be more favourable than originally believed, and should receive further attention in future exploration.

The limited geochemical data compiled for the granitic plutons (Table 21) indicate that most of them are, in general, highly silicic (SiO_2 70wt%). The plots of eU vs SiO_2 and eTh vs SiO_2 (Fig. 27) reveal that both the mean eU

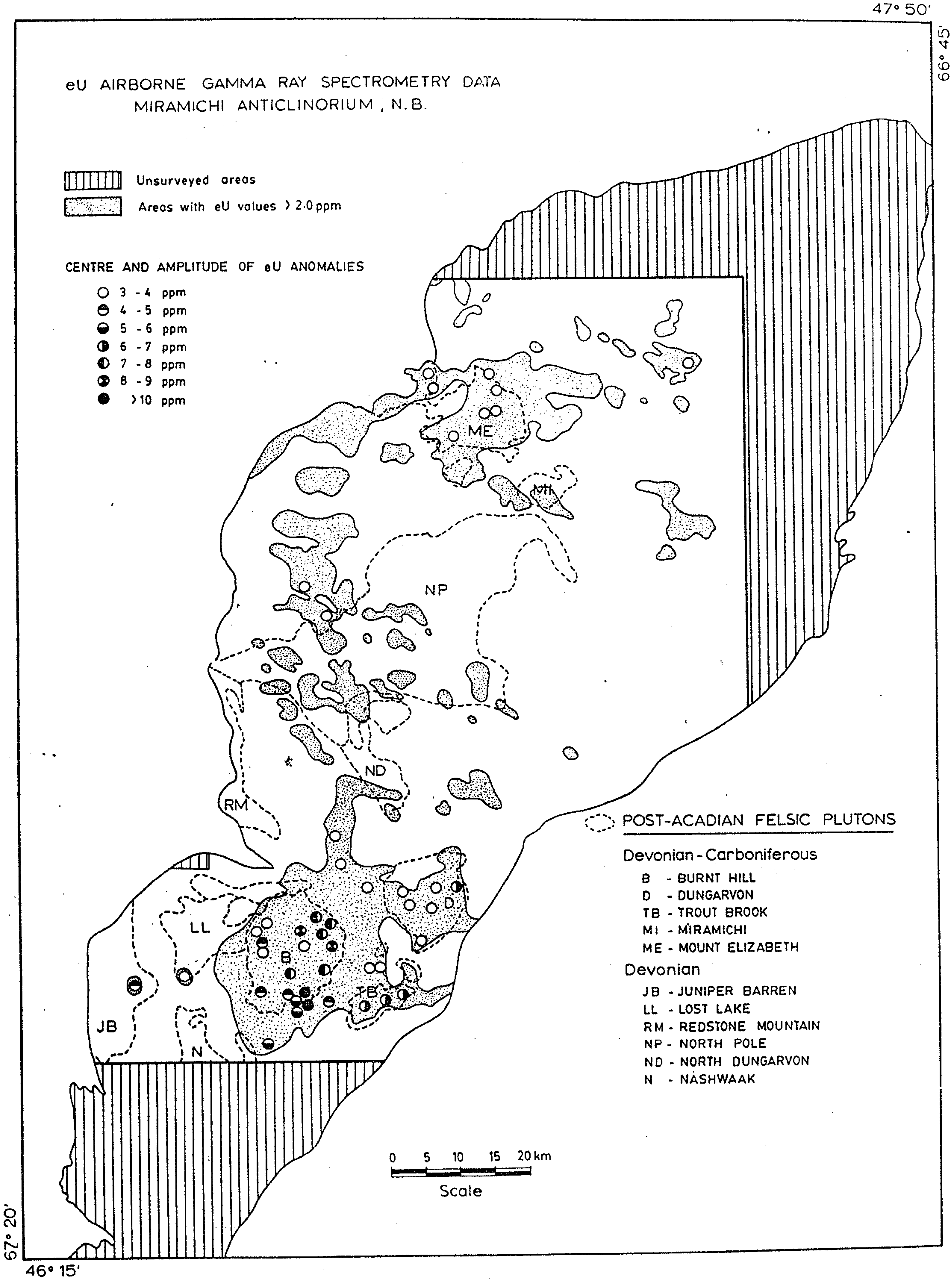

47° 50'
66° 45'
eU AIRBORNE GAMMA RAY SPECTROMETRY DATA
MIRAMICHI ANTICLINORIUM, N.B.
Unsurveyed areas
Areas with eU values > 2.0 ppm
CENTRE AND AMPLITUDE OF eU ANOMALIES
3 - 4 ppm
4 - 5 ppm
5 - 6 ppm
6 - 7 ppm
7 - 8 ppm
8 - 9 ppm
> 10 ppm
ME
MI
NP
ND
RM
LL
B
D
TB
JB
N
POST-ACADIAN FELSIC PLUTONS
Devonian-Carboniferous
B - BURNT HILL
D - DUNGARVON
TB - TROUT BROOK
MI - MIRAMICHI
ME - MOUNT ELIZABETH
Devonian
JB - JUNIPER BARREN
LL - LOST LAKE
RM - REDSTONE MOUNTAIN
NP - NORTH POLE
ND - NORTH DUNGARVON
N - NASHWAAK
0 5 10 15 20 km
Scale
67° 20'
46° 15'

Figure 26

Table 21. Aeroradiometric abundances of eU, eTh and K; silica, aluminum and alkalies contents and the amplitude of gravity anomalies for the selected granitic plutons in the Miramichi Anticlinorium.

Plutons	Aeroradiometric data				Geochemical data							Amplitude of Bouguer gravity anomaly (mgal)
	n	eU (ppm)	eTh (ppm)	K (%)	n	SiO_2 (%)	Al_2O_3 (%)	CaO (%)	Na_2O (%)	K_2O (%)	$\frac{Al_2O_3}{(CaO+Na_2O+K_2O)}$	
Burnt Hill	189	4.5±2.2	10.3±2.3	1.8±0.2	6	75.2	13.5	0.6	4.4	3.6	1.6	-54
Trout Brook	39	3.9±1.2	7.8±1.1	1.6±0.3	1	71.7	11.4	0.2	3.7	3.1	1.6	-53
Dungarvon	101	2.5±0.8	8.0±1.1	1.4±0.2	3	77.7	14.0	0.6	4.5	3.5	1.6	-48
Mount Elizabeth	106	2.5±0.6	8.5±1.9	1.7±0.4	14	73.7	13.6	1.4	4.6	3.6	1.4	-20
Miramichi	37	1.9±0.4	7.1±1.2	1.6±0.2	2	72.8	16.2	1.9	4.3	3.3	1.7	-25
Lost Lake	61	1.7±0.2	5.5±1.1	1.6±0.2								-50
Redstone Mountain	55	1.4±0.3	6.7±2.3	1.2±0.5	2	67.6	15.5	2.9	2.2	5.0	1.5	-30
Juniper Barren	110	1.3±0.4	4.5±1.2	1.1±0.3								-50
Older Granites	61	1.9±0.3	7.6±0.8	1.4±0.1	15	72.0	14.7	1.4	4.3	3.2	1.7	-35

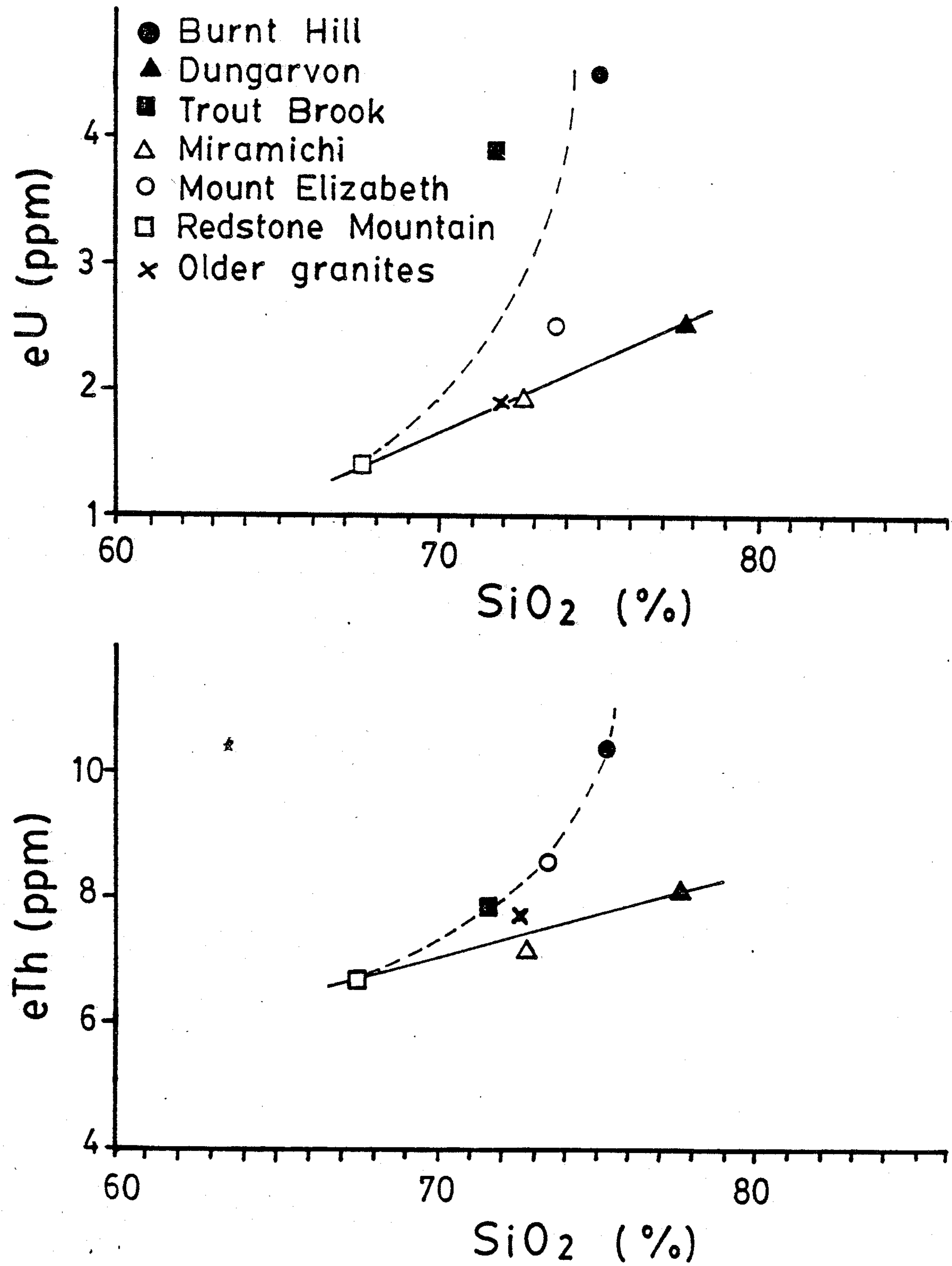


Figure 27. Plots of eU vs. SiO_2 and eTh vs SiO_2 for selected granitic plutons in the Miramichi Anticlinorium

and eTh contents increase with increasing mean contents of the mean SiO_2 in the plutons. Two groups of plutons can be distinguished in these two plots. The first group includes the Redstone Mountain Pluton, the older granites, the Miramichi Pluton and the Dungarvon Pluton. The trend within this group appears to be smooth and represents a systematic increase in both eU and eTh contents with increase in SiO_2 content. The other group includes the Burnt Hill, the Trout Brook and the Mount Elizabeth Pluton. In this latter group, there is a sharp increase in eU and eTh contents with increase in SiO_2 content (Fig. 27).

All of the granitic plutons appear to be peraluminous where $Al_2O_3/(CaO+Na_2O+K_2O)$ ratios exceed 1.1 (Table 21). The average peraluminous indices of these plutons are in general comparable. This may suggest that these granitic plutons are derived from anatexial melting of sedimentary protolith. Moreover, it appears that most of the granitic plutons in the Miramichi Anticlinorium are possibly derived from a common source magma.

The eU, eTh and K contents in the Miramichi Anticlinorium plutons were plotted on an eU-eTh-K variation diagram (Fig. 28), which illustrates that all of the plutons plot close to each other, indicating that only minor variations exist within the plutons in terms of radioelement content. Furthermore, Figure 28 indicates that the Burnt Hill and the Trout Brook plutons are plotted adjacent to uraniferous granites from the Hercynian Cornubian Batholith and the Caledonide Cairngorm granite of Europe (Fig. 28).

9.3.0 Favourability Indices of the Granitic Plutons

The principal component analysis of Pirkle et al. (1982) was performed to determine the favourability of the granitic plutons for U mineralization.

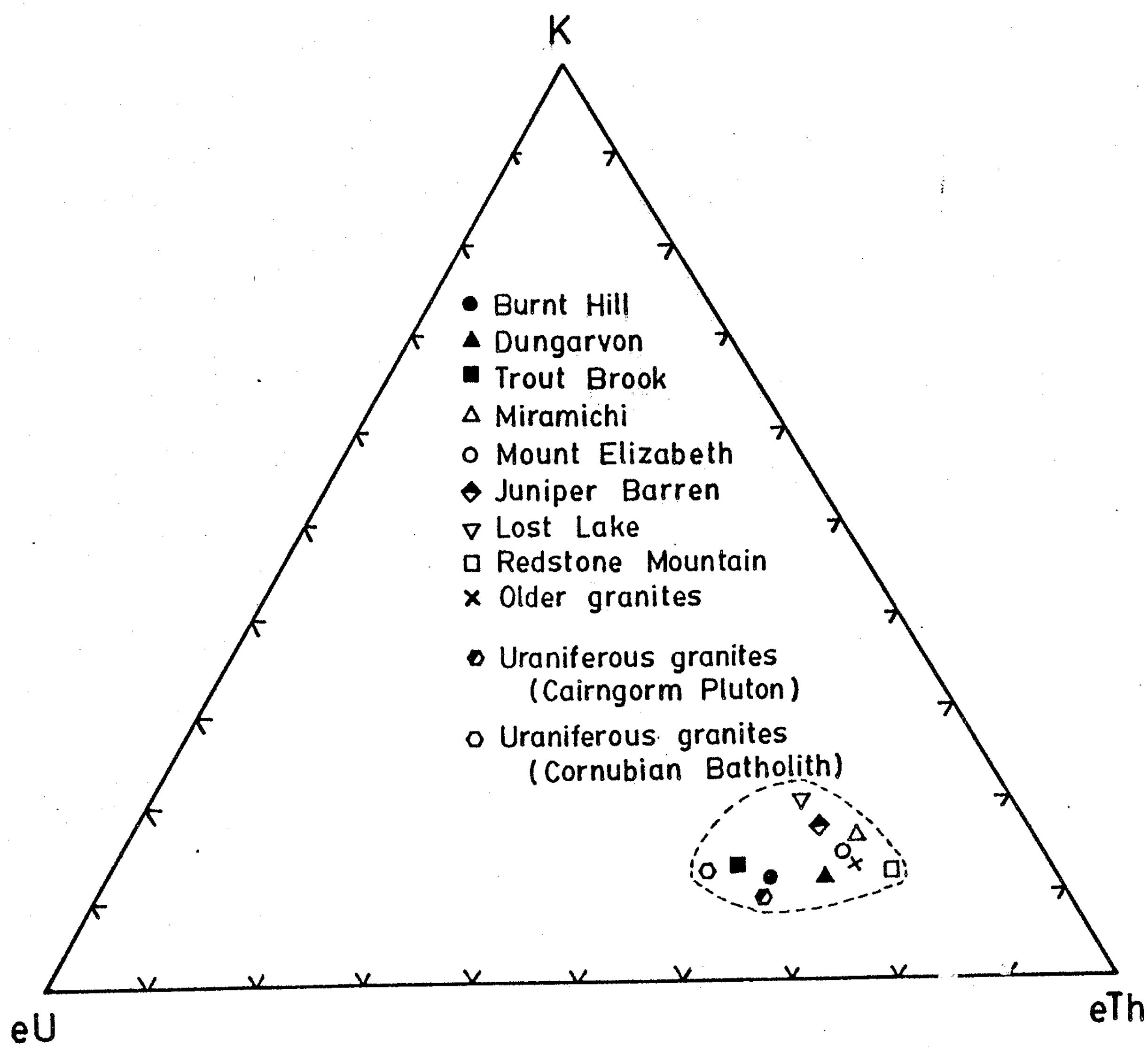


Figure 28. eU - eTh - K ternary variation diagram of the selected granitic plutons in the Miramichi Anticlinorium and for some uraniferous granites.

The ratios of the U loadings (UPC1/UPC3 and UPC2/UPC3) were calculated by using a computer program adopted from Statistical Analysis System (SAS, 1982). The results of the analysis are given in Table 22.

A plot of UPC1/UPC2 vs UPC1/UPC3 ratios for the granitic plutons is shown in Figure 29. The plot illustrates that the favourability of the plutons is in the following order: the Miramichi Pluton (least favourable), Lost Lake Pluton, Burnt Hill Pluton, Juniper Barren Pluton, Dungarvon Pluton, Trout Brook Pluton, older granites, Redstone Mountain Pluton and the Mount Elizabeth Pluton (most favourable). However, the results of the analysis are not as encouraging as was expected, because some plutons with no U associations appear to be most favourable (e.g., Mount Elizabeth and Redstone Mountain) while others with known U mineralization appear to be less favourable (e.g., Burnt Hill Pluton). One possible explanation for this situation is that all of these plutons are geochemically favourable for U mineralization, but have suffered less than other plutons in terms of geological disturbances, such as fracturing, veining, hydrothermal alterations and weathering, that may have aided in uranium leaching and concentration. Alternatively, these plutons have received less attention than the other plutons by exploration companies.

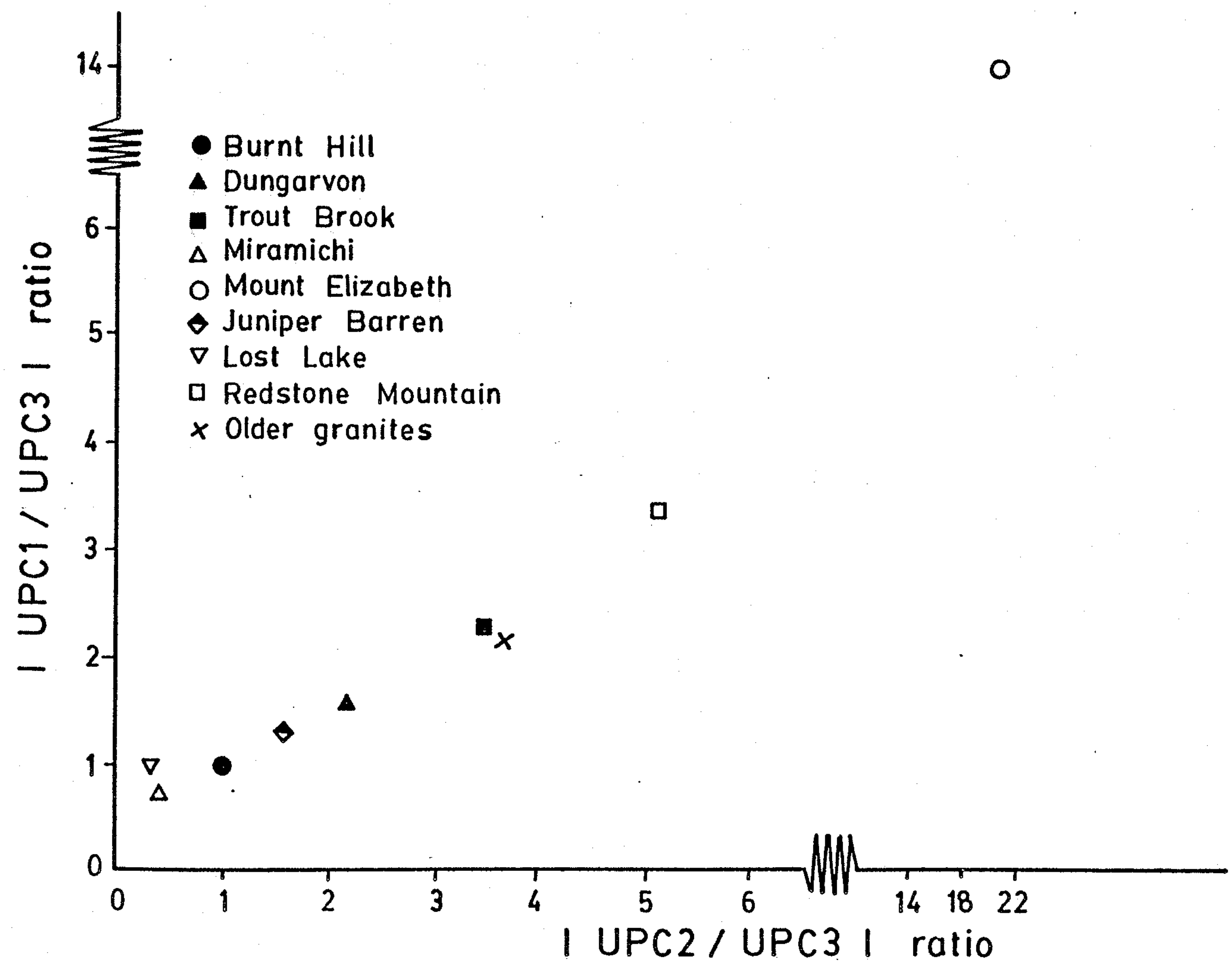


Figure 29. Plot of |UPC1/UPC3| ratio vs. |UPC2/UPC3| ratio for selected granitic plutons in the Miramichi Anticlinorium:

Table 22. Uranium favourability indices for the granitic plutons in the Miramichi Anticlinorium.

Pluton Name	n	Eigenvalues	% of Total Variance Explained	Principal Component P.C.	Eigenvectors U	Th	K	Favourability Indices* |UPC1/UPC3|	|UPC2/UPC3|
Burnt Hill	189	2.08	0.69	1	0.58	0.63	0.52	1.0	1.0
		0.63	0.21	2	-0.57	-0.14	0.81		
		0.28	0.10	3	0.58	-0.76	0.27		
Dungarvon	101	2.51	0.84	1	0.56	0.60	0.57	1.6	2.2
		0.33	0.11	2	0.76	-0.09	-0.65		
		0.15	0.05	3	0.34	-0.80	0.50		
Trout Brook	39	2.56	0.85	1	0.54	0.58	0.61	2.3	3.5
		0.38	0.13	2	0.81	-0.56	-0.19		
		0.05	0.02	3	0.23	0.59	-0.77		
Miramichi	37	2.54	0.85	1	0.58	0.58	0.58	0.	0.4
		0.24	0.08	2	-0.32	0.81	-0.49		
		0.22	0.07	3	-0.75	0.10	0.65		
Mount Elizabeth	106	2.69	0.90	1	0.56	0.59	0.59	14.0	20.8
		0.25	0.08	2	0.83	-0.36	-0.42		
		0.06	0.02	3	0.04	-0.72	0.69		
Juniper Barren	110	2.62	0.87	1	0.57	0.60	0.56	1.3	1.6
		0.30	0.10	2	-0.70	-0.01	0.71		
		0.08	0.03	3	0.43	-0.80	0.42		
Lost Lake	61	1.50	0.50	1	0.70	0.11	0.71	1.0	0.3
		1.01	0.34	2	-0.19	0.98	0.04		
		0.50	0.16	3	0.69	0.17	-0.70		
Redstone Mountain	55	2.64	0.88	1	0.55	0.60	0.58	3.4	0.4
		0.28	0.09	2	0.82	-0.25	-0.52		
		0.08	0.03	3	0.16	-0.76	0.63		
Older Granite	61	1.98	0.66	1	0.49	0.59	0.64	2.1	3.7
		0.72	0.24	2	0.84	-0.51	-0.17		
		0.30	0.10	3	0.23	0.62	-0.75		

*UPC1 represents original U deposited in rock unit
UPC2 represents the mobilized U
UPC3 represents the nonmobilized U

SECTION TEN

SUMMARY, CONCLUSIONS AND GUIDELINES FOR FUTURE EXPLORATION

10.1.0 Summary and Conclusions

Polymetallic vein-type U deposits occur in at least four northwesterly trending quartz (chalcedony)-filling fractures that crosscut the Lower Devonian granitic rocks of North Pole Pluton, Long Lake area. The U deposits are mostly associated with Cu, Pb, Zn, Sn, W, Mo, Bi, Ag and Au. Pyrite, chalcopyrite, sphalerite, galena, covellite and molybdenite are the major sulphide minerals identified in the veins. Small amounts of arsenopyrite, matildite and native bismuth were also identified. No mineral identification was carried out for uranium in these veins. However, cassiterite, autunite and torbernite have been recognized in float samples.

The polymetallic vein-type U deposits are related spatially and probably genetically, to the granitic rocks of North Pole Pluton. These veins are commonly associated with the highly altered and brecciated fracture zones in the pluton.

Chemical data on the host granites of the North Pole Pluton indicate that the pluton contains important anomalous quantities of metals relative to normal granites. The North Pole Pluton is massive, post-tectonic, and emplaced discordantly in the epizone. The pluton is also peraluminous and has characteristic features similar to U-producing S- and A-type granitic rocks.

The northwest-southeast trending fractures were the dominant structural features open as pathways for hydrothermal fluids during mineralization in North Pole Pluton. These fractures are related to the final stages of the

Acadian Orogeny. These late Acadian fractures opened the rocks to convective hydrothermal circulation, allowing wall-rock alteration, brecciation and deposition of U and associated metals. Interestingly, these fractures appear to be tectonically active (a series of earthquake epicentres located within the pluton). Therefore, this may suggest that the seismic activities in the area were very necessary factors to prolong the hydrothermal convective cell within the North Pole Pluton and hence increase the capacity of the hydrothermal system for U and associated metals mineralization.

The existing data support a combination of hypogene and supergene origins for the U and associated metals deposits in North Pole Pluton.

The Long Lake polymetallic vein-type U deposits are located in the Miramichi Anticlinorium metallogenic domain, which is apparently part of a U-producing metallogenic belt that extends from Europe (Schartzach area, Germany-Massif Central, France - Hercynian and Caledonian granites, Britain) to North America (South Mountain Batholith, Nova Scotia). The polymetallic vein-type U deposits in this belt have a common characteristic in that they all occur in late-tectonic plutons and fractures. The mineralization is associated with faults intersecting highly evolved, peraluminous two-mica granites.

The plutonic granitic rocks of the Miramichi Anticlinorium are in general favourable for U mineralization, especially those that have undergone repeated geological disturbances (faulting, veining, alteration and weathering). These highly favourable plutons were identified as the Burnt Hill, Trout Brook and the Dungarvan. They also coincide with strong negative Bouguer gravity anomalies. Furthermore, these radioactive granitic plutons host Sn, Mo and W deposits.

10.2.0 Guidelines for Future Vein-type Uranium Exploration

The following conclusions should act as guidelines for future polymetallic vein-type U exploration in New Brunswick and elsewhere:

(1) The deposits are preferentially associated with highly evolved peraluminous, two-mica granitic plutons that were emplaced at shallow depth in the earth's crust.

(2) The host plutons are usually hosting other lithophile metals such as Sn, Mo and W.

(3) Geophysically, the host pluton is highly radioactive and associated with a strong negative Bouguer gravity anomaly and low magnetic values.

(4) The host pluton is emplaced in a seismically active area. The known mineralization appear to be restricted to fracture.

(5) The vein-type U mineralization is, in general associated with hydrothermaly altered and highly brecciated zones of the fractures.

(6) Vein-type U mineralizations are generally associated with chalcedony-filling fractures.

REFERENCES

Allman, R. and Koriting, S.
1969: Fluorine; in Handbook of Geochemistry, ed. K.H. Wedepohl, v. 2, No. 1, Springer-Verlag, Berlin.

Allman-Ward, P., Halls, C., Rankin, A. and Bristow, C.M.
1982: An intrusive hydrothermal breccia body at Wheat Remfry in the western part of the St. Austell Granite Pluton, Cornwall, England; in Metallization Associated with Acid Magmatism, ed. A.M. Evans, John Wiley and Sons Ltd., pp. 1-28.

Anderson, F.D.
1972: The Catamaran Fault, north-central New Brunswick; Can. J. Earth Sci., v.g., pp. 1278-1286.

Anderson, J.L.
1983: Proterozoic anorogenic granite plutonism of North America; Geol. Soc. Am. Mem. 161, pp. 133-154.

Barbier, M.J.
1974: Continental weathering as a possible origin of vein-type uranium deposits; Mineral. Deposita, v. 9, pp. 271-288.

Barwise A.J.G. and Whitehead, E.V.
1983: Fossil Fuel Metals; in The significance of trace elements in solving petrogenetic problems and contraversies, ed. S.S. Augustithis, Theophractus Publ., Athens, Greece.

Berry, M.J., Wetmiller, R.J., Stevens, A.E., Hasegawa, H.S. and Adams, J.
1982: The Miramichi, New Brunswick earthquake sequence of January, 1982; Canadian Geophysical Society Annual Meeting, 9th, Abstr., p. 10.

Boyle, R.W.
1982: Geochemical prospecting for thorium and uranium deposits; in Developments in Economic Geology 16, Elsevier Scientific Pub. Co., 498 p.

Burke, K.B.S. and Chandra, J.J.
1983: Gravity survey of the epicentral area of the main sequence of Miramichi earthquakes; N.B. Dept. of Natural Resources, Open File Report 83-3, 27 p.

Burnham, C.W. and Ohmoto, H.
1980: Late-stage processes of felsic magmatism; Min. Geol. Special Issue, No. 8, pp. 1-11.

Carmichael, I.S.E., Turner, F.J. and Verhoogen, J.
1974: Igneous petrology; McGraw Hill, Inc., 739 p.

Chappell, B.W. and White, A.J.R.
1974: Two contrasting granite types; Pacific Geology, v. 8, pp. 173-174.

Chatterjee, A.K. and Muecke, G.K.
1982: Geochemistry and the distribution of uranium and thorium in the granitoid rocks of the South Mountain Batholith, Nova Scotia: some genetic and exploration implications; in Uranium in Granites, ed. Y.T. Maurice, Geol. Surv. Can., Paper 81-23, pp. 11-17.

Chatterjee, A.K., Robertson, J. and Pollock, D.
1982: A summary on the petrometallogenesis of the uranium mineralization of Millet Brook, South Mountain Batholith, Nova Scotia; in Mineral Resources Division, Report of Activities, pp. 57-66.

Chatterjee, A.K. and Strong, D.F.
1985: Review of some chemical and mineralogical characteristics of granitoid rocks hosting Sn, W, U, Mo deposits in Newfoundland and Nova Scotia; in High heat production (HHP) granites, hydrothermal circulation and ore genesis, Instit. Min. Metall., pp. 489-516.

Clarke, D.B. and Muecke, G.K.
1985: Review of the petrochemistry and origin of the South Mountain Batholith and associated plutons, Nova Scotia, Canada; in High heat production (HHP) granites, hydrothermal circulation and ore genesis, Instit. Min. Metall., pp. 41-54.

Collins, W.J., Beams, S.D., White, A.J.R. and Chappell, B.W.
1982: Nature and origin of A-type granites with particular reference to southeastern Australia; Contrib. Mineral. Petrol., v. 80, pp. 189-200.

Crouse, G.
1977: Geological notes, Long and Trousers Lakes (map area K-11), New Brunswick; N.B. Dept. Natural Resources, PM 77-191, 16 p. (map revised 1982).

Crouse, G.W.
1981: Geology of parts of Burnt Hill, Clearwater and McKiel Brooks; N.B. Dept. Natural Resources, MR 81-5.

Davies, J.L.
1966: Geology of the Bathurst-Newcastle area, New Brunswick; Guidebook, Geology of parts of Atlantic Provinces, ed. W.H. Poole, Geol. Assoc. Can., 155 p.

Davies, J.L.
1983: Stream and spring sediment geochemistry maps, Serpentine Lake (210/2), Cu, Pb, Zn, U, Ag, Co, Mn, Fe, Ni, Mo, and W; N.B. Dept. Natural Resources, MP 83-33 (A-K).

Davies, J.L., Fyffe, L.R. and McAllister, A.L.
1983: Geology and massive sulphides of the Bathurst area, New Brunswick; in Field Trip Guidebook to Stratabound Sulphide Deposits, Bathurst area, N.B., Canada and West-Central New England, U.S.A., ed. D.F. Sangster, Geol. Surv. Can., Miscell. Rept. 36, pp. 2-30.

Dill, H.
1983: On the formation of vein-type uranium "yellow ores" from the Schwarzach Area (NE-Bavaria, Germany) and on the behaviour of P, As, V and Se during supergene processes; Geol. Rundsch, v. 72, pp. 955-980.

Dill, H.
1985: Granite-related and granite-induced ore mineralization on the western edge of the Bohemian Massif; in High heat production (HHP) granites, hydrothermal circulation and ore genesis, Instit. Min. Metall., pp. 55-70.

D. N. R.
1977: Airborne gamma-ray spectrometric contour maps, 1976 Canada - New Brunswick Uranium Reconnaissance Program, Campbellton (210); N.B. Dept. Natural Resources, MP 77-48 (a-g).

D. N. R. E.
1986: Geological series maps of airborne gamma ray spectrometric survey, Miramichi Highlands; N.B. Dept. Natural Resources, MP 86-55 (a-g).

Dreimanis, A.
1958: Tracing ore boulders as a prospecting method in Canada; Can. Instit. Min. Metall., v. 61, pp. 49-56.

Durrance, E.M.
1985: Hydrothermal circulation and isostasy, with particular reference to the granites of southwest England; in High heat production (HHP) granites, hydrothermal circulation and ore genesis, Instit. Min. Metall., pp. 71-85.

El Bouseily, A.M. and El Sokkary, A.A.
1975: The relation between Rb, Ba and Sr in granitic rocks; Chem. Geol., v. 16, pp. 207-219.

Fehn, U., Cathles, L.M. and Holland, D.H.
1978: Hydrothermal convection and uranium deposits in abnormally radioactive plutons; Econ. Geol., v. 73, pp. 1556-1566.

Fisher, J.C.
1976: Remote sensing applied to exploration for vein-type uranium deposits, Front Range, Colorado; Unpubl. Ph.D. thesis, Colorado School of Mines, 141 p.

Fletcher, C.J.N.
1977: The geology, mineralization and alteration of Ilkwang Mines, Republic of Korea. A cu-W-bearing tourmaline breccia pipe; Econ. Geol., v. 72, pp. 753-768.

Fournier, R.O.
1986: The behaviour of silica in hydrothermal solutions; in Geology and Geochemistry of Epithermal Systems, eds. B.R. Berger and P.M. Bethke, Reviews in Economic Geology, v. 2, pp. 45-61.

Fyffe, L.R.
1982: Geology in the vicinity of the 1982 Miramichi earthquake; in Earth Physics Branch Open File Report 82-24, Ottawa, pp. 44-46.

Fyffe, L.R. and Cormier, R.F.
1979: The significance of radiometric ages from the Gulquac Lake area of New Brunswick; Can. J. Earth Sci., v.6, pp. 2046-2052.

Fyffe, L.R., Pajari, G.E., Jr., and Cherry, M.E.
1981: The Acadian plutonic rocks of New Brunswick; Maritime Sediments and Atlantic Geology, v. 17, pp. 23-36.

Fyffe, L.R. and Pronk, A.G.
1985: Bedrock and surficial geology-rock and till geochemistry in the Trousers Lake area, Victoria County, New Brunswick; 8N.B. Dept. Natural. Resources, Report of Investigation No. 20, 74 p.

Gasparrini, C.
1981: Identification and description of the uranium minerals in a rock sample, project Campy (Long); N.B. Dept. Natural Resources, Assessment Report 472695, Report No. 239, Can. Occidental Petroleum.

Glackmeyer, K.
1973: Induced polarization survey, Long Lake claim group; N.B. Dept. Natural Resources, Assessment Report 470797.

Gleeson, C.F.
1980: Soil geochemistry of the Long claims: N.B. Dept. Natural Resources, Assessment Report 472695, Interim Report, Can. Occidental Petroleum.

Golovin, Ye. A.
1979: Possible mechanism for formation of stratiform uranium deposits in non-magmatic seismoactive regions; Intern. Geol. Rev., v. 21, No. 11, pp. 1297-1300.

Gustafsson, B. and Minell, H.
1977: Case history of discovery and exploration of Pleutojokk uranium deposit, northern Sweden; in Prospecting in Areas of Glaciated Terrain, Instit. Min. Metall., pp. 72-79.

Hanford, T., Shacklette and Boerngen, J.G.
1984: Element concentrations in soils and other surficial materials of the Conterminous United States; U.S. Geol. Surv., Prof. Pap. 1270, 105 p.

Harley, D.N.
1979: A mineralized Ordovician resurgent caldera complex in the Bathurst-Newcastle Mining district, New Brunswick, Canada; Econ. Geol., v. 74, pp. 786-796.

Hassan, H.H., Hale, W.E. and Chrzanowski, M.
in press: Geology of Uranium and Associated Elements in New Brunswick; To be published as an Open File, Geol. Surv. Can.

Hauseux, M.
1980a: Diamond drilling summer 1980, Long claim group; N.B. Dept. Natural Resources, Assessment Report 473155, Can. Occidental Petroleum.

Hauseux, M.
1980b: Geology and geochemistry of Long claim group; N.B. Dept. Natural Resources, Assessment Report 472695, Can. Occidental Petroleum Ltd.

Hauseux, M.
1981: Trenching, diamond drilling and rock geochemistry, Long South Claim Group; N.B. Dept. Natural Resources Assessment Report 473156, Can. Occidental Petroleum.

Hauseux, M.
1982: Diamond drilling, winter 1982, Long Lake, Long South, Shawn, Shawn North and Swamp claims; N.B. Dept. Natural Resources, Assessment Report 473157, Can. Occidental Petroleum.

Helmstaedt, H.
1971: Structural geology of Portage Lake area, Bathurst-Newcastle district, New Brunswick; Geol. Surv. Can., Paper 70-28.

Holdaway, M.J.
1971: Stability of andalusite and the aluminum silicate phase diagram. Am. J. Sci., v. 271, pp. 97-131.

Irrinki, R.R.
1979: Geology of north and south Little Sevogle River - north branch, Little Southwest Miramichi River - McKendrick and Catamaran Lakes region Map-Areas O-12, N-12, and N-13; N.B. Dept. Natural Resources, MR 79-1, 35 p.

Ishihara, S.
1977: The magnetite-series and ilmenite-series granitic rocks; Min. Geol., v. 27, pp. 293-305.

Jagodits, F.L.
1981: Geophysical survey on Shawn claim group; N.B. Dept. Natural Resources, Assessment Report 472796, Barclay Exploration Services Ltd. to Can. Occidental Petroleum.

Kents, P.
1964: Special breccias associated with hydrothermal developments in the Andes; Econ. Geol., v. 59, pp. 1551-1563.

Keppie, J.D.
1977: Plate tectonic interpretation of Paleozoic World Maps; N.S. Dept. Mines, Paper 77-3, 45 p.

LeMaitre, R.W.
1976: The chemical variability of some common igneous rocks; J. Petrol., v. 17, pp. 589-637.

Leonard, K.W.
1982: Geology and geochemistry of Long claim group; N.B. Dept. Natural Resources, Assessment Report 472797, Can. Occidental Petroleum.

Lindsey, D.A. and Fisher, F.S.
1985: Mineralized breccias in intrusive complexes of Late Cretaceous and Paleocene age, North-central Montana; U.S. Geol. Surv., Prof. Pap. 1301A, pp. 3-34.

Lipowicz, T.
1980: Geology and geochemistry of the northern part of the Shawn claim group; N.B. Dept. Natural Resources, Assessment Report 472697, Can. Occidental Petroleum.

Loiselle, M.C. and Wones, D.R.
1979: Characteristics and origin of anorogenic granites; Geol. Soc. Am. Abstr., v. 11, p. 468.

Mawer, C.K. and Williams, P.F.
1985: Crystalline rocks as possible paleoseismicity indicators; Geology, v. 13, pp. 100-102.

McAllister, A.L.
1960; Massive sulphide deposits in New Brunswick; Can. Instit. Min. Metall. Bull., v. 53, No. 573, pp. 88-98.

McBride, D.E.
1976a: Tectonic setting of the Tetagouche Group, host to the New Brunswick polymetallic massive sulphide deposits; in Metallogeny and Plate Tectonics, ed. D.F. Strong, Geol. Assoc. Can., Special Paper 14, pp. 473-485.

McBride, D.E.
1976b: Geology of Heath Steele Mines, New Brunswick; Unpubl. Ph.D. thesis, Univ. New Brunswick, N.B.

McKerrow, W.S. and Ziegler, A.M.
1971: The Lower Silurian paleogeography of New Brunswick and adjacent area; Jour. Geol., v. 71, ppl 635-646.

Moreau, M.
1976: L'uranium et les granitoides: essai d'interpretation; in Geology, Mining and Extractive Processing of Uranium, ed. M.J. Jones, Instit. Min. Metall., pp. 83-102.

Oshin, I.O. and Rahman, M.A.
1986: Uranium favourability study in Nigeria; J. African Earth Sci., v. 5, No. 2, pp. 167-175.

Parker, A.
1970: An index of weathering for silicate rocks; Geol. Mag., v. 107, pp. 501-504.

Patterson, N.R., Bosschart, R., Misener, D.J. and Watson, R.K.
1979: Geophysical prospecting for uranium in the Athabasca Basin; Can. Min. J., p. 32.

Pirkle, F.L., Campbell, K. and Wecksung, G.W.
1980: Principal components analysis as a tool for interpreting NURE aerial radiometric survey data; J. Geol., v. 88, pp. 57-67.

Pirkle, F.L., Beckman, R.J. and Fleischhauer, H.L., Jr.
1982: A multivariate uranium favourability index using aerial radiometric data; J. Geol., v. 90, pp. 109-124.

Pitcher, W.S.
1979: The nature, ascent and emplacement of granitic magmas; Geol., Soc. Lond. J., v. 136. pp. 627-662.

Plant, J., Brouen, G.C., Simpson, P.R. and Smith, R.T.
1980; Signatures of metalliferous granites in the Scottish Caledonides; Instit. Min. Metall. Trans., section B, v. 89, pp. B198-B210.

Plant, J.A., O'Brien, C., Tarney, J. and Hurdley, J.
1985: Geochemical criteria for the recognition of high heat production granites; in High heat production (HHP) granites, hydrothermal circulation and ore genesis, Instit. Min. Metall., pp. 263-285.

Poole, W.H.
1963: Geology of Hayesville map-area, New Brunswick; Geol-Surv. Can., Map 6.

Poole, W.H.
1967: Tectonic evolution of the Appalachian region of Canada; in Geology of the Atlantic region, Royal Soc. Can. Spec. Pap. 4, pp. 9-51.

Poole, W.H.
1980: Rb-Sr ages of the "Sugar" Granite and Lost Lake Granite, Miramichi Anticlinorium, Hayesville Map Area, New Brunswick; in Current Research, Part C, Geol. Surv. Can., Paper 80-1C.

Rast, N.
1983: The northern Appalachian traverses in the Maritimes of Canada; in Profiles of Orogenic Belts, eds. N. Rast and F.M. Delany, Geodynamics Series Volume 10, Amer. Geophys. Union, Washington, D.C., 310 p.

Rich, R.A., Holland, H.D. and Peterson, U.
1977: Hydrothermal uranium deposits; Developments in Economic Geology, No. 6, Elsevier Scientific Publ. Co., N.Y., 264 p.

Robertson, D.M.
1980; Geology and geochemistry of the Long claim group; N.B. Dept. Natural. Resources, Assessment Report 472556, Can. Occidental Petroleum.

Ruitenberg, A.A. and Fyffe, L.R.
1982: Mineral deposits associated with granitoid intrusions and related subvolcanic stocks in New Brunswick and their relationship to Appalachian tectonic evolution; Can. Instit. Min. Metall., v. 75, No. 342, pp. 83-97.

Ruitenberg, A.A., Fyffe, L.R., McCutcheon, S.R., St. Peter, C.J., Irrinki, 1977: R.R. and Venugopal, D.V.
Evolution of Pre-Carboniferous Tectonostratigraphic Zones in the New Brunswick Appalachians; Geosci. Canada, v. 4, pp. 171-181.

Ruzicka, V. and LeCheminant, G.M.
1986: Developments in uranium geology in Canada, 1985; Geol. Surv. Can., Paper 86-1A, pp. 531-540.

Saracoglu, N.
1974: Diamond drilling - Long Lake area (210/2W); N. B. Dept. Natural Resources, Assessment Report 473002, Can. Occidental Petroleum.

SAS
1982: SAS user's guide: Statistics; Statistical Analysis System, SAS Instit. Inc., Cary, North Carolina.

Sato, T.
1974: Distribution and geological setting of the Kuroko deposits; Soc. Mining Geologists, Japan, Special Issue 6, pp. 1-9.

Saunders, D.F.
1978: Characterization of uraniferous geochemical provinces by aerial gamma-ray spectrometry; Paper presented at the 1978 AIME Annual Meeting, Denver, Colorado, Feb. 18 - Mar. 2, 25 p.

Saunders, D.F.
1979: Characterization of uraniferous geochemical provinces by aerial gamma-ray spectrometry; Min. Engn., v. 31, pp. 1715-1722.

Sawka, W.N. and Chappell, B.W.
1986: The distribution of radioactive heat production in I- and S-type granites and residual source regions: implications to high heat flow areas in the Lachlan Fold Belt, Australia; Australian J. Earth Sci., v. 33, pp. 107-118.

Sawkins, F.J.
1969: Chemical brecciation, an unrecognized mechanism for breccia formation?; Econ. Geol., v. 64, pp. 613-617.

Scherkenbach, D.A.
1982: Geologic, mineralogic, fluid inclusion and geochemical studies of the mineralized breccias at Cumobabi, Sonora, Mexico; Unpubl. Ph.D. thesis, Univ. Minnesota, 190 p.

Seguin, M.K., Gaucher, E. and Desbiens, R.
1984: Beep Mat 1 - an automated miniaturized EM mineral detector; in Prospecting in areas of glaciated terrain 1984, Instit. Min. Metall., pp. 193-200.

Shewman, R.
1964a: Cheaver group; N.B. Dept. Natural Resources, Assessment Report 470800, Consolidated Mining and Smelting Co., 6 p.

Shewman, R.
1964b: Anthonian Property; N.B. Dept. Natural Resources, Assessment Report 470801, 13 p.

Sibson, R.H., McMoore, J.M. and Rankin, A.H.
1975: Seismic pumping - A hydrothermal fluid transport mechanism; Geol. Soc. Lond. J., v. 131, pp. 653-659.

Simmons, S.F. and Sawkins, F.J.
1983: Mineralogic and fluid inclusion studies of the Washington Cu-Mo-W-bearing breccia pipe, Sonora, Mexico; Econ. Geol., v. 78, pp. 521-526.

Simpson, P.R., Brown, G.C., Plant, J. and Ostle, D.
1979; Uranium mineralization and granite magmatism in the British Isles; Phil. Roy. Soc. London Trans., series A, v. 291, pp. 385-412.

Simpson, P.R. and Plant, J.A.
1984: Role of high heat production granites in uranium province formation; in Uranium geochemistry, mineralogy, geology, exploration and resources, eds. B. DeVivo, F. Ippolito, G. Capaldi and P.R. Simpson, Instit. Min. Metall., pp. 167-178.

Simpson, P.R., Plant, J.A., Watson, J.V., Green, P.M. and Fowler, M.B.
1982: The role of metalliferous and mineralized uranium granites in the formation of U provinces; in Proceedings of the Symposium on Uranium Exploration Methods, Review of the NEA/IAEA R & D programme, Paris, pp. 157-170.

Sotnikov, V.I., Berzina, A.P., Nikitina, E.I., Skuridin, V.A. and Proskuryakov, A.A.
1974: Relationship between copper-molybdenum mineralization and subvolcanic granitoids; in Metallization Associated with Acid Magmatism, ed. M. Stemprok, v. 1, pp. 123-126.

St. Julien, P. and Beland, J.
1982: Orogenies; in Major structural zones and faults of the Northern Appalachians, Geol. Assoc. Can., Spec. Pap. 24, pp. 6-9.

St. Peter, C.
1982: Geology of Juniper-Knowlesville-Carlisle area; N.B. Dept. Natural Resources, MR 82-1, 81 p.

Tahakashi, M., Aramaki, S. and Ishihara, S.
1980: Magnetite-series/Ilmenite-series vs. I-type/S-type granitoids; Min. Geol. Special Issue, No. 8, pp. 13-28.

Taylor, S.R.
1964: Abundance of Chemical elements in the continental crust: A new table; Geochim. Cosmochim. Acta, v. 28, p. 1273.

Tupper, W.M. and Hart, S.R.
1961: Minimum age of the middle Silurian method; Bull. Geol. Soc. Am., v. 72, No. 8, pp. 1285-1288.

Tuttle, O.F. and Bowen, N.L.
1958: Origin of granite in the light of experimental studies in the system $NaAlSi_3O_8$-$KAlSi_3O_8$.SiO_2-H_2O; Geol. Soc. Am. Mem. No. 74.

van Staal, C.R.
1985: The structure and metamorphism of the Brunswick Mines area, Bathurst, New Brunswick, Canada; Unpubl. Ph.D. thesis, University of New Brunswick, 484 p.

Wanless, R.K., Stevens, R.D., Lachance, G.R. and Delabio, R.N.
1973: Age determinations and geological studies (K-Ar isotopic ages, Report 11); Geol. Surv. Can., Paper 73-2, pp. 84-87.

Williams, H.
1979: Appalachian Orogen in Canada; Can. J. Earth Sci., v. 16, No. 3, pp. 792-807.

Wilson, J.T.
1966: Did the Atlantic close and then re-open? Nature, v. 211, pp. 676-681.

White, A.J.R. and Chappell, B.W.
1983: Granitoid types and their distribution in the Lachlan Fold Belt, southeastern Australia; Geol. Soc. Am. Mem. 159, pp. 21-34.

APPENDICES

APPENDIX I. Element contents in spring and stream sediment samples (after Davies, 1983)

No.	U ppm	Cu ppm	Pb ppm	Zn ppm	Mn ppm	Fe %	Ni ppm	Co ppm	Mo ppm	W ppm	Ag ppm	As ppm	Sb ppm	Ba ppm	Au ppm
1	10.6	4	19	40	140	0.63	7	5	-	-	0.5				
2	9.2	4	19	38	260	0.65	7	5	-	-	0.5				
3	13.7	7	31	44	100	0.7	10	8	2	2	1.5				
4	28.9	6	5	87	2300	1.75	9	11	2	4	1.0				
5	15.6	-	-	0	-	-	-	-	-	2	-				
6	18.7	4	32	45	400	0.76	6	6	2	2	0.5				
7	3.6	13	63	214	820	0.71	16	11	-	-	1.0	9	0.1	220	-
8	5.4	5	74	33	900	0.37	5	9	2	2	1.0				
9	9.7	11	71	99	830	0.51	5	4	-	-	1.0				
10	19.1	17	62	315	1200	0.83	7	7	-	4	1.0				
11	13.2	9	59	271	980	0.65	5	5	-	4	1.0				
12	15.2	7	50	310	520	0.32	4	3	-	2	1.0				
13	3.5	14	27	54	250	1.74	20	9	-	2	0.5	6	0.1	340	-
14	31.9	2	9	33	180	0.31	4	1	-	2	0.5	3	0.1	360	-
15	27.4	20	69	338	740	0.85	8	9	2	8	1.0				
16	19.4	7	36	124	500	0.30	4	4	-	20	0.5	6	0.1	320	-
17	28.6	108	129	207	790	0.59	8	9	2	4	1.0	7	0.1	260	
18	7.4	23	42	94	480	1.94	20	11	-	4	0.5	10	0.2	340	-
19	29.8	11	120	231	4000	2.28	16	12	8	24	2.0				
20	40.1	33	114	507	1400	0.83	10	13	4	2	1.5				
21	15.[illegible]	24	72	428	880	0.65	8	9	-	4	1.0				
22	5.5	27	269	305	860	2.10	14	12	2	4	1.5	39	0.4	220	-
23	3.7	49	48	146	730	0.47	10	4	2	-	3.0				
24	5.8	57	60	184	190	0.79	10	5	2	8	3.0	12	0.1	220	-
25	21.6	34	89	801	2600	1.16	16	12	-	2	1.0				
26	13.5	50	109	694	3200	2.90	2	50	28	2	1.0				
27	12.8	36	107	565	2300	2.51	40	23	2	2	1.0	10	0.2	320	-
28	141.0	18	77	224	410	0.46	-	8	2	5	1.5				
29	19.7	32	123	767	970	1.92	14	26	4	12	1.5				
30	63.3	25	263	818	740	2.09	-	19	6	28	1.5				
31	67.4	41	687	528	900	0.67	15	8	-	4	2				
32	99.3	117	399	952	1900	1.86	23	20	4	4	3.5				
33	102.0	50	2336	959	5700	3.29	18	25	6	8	3.0				
34	48.8	111	826[illegible]	1156	2400	2.18	15	10	3.5	18	-				
35	31.7	82	372[illegible]	3596	29500	2.97	27	31	15	2	3.0				
36	32.4	80	816	900	240	0.33	13	5	2	-	3.0				
37	89.4	89	608	516	100	0.49	15	5	2	4	3.0				
38	16.3	27	102	804	1600	1.73	19	12	-	2	1.5				
39	9.3	18	68	519	1700	1.86	24	16	-	-	1.0				
40	12.9	20	71	657	1100	1.72	26	15	-	2	1.5	3	0.1	300	-
41	12.3	15	76	554	800	1.74	22	12	-	2	1.0				
42	5.4	10	34	772	3000	2.19	25	22	2	2	1.0				
43	4.1	9	31	622	1500	2.13	27	17	-	2	1.0	7	0.1	230	-
44	5.3	9	34	772	4100	2.41	27	27	2	2	1.0	10	0.1	320	
45	4.1	47	192	674	1700	1.36	17	14	2	2	2.0				
46	6.3	13	40	737	2800	2.43	28	20	2	2	1.0				
47	3.1	19	104	163	1300	2.06	29	17	-	-	1.0				
48	7.2	17	107	142	850	1.47	22	13	-	2.	1.5				
49	13.2	15	53	188	270	0.69	14	7	-	-	1.5				
50	2.8	8	33	86	490	1.33	21	11	-	-	0.5				
51	8.1	16	98	356	6600	2.69	29	39	4	8	1.0				
52	7.1	14	69	300	920	2.01	28	16	-	8	1.0				
53	6.9	14	80	260	1100	1.73	75	14	2	8	1.0				
54	13.3	15	129	3483	19100	1.00	41	77	15	8	1.0	6	0.1	240	-
55	6.5	11	28	567	890	1.87	24	13	-	2	1.0				
56	11.4	17	62	502	720	1.87	27	13	-	2	1.0				
57	21.7	16	42	180	510	0.80	17	8	2	2	2.0				
58	70.8	11	72	274	1700	3.21	16	13	40	2	2.0				
59	54.5	8	78	201	960	0.99	11	8	6	-	1.5				
60	34.5	6	202	220	18700	8.64	21	124	80	-	1.5	85	0.6	320	-
61	103.0	11	277	1038	38400	8.18	27	156	120	-	1.5				
62	68.1	23	160	3337	18600	10.70	57	166	30	-	2.0				
63	55.6	12	30	60	680	0.62	13	5	2	-	1.5				
64	4.1	18	20	66	560	2.16	38	19	-	2	1.0	5	0.1	320	-
65	3.2	21	23	119	340	2.18	37	16	-	4	0.5	3	0.1	340	-
66	3.5	19	23	120	390	2.42	40	17	-	2	0.5	3	0.1	340	-
67	4.0	18	29	177	390	2.33	40	17	-	4	1.0	3	0.1	360	-
68	2.7	15	28	64	490	2.54	43	18	-	-	1.0	6	0.1	300	-
69	2.6	17	28	55	550	3.15	41	23	-	2	1.0	5	0.1	340	-
70	2.5	16	54	140	3800	2.29	21	28	2	2	1.5				
71	58.3	11	38	61	660	0.89	13	12	-	-	1.5				
72	16.4	5	19	46	170	0.84	9	7	-	2	1.0				

A PENDIX II. Chemical analysis of Au, Th, U, Cu, Pb, Zn, Mo and Ag in outcrop, float and trench samples in the Long Lake area (after Hauseux, 1980, 1981)

A. Outcrop Samples:

Sample No.	Au [ppb]	Th [ppm]	U [ppm]	Cu [ppm]	Pb [ppm]	Zn [ppm]	Mo [ppm]	Ag [ppm]	Rock Type	Latitude	Longitude
80/26	ND	14	5.8	15	470	2030	ND*	ND	Silicified and mineralized granite	47° 02' 21"	66° 52' 31"
80/28	-	16	6.7	10	16	87	ND	ND	Quartz feldspar porphyry	47° 02' 10"	66° 52' 02"
80/29	-	22	3.7	11	16	57	ND	ND	Quartz feldspar porphyry	47° 02' 10"	66° 52' 02"
80/44	ND	22	14.7	120	48	3720	44	2	Altered and mineralized quartz feldspar porphyry	47° 01' 23"	66° 50' 52"
80/45	ND	14	8.7	66	28	8500	8	1	Altered and mineralized quartz feldspar porphyry	47° 01' 18"	66° 50' 30"
80/48	-	9	18.8	100	140	120	12	8	Sericitized biotite granite	47° 01' 30"	66° 51' 05"
80/49	200	21	7.7	53	32	180	8	1	Mineralized biotite granite	47° 01' 25"	66° 51' 04"
80/51	-	7	5.1	97	8	63	12	ND	Silicified mineralized and brecciated biotite granite	47° 01' 34"	66° 51' 05"
80/53	-	14	6.4	130	4	41	ND	1	Altered and mineralized biotite granite	47° 01' 43"	66° 51' 05"
80/54	-	24	12	140	12	43	4	ND	Mineralized quartz feldspar porphyry	47° 01' 53"	66° 51' 34"
80/55	-	12	6.3	42	8	18	4	ND	Silicified and limonitized quartz feldspar porphyry	47° 01' 53"	66° 51' 34"
80/58	-	9	5.4	6	150	6700	18	1	Mineralized quartz feldspar porphyry	47° 01' 18"	66° 50' 41"
80/91	-	81	1.1	21	13	160	6	0.5	Biotite granite	47° 02' 49"	66° 52' 31"
80/95A	-	27	1.6	91	17	14	8	0.6	Altered quartz feldspar porphyry	47° 02' 08"	66° 51' 09"
80/95B	-	32	3.6	93	156	72	6	1.4	Altered and mineralized quartz feldspar porphyry	47° 02' 08"	66° 51' 09"
80/97	-	25	2.3	22	28	63	6	0.7	Quartz feldspar porphyry	47° 01' 53"	66° 49' 33"
80/100	-	25	ND	34	920	1240	15	1.8	Altered and mineralized biotite granite	47° 01' 53"	66° 49' 32"
80/101	-	29	0.9	101	88	31	8	1.0	Altered and mineralized biotite granite	47° 02' 08"	66° 50' 48"
80/102	-	13	2.1	30	34	440	6	0.5	Quartz feldspar porphyry	47° 01' 18"	66° 50' 56"

*ND = not detected

B. **Float Samples:**

Sample No.	Au [ppb]	Th [ppm]	U [ppm]	Cu [ppm]	Pb [ppm]	Zn [ppm]	Mo [ppm]	Ag [ppm]	Rock Type	Latitude	Longitude
80/11A	–	3	420	19	126	210	16	ND	Altered two-mica granite	47° 00' 30"	66° 50' 10"
80/11B	–	12	130	17	40	70	20	1	Altered and mineralized two-mica granite	47° 00' 30"	66° 50' 10"
80/12A	–	11	18	120	900	1100	8	3	Mineralized biotite granite	47° 01' 03"	66° 50' 33"
80/12B	–	15	59	83	60	620	ND	1	Altered and mineralized biotite granite	47° 01' 03"	66° 50' 33"
80/16	–	5	63	14	130	48	ND	ND	Altered and mineralized two-mica granite	47° 00' 56"	66° 51' 30"
80/19A	31	1	310	11	96	17	190	1	Brecciated and altered biotite granite	47° 00' 33"	66° 50' 03"
80/19B	31	ND	87	5	220	6	140	ND	Brecciated and hematitized biotite granite	47° 00' 33"	66° 50' 03"
80/19C	ND	17	5	25	36	550	ND	ND	Brecciated and altered biotite granite	47° 00' 33"	66° 50' 03"
80/19E	12	1	70	16	96	10	25	ND	Brecciated, altered and mineralized biotite granite	47° 00' 33"	66° 50' 03"
80/19F	12	2	39	5	240	4	140	ND	Altered and mineralized biotite granite	47° 00' 33"	66° 50' 03"
80/27	–	6	6.1	1110	480	18400	4	4	Altered and mineralized biotite granite	47° 02' 19"	66° 51' 04"
80/36	–	ND	41	5	100	13	4	ND	Mineralized and altered biotite granite	47° 00' 55"	66° 50' 53"
80/37A	–	11	8.3	30	1100	210	4	ND	Altered and mineralized quartz feldspar porphyry	47° 00' 54"	66° 50' 53"
80/37B	–	16	23	94	2000	820	14	ND	Altered and mineralized biotite granite	47° 00' 54"	66° 50' 52"
80/37C	–	22	3.7	2	28	1260	4	ND	Altered quartz feldsspar porphyry	47° 00' 54"	66° 50' 52"
80/37D	–	ND	570	9	140	36	24	ND	Brecciated, altered and mineralized quartz feldspar porphyry	47° 00' 54"	66° 50' 52"
80/27F	–	16	17	2	32	18	2	ND	Altered quartz feldspar porphyry	47° 00' 54"	66° 50' 52"
80/37G	–	7	7.2	2	100	17	ND	ND	Altered quartz feldspar porphyry	47° 00' 54"	66° 50' 52"
80/37K	–	8	14	5	88	8	8	ND	Altered and mineralized quartz feldspar porphyry	47° 00' 54"	66° 50' 52"
80/38	23	2	37	9	250	16	1060	ND	Brecciated and silicified biotite granite	47° 00' 39"	66° 49' 49"
80/46	–	ND	18	12	12	23	120000	ND	Mineralized two-mica granite	47° 00' 39"	66° 50' 39"
80/47A	ND	ND	1560	360	68	42	100	17	Brecciated autunite-torbernite-bearing two-mica granite	47° 00' 43"	66° 50' 56"
80/47B	ND	ND	3300	170	36	12	20	7	Brecciated two-mica granite	47° 00' 43"	66° 50' 56"
80/56	1	15	26.4	110	400	740	ND	1	Altered and mineralized biotite granite	47° 01' 07"	66° 50' 26"
80/59	–	4	1360	4	250	84	78	1	Brecciated, altered and mineralized two-mica granite	47° 01' 07"	66° 50' 26"
80/64A	–	9	298	54	204	64	106	1.2	Altered and mineralized two-mica granite	47° 01' 00"	66° 50' 30"
80/82	–	14	1.6	20	190	80	4	0.5	Weathered biotite granite	47° 00' 42"	66° 50' 45"
80/98A	–	20	2.2	110	13	36	10	1.4	Silicified and mineralized biotite granite (weathered)	47° 01' 55"	66° 49' 34"

APPENDIX IIIa. Chemical composition (by weight) of selected rock samples from the North Pole Pluton (after Fyffe and Pronk, 1985)

	QUARTZ FELDSPAR PORPHYRY						BIOTITE-MUSCOVITE GRANITE				BIOTITE GRANITE								
Elements	Unaltered	Mildly altered (light pink)		Intensely altered			Unaltered		Silicified and brecciated		Unaltered				Altered (containing visible sulphides)				
	17	15C	16C	15B	16A	16B	20	21	18	19	10	11	12A	14A	12B	12C	13	14B	15A
SiO_2 %	76.45	76.53	76.80	77.60	77.02	75.92	74.28	73.47	86.47	80.72	71.10	71.79	71.96	70.00	73.06	72.32	74.42	68.88	74.69
TiO_2 %	0.15	0.09	0.15	0.09	0.13	0.20	0.02	0.27	0.08	0.20	0.38	0.43	0.35	0.60	0.28	0.28	0.50	0.43	0.47
Al_2O_3 %	13.32	12.99	13.76	12.55	13.08	23.84	14.32	14.17	6.48	10.91	14.04	14.97	14.98	15.15	13.89	14.24	12.57	14.75	14.76
Fe_2O_3 %	0.70	0.69	1.04	2.83	1.68	1.05	0.46	0.63	0.83	0.50	0.53	0.92	0.34	0.31	1.37	1.35	1.46	1.60	2.38
FeO %	0.64	0.74	0.24	0.54	2.02	3.17	1.13	0.98	0.20	0.47	0.51	1.75	1.72	2.94	3.22	4.05	2.63	4.62	0.91
MnO %	0.05	0.02	0.04	0.03	0.34	0.34	0.03	0.04	0.02	0.01	0.07	0.06	0.06	0.08	0.16	0.22	0.12	0.15	0.02
MgO %	0.30	0.20	0.29	0.13	0.19	0.39	0.43	0.44	0.17	0.19	0.60	0.71	0.70	1.00	0.54	0.58	0.84	1.00	0.51
CaO %	0.28	0.08	0.10	0.12	0.08	0.09	0.88	0.59	0.10	0.11	1.14	0.91	1.32	1.79	0.09	0.00	0.21	0.19	0.10
K_2O %	4.91	5.17	5.14	4.07	3.87	3.60	4.84	4.96	2.66	4.62	4.24	4.07	4.33	3.92	4.09	4.02	3.67	3.66	4.66
Na_2O %	3.35	1.64	0.09	0.19	0.17	0.11	3.44	3.24	0.17	0.21	3.58	3.57	3.55	3.16	0.17	0.15	0.26	0.13	0.20
H_2O+ %	0.81	1.66	2.37	1.00	2.04	2.20	0.93	1.30	1.56	2.00	1.21	1.36	1.29	1.73	2.25	2.83	2.10	3.20	1.79
H_2O- %	0.09	0.23	0.28	0.00	0.00	0.00	0.00	0.07	0.11	0.11	0.00	0.32	0.24	0.10	0.16	0.13	0.18	0.10	0.10
P_2O_5 %	0.04	0.01	0.04	0.06	0.08	0.04	0.10	0.08	0.04	0.08	0.08	0.10	0.08	0.16	0.08	0.06	0.05	0.16	0.08
CO_2 %	0.18	0.107	0.05	0.05	0.03	0.05	0.10	0.07	0.05	0.03	0.00	0.10	0.02	0.10	0.03	0.02	0.02	0.02	0 10
TOTAL	101.27	100.12	100.39	99.26	100.73	100.00	100.96	100.31	98.96	100.17	98.48	101.66	100.94	101.04	99.39	100.25	99.03	99.89	100.77
Be (ppm)	6.8	11.0	5.5	7.1	6.0	4.1	5.4	6.6	10.0	4.3	5.4	6.4	6.5	5.7	5.5	6.5	1.8	4.5	5.6
Ba (ppm)	300	170	180	125	200.0	180	400	470	150	290	430	440	440	720	180	260	265	415	235
Cu (ppm)	3	66	9	105	99	77	4	17	2	10	4	15	10	21	86	31	120	60	70
F (ppm)	600	300	600	640	600	780	290	320	410	360	290	340	400	420	690	750	640	780	1120
Mo (ppm)	1	2	4	7	6	7	1	0.5	8	6	1	2	2	2	7	6	5	25	4
Pb (ppm)	18	13	246	2	360	22	22	28	10	140	36	20	28	12	100	282	24	82	10
Rb (ppm)	201	300	261	420	345	347	204	234	186	271	136	163	197	159	386	341	210	308	440
B (ppm)	-	9	12	16	9	9	4	2	57	48	7	5	3	3	21	65	16	11	25
Sn (ppm)	4.6	8.0	8.0	86.0	72.0	68.0	76	6.0	6.0	8.1	6.9	7.0	7	6.0	97.0	124.0	90.0	102.0	86.0
Sr (ppm)	99	19	8	-	7	7	52	85	15	14	120	150	108	90	7	-	-	5	5
Zn (ppm)	96	260	145	29.	1160	2750	54	51	45	75	312	98	82	230	780	135	1000	128	52
U (ppm)	4.9	8.5	26.8	5.0	18.5	11.1	4.2	4.2	6.4	9.1	3.3	6.7	6.5	3.9	5.6	6.3	3.2	5.0	6.6
W (ppm)	-	4	-	4	-	8	-	-	-	-	-	-	4	-	16	16	12	20.0	8
Li (ppm)	6	9	10	18	17	22	23	25	52	140	13	11	10	17	17	25	18	28	31
Bi (ppm)	-	0.08	-	3.20	1.60	1.80	0.06	0.06	0.07	0.05	0.06	0.08	0.05	0.06	2.70	1.70	2.20	4.20	6.00
Zr (ppm)	75	75	45	105	60	70	100	75	30	115	240	85	75	155	220	410	180	215	340
S (ppm)	120	40	40	13300	1900	2520	20	20	400	340	60	100	50	40	1200	100	2260	2500	60

C. Trench Samples:

Sample No.	Au [ppb]	Th [ppm]	U [ppm]	Cu [ppm]	Pb [ppm]	Zn [ppm]	Mo [ppm]	Ag [ppm]	Rock Type	Latitude	Longitude
80/41	-	15	19.8	24	540	180	4	1	Altered and mineral-ized biotite granite	47° 02' 24"	66° 51' 55"
80/42	-	11	17.3	96	180	600	8	1	Altered and mineral-ized biotite granite	47° 02' 24"	66° 51' 55"
80/43	-	16	14.7	75	3120	2270	8	2	Altered and mineral-ized biotite granite	47° 02' 24"	66° 51' 55"
80/50	-	27	23.5	55	12	160	4	ND	Altered biotite granite	47° 01' 35"	66° 51' 55"
80/52	-	18	4.5	36	ND	80	4	ND	Altered biotite granite	47° 01' 42"	66° 51' 20"
80/57	-	13	8.3	11	260	33800	4	3	Altered and mineral-ized biotite granite	47° 02' 29"	66° 51' 25"
80/60A	-	315	2.3	30800	407	312	23	292	Mineralized biotite granite	47° 01' 18"	66° 50' 25"
80/60B	-	173	2.3	31200	128	260	19	70	Mineralized biotite granite	47° 01' 18"	66° 50' 25"
80/61A	-	224	2.8	10400	284	80	13	52	Weathered mineral-ized biotite granite	47° 01' 18"	66° 50' 25"
80/61B	-	168	1.4	19600	218	180	24	130	Weathered mineral-ized biotite granite	47° 01' 18"	66° 50' 25"
80/62	-	33	7.4	192	840	660	52	5.2	Mineralized biotite granite	47° 01' 18"	66° 50' 30"
80/63	-	18	0.6	80	81	2720	25	1.8	Mineralized quartz feldspar porphyry	47° 01' 18"	66° 50' 30"
80/64B	-	28	2.6	45	1360	296	40	1.6	Altered and mineral-biotite granite	47° 01' 20"	66° 50' 30"
80/65A	ND	ND	845	177	620	580	420	3.2	Altered and mineral-ized [Mo,U] quartz feldspar porphyry	47° 01' 21'	66° 50' 42"
80/65B	ND	38	273	92	2880	1000	11	3.4	Altered and mineral-ized [U, base metal sulphides] quartz feldspar porphyry	47° 01' 21"	66° 50' 42"
80/65C	ND	ND	26	60	100	48	290	2	Altered quartz feld-spar porphyry	47° 01' 21"	66° 50' 42"

Sample No.	Au [ppb]	Th [ppm]	U [ppm]	Cu [ppm]	Pb [ppm]	Zn [ppm]	Mo [ppm]	Ag [ppm]	Sn [ppm]	Rock Type	Latitude	Longitude
81/15071	3000	349	2.2	17000	120	269	13	72	439	Mineralized [base-metal sulphides] biotite granite	47° 01' 18"	66° 50' 25"
81/15072	2600	590	4.5	1800	1800	800	23	54	976	Mineralized [base-metal sulphides] biotite granite	47° 01' 21"	66° 50' 26"
81/15078	40	138	2.6	640	3160	720	134	6	34	Mineralized [base-metal sulphides] biotite granite	47° 01' 21"	66° 50' 26"
81/15074	-	133	4.3	760	2880	3840	8	4.8	169	Altered and mineralized [base-metal sulphides] biotite granite	47° 01' 21"	66° 50' 26"
81/15075	-	480	3.4	196	17600	3880	18	6.8	55	Mineralized [base-metal sulphides] quartz feld-spar granite	47° 01' 19"	66° 50' 37"
81/15076	-	48	5.4	256	800	1360	400	9.2	119	Altered and mineralized [base-metal sulphides] quartz feldspar porphyry	47° 01' 19"	66° 50' 37"
81/15077	-	13	6.4	200	60	3080	10	1.4	67	Altered and mineralized [base-metal sulphides] quartz feldspar porphry	47° 01' 19"	66° 50' 37"
81/15078	-	43	90	2780	760	16000	2000	9.8	ND	Mineralized [base-metal sulphides] quartz feld-spar porphyry	47° 01' 18"	66° 50' 41"
81/15079	-	6	35	158	70	1640	28	3.4	7	Silicified quartz feldspar porphyry	47° 01' 18"	66° 50' 41"
81/15080	-	57	10.7	91	640	11200	16	5.5	134	Altered and mineralized [base-metal sulphides] biotite granites	47° 01' 18"	66° 50' 41"
81/15081	-	24	390	37	332	1040	9	1.0	8	Moderately altered and mineralized [base-metal sulphides] quartz feld-spar porphyry	47° 01' 18"	66° 50' 41"
81/15082	-	33	8.6	35	800	480	4	1.0	58	Altered and mineralized [base-metal sulphides] quartz feldspar porphyry	47° 01' 18"	66° 50' 41"
81/15083	-	17	5.6	21	69	188	6	0.4	55	Strongly altered biotite granite		
81/15084	-	24	7.4	61	180	324	4	1.3	130	Strongly altered biotite granite		
81/15085	10	3	6.6	46	77	540	2	0.6	ND	Altered biotite granite		
81/15086	-	13	1.5	16	10	220	2	0.2	9	Mildly altered biotite granite	47° 01' 16"	66° 50' 48"
81/15087	-	75	50	352	1760	1200	4	5.4	2	Mineralized [base-metal sulphides] quartz feld-spar porphyry	47° 01' 21"	66° 50' 42"
81/15110	-	27	6.3	128	2640	10800	50	4.0	-	Altered and mineralized [base-metal sulphides] quartz feldspar porphyry	47° 01' 19"	66° 50' 37"
81/15111	-	26	13.5	680	2400	36000	44	9.7	-	Altered and mineralized [base-metal sulphides] quartz feldspar porphyry	47° 01' 19"	66° 50' 37"
81/15112	-	ND	3036	117	800	4080	18	8.0	-	Mineralized [U, base-metal sulphides] quartz feldspar porphyry	47° 01' 21"	66° 50' 42"

APPENDIX IIIb. Geographic locations of the chemically analysed selected samples of the North Pole Pluton.

Sample No.	Latitude	Longitude
9	49° 02' 49"	66° 52' 33"
10	47° 02' 20"	66° 51' 19"
11	47° 02' 18"	66° 51' 12"
12A	47° 02' 20"	66° 51' 03"
12B	47° 02' 20"	66° 51' 00"
12C	47° 02' 20"	66° 50' 58"
13	47° 02' 50"	66° 50' 21"
14A	47° 01' 35"	66° 51' 19"
14B	47° 01' 34"	66° 51' 20"
15A	47° 01' 55"	66° 51' 41"
15B	47° 01' 54"	66° 51' 41"
15C	47° 01' 53"	66° 51' 40"
16A	47° 01' 20"	66° 50' 41"
16B	47° 01' 20"	66° 50' 39"
16C	47° 01' 20"	66° 50' 37"
17	47° 00' 38"	66° 49' 37"
18	47° 00' 35"	66° 50' 30"
19	47° 00' 44"	66° 51' 57"